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Dynamic control method of construction cost based on fuzzy neural network

Qiao hui Liu and Qian Cao

College of Engineering, Zheng zhou Technology and Business University, Zhengzhou, People's Republic of China

ABSTRACT

For improving the dynamic management performance of construction cost, the dynamic control model of cost of construction based on fuzzy neural network is studied. Consider the effect of resource allocation, construction progress and construction quality on the cost of project in construction stage, and build the cost control index for the project in stage of construction. The fuzzy logic model is used in selecting the main cost related indicators from project cost control index system at the construction stage as input neurons of the BP NN, and the BP neural network is employed to output the results of prediction of cost at the construction stage. The project cost prediction results are set as the data basis for the dynamic control of the project cost, determine the most optimistic cost, the most probable cost and the most pessimistic cost of project cost in stage of construction through key chain method, and set buffers to realize dynamic control of project cost in stages of construction. The evaluation results prove that the developed method will be able to accurately predict the project cost in stages of construction, and the cost saved in the construction phase of the project is more than 300000 yuan.

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KEYWORDS
Fuzzy neural network; construction stage; project cost; dynamic control method; fuzzy logic method; key chain

1. Introduction

The scale of China's construction industry continues to expand and the cost is getting increased. On the one hand, its efficient development means that China's construction operations are high-tech, on the other hand, it also shows that China's construction industry's demand for the control and management of project cost continues to increase [1]. Generally speaking, because the construction project itself has the attribute of high investment, and the cost management in specific operations is of extremely obvious importance, the dynamic control of cost often follows the project. Construction projects basically has the phase of long construction, large investment funds and easy to be affected by other external factors [2]. Therefore, in the construction process of the project, first of all, reasonably arrange the required resources in the project, and to establish and improve a good management system [3] in the subsequent construction process, to control various problems affecting the cost the process of construction. At the same time, it is also necessary to set up a monitoring system to avoid related problems and effectively enhance the efficiency of the process of construction.

To a certain extent, the project cost refers to the price built in the whole construction process. However, from different perspectives, the corresponding project cost also has other definitions. Cost control is generally divided into three stages in the actual process: cost control before construction [4], cost control during construction and cost control after construction. Among them, the most important is the cost control in the stages of construction. A certain cost control in the construction phase [5] is of great significance for the follow-up project construction. At the same time, it can save funds for the whole enterprise and improve the follow-up construction observation, which has an extremely significant role in encouraging the enterprise [6]. At the same time, the cost control in the construction stage is also of much practical importance for enterprises to realize the economic and reasonable investment in the project. However, since the project itself has the characteristics of high construction difficulty [7], long period and complex situation in the construction process, difficulty of control of cost in the construction process has also increased a lot. In general, in today's construction projects, the cost of construction projects is mainly composed of costs, taxes and profits, and the most common manifestation of project cost is the contract price of the project [8]. That is, the price jointly recognized by investors and contractors, which cannot be unified to a certain extent, because a series of cost problems will occur in the subsequent construction process, therefore, it is necessary to control the cost and ensure the stability of the funds of whole construction project [9]. Cost control in construction process is to use professional skills and control measures to work, carry out reasonable system and staff arrangement, and cost control in phase of construction directly affects a series of cost control after construction.

CONTACT Qiao hui Liu qiaohuiliu6@gmail.com College of Engineering, Zhengzhou Technology and Business University, Zhengzhou, 450000, People's Republic of China
This article has been corrected with minor changes. These changes do not impact the academic content of the article.

At present, there are many studies on the cost of engineering projects. Reference [10] studies the cost control of post-earthquake building group restoration projects. This method fully considers that the dynamic control of engineering cost in the post-earthquake building group restoration construction stage is more variable than that in other stages. An improved genetic algorithm is used to build the cost model of post-earthquake building group restoration projects and complete the dynamic control of the cost of post-earthquake building group restoration projects; Reference [11] applies BIM Technology to the cost control of highway engineering. The present situation of management of cost is analyzed in this method in various stages of highway engineering. Combined with the core content of BIM Technology, it deeply analyses the importance of using BIM in the cost control and management of Highway Engineering in 4 stages: bidding, designing, constructing and delivery. Through experiments, it is verified that this method can work synchronously with each link to effectively control the cost of highway projects. Through project cost control, it can ensure that cost management can tend to flow, refinement and standardization;Shi et al. Applied SD technology to expressway project cost control [12]. This method uses SD theory to draw the causal relationship diagram of the factors affecting project cost, reveal the logical relationship and action mechanism of the factors affecting project cost, draw the stock flow diagram of the project cost control index system, build the expressway project cost control model based on SD, and quantitatively study the structure of the cost control index system; Finally, the JT expressway project is taken as a case project to evaluate the progressiveness and model's efficiency. Although the above three methods can achieve dynamic control of project cost, they ignore the importance of construction stage for project cost control and have poor application performance. For enhancing the application of dynamic control of cost of construction, this work studies the dynamic control model of cost of construction based on fuzzy neural network, and discusses the dynamic control of construction cost, so as to offer a feasible theoretical basis for the cost work of construction projects in China.

2. Material method

2.1. Project cost control index in construction stage

The project cost control index in the phase of construction is affected by many factors, and the factors affecting the project cost control in the phase of construction are mainly as follows:

2.1.1. Impact of construction progress on project cost at construction stage

The reasons for deviation of project cost caused by construction progress are shown in Figure 1.

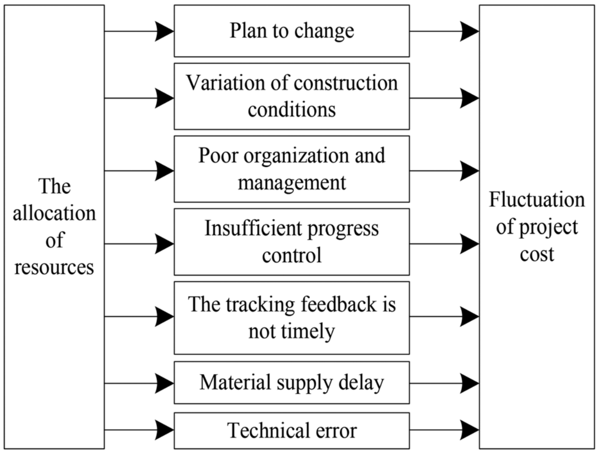

Figure 1. The reasons for the deviation of the project cost caused by the progress.

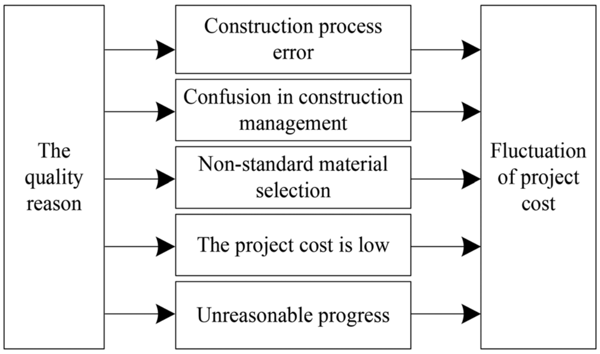

Figure 2. Reasons for the deviation of engineering cost caused by quality.

Analyze the reasons for the project cost deviation caused by the project progress in Figure 1, mainly including the following reasons: (1) The schedule is unclear and the supply of resources is delayed. (2) The construction technology is wrong, and the on-site organization and management are not effective. Errors in engineering geology, hydrology and other surveys affect the total construction period [14]. (3) Construction progress control is insufficient and tracking feedback is not timely. The plan is not coordinated with the implementation and lacks adjustment measures, resulting in disorderly construction.

2.1.2. Impact of construction quality on project cost at construction stage

The reasons for deviation of project cost caused by construction quality are shown in Figure 2.

Analyze the reasons for the project cost deviation caused by the project quality in Figure 2, mainly including the following reasons: (1) The construction management is chaotic and lacks a sound quality control system. There are relatively few management personnel, and the subjective sense of responsibility is not strong, which leads to inadequate management of construction operations on the site, such as disorderly stacking and random damage of finished and semi-finished products, resulting in serious damage to the overall quality of the project; There is a lack of strict handover measures between various processes and types of work in the construction process, improper handling of hidden dangers between processes, and inadequate quality control system. (2) The construction process is wrong, the material selection is not standardized, and the project cost is too low. Reinforcement ratio, vibration technology, concrete curing conditions, etc. will affect the project quality [15], resulting in increased secondary rework cost; Construction enterprises overemphasize project cost, neglect project quality, purchase substandard main materials, cut corners on work and materials, and form a situation of "low price and low quality". (3) The project progress is unreasonable. Whether the project can be completed on schedule or ahead of schedule is closely related to the cost and benefit of the project. Builders shorten the construction period, omit the process and shorten the process, so as to complete the sales of products ahead of schedule and recover the funds. Therefore, unreasonable reduction of the construction period leads to an increase in quality cost.

Based on the above analysis, the construction cost control index system at the construction stage is displayed in Table 1.

The selected indexes in the construction stage project cost control index system are used to obtain the prediction results through fuzzy control, and the prediction results of the construction stage project cost are used as the basis of dynamic control.

Table 1. Project cost control index system in construction stage.

Overall control index	Primary control index	Secondary control index
Construction stage project cost control	Manual control	The allocation of resources
		Human configuration
		Material resources configuration
		Comprehensive configuration
		schedule
		Site management
	Material control	Purchase way
		Supply way
		Material way
		Warehouse management
	Mechanical control	The construction technology
		Construction process

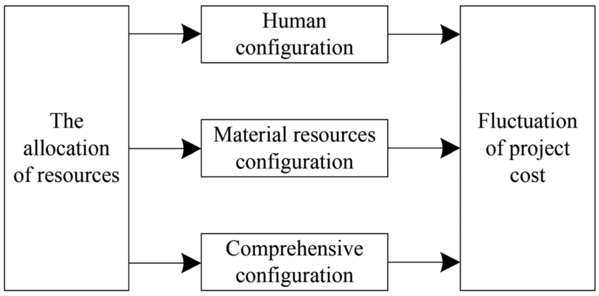

Figure 3. Resource allocation leads to engineering cost deviation.

2.2. Project cost prediction method in construction stage based on Fuzzy Neural Network

2.2.1. Impact of resource allocation on project cost in construction stage

The reasons for the deviation of project cost in the construction stage caused by resource allocation are shown in Figure 3.

Analyze the reasons for the deviation of project cost caused by resource allocation in Figure 3, mainly including the following reasons: (1) lack of reasonable human resource allocation. The ability and quality of some construction personnel do not match their posts, and there are relatively too many non production workers; The basic work is not perfect, the talent evaluation and work analysis are not properly carried out, the operation discipline is poor, the phenomenon of idling workers occurs from time to time, and the human resource allocation has not been dynamically optimized and adjusted. (2) Lack of scientific material procurement and use planning. There are grey areas in the bidding for important material procurement, the procurement method is single, and the optimal procurement approach is neglected; Lack of warehouse management planning; Excessive material requisition is serious; The material budget plan is not perfect; Lack of planning and management of purchased materials, irregular stacking of steel, plates and other main materials, resulting in increased waste and loss of materials and substantial increase in cost. (3) Lack of comprehensive resource allocation plan. The comprehensive allocation of labor, materials and machinery resources has not reached the maximum utilization efficiency [13], and idle working faces, idle equipment and idle workers are common; During the operation of mechanical equipment, the lack of necessary maintenance and neglect of the normal storage of equipment artificially reduced the service life of equipment and increased the depreciation expenses of construction projects.

2.2.2. Selection of input neurons of neural network based on fuzzy logic

Fuzzy logic method is used to select the input neurons of BP neural network from the index system of project cost control in the construction stage. The purpose of building a fuzzy logic model is to select input neurons. There are many factors affecting the project cost in the construction stage, and some of them are related and redundant. The varying selection of input vectors for the same prediction model can lead to differences in prediction accuracy and generalization ability among the resulting models. Therefore, finding the main factors related to the cost can improve the prediction accuracy [16]. The essence of the fuzzy neural network to predict the project cost in the construction stage is to input a plurality of relevant variables related to the project characteristics, that is, input neurons, into the model, and then output the predicted value after calculation in the model. The process of constructing a fuzzy logic model for selecting input neurons of BP neural network is as follows:

Establishing intuitionistic fuzzy sets Let $S = \{s_1, s_2, .., s_n\}$be the attribute set or scheme set of the project cost in the construction stage, and

$$R = \{[(s_i, s_j), \mu_R(s_i, s_j), \upsilon_R(s_i, s_j)](s_i, s_j)\epsilon S \times S\}$$

It be an intuitionistic fuzzy partial order relationship on S. Where,$\mu_R(s_i, s_l)$ represents the degree to which s_i is superior (inferior) tos_j, and $\upsilon_R(s_i, s_l)$represents the degree to which s_i is not superior (inferior) tos_j.

When the membership degree is given, it is a fixed value. In intuitionistic fuzzy sets [17], non membership and membership are two independent indicators, and both membership and non membership can be regarded as fuzzy sets on X. Uncertain indicators are introduced, which are the most important features of intuitionistic fuzzy sets [18]. In actual decision-making, there are factors such as insufficient, missing and inaccessible information, and decision makers can not accurately express preference information. It is very appropriate to apply intuitionistic fuzzy expression [19].

(1) (2) Determining the algorithm of fuzzy logic model Let $\alpha\epsilon X$ be the three intuitionistic fuzzy numbers of the fuzzy logic model, where, $\mu_\alpha\epsilon[0, 1]$, $\upsilon_\alpha\epsilon[0, 1]$, $\mu_\alpha + \upsilon_\alpha \le 1$ and X are the sets of all intuitionistic fuzzy numbers, then:

$$\upsilon_\alpha = (1 - (1 - \mu_\alpha)^\lambda) \tag{1}$$

For any intuitionistic fuzzy sets A and B, the subtraction operation is:

$$A - B = \{(x, \mu_{A-B}(x), \upsilon_{A-B}(x)|x\epsilon X)\} \tag{2}$$

For arbitrary intuitionistic fuzzy sets A and B, the division operation is:

$$A \div B = \{(x, \mu_{A+B}(x), \upsilon_{A+B}(x)|x\epsilon X)\} \tag{3}$$

The score function $(S(\alpha))$ and exact function expression $(L(\alpha))$ of intuitionistic fuzzy number are as follows:

$$S(\alpha) = \mu_\alpha - \upsilon_\alpha \tag{4}$$

$$L(\alpha) = \mu_\alpha + \upsilon_\alpha \tag{5}$$

(3) Consistency checking of fuzzy logic model

Consistency is an important research topic in the theory of project cost decision-making in the construction stage. The results obtained without the preference relationship of consistency are unreliable. Therefore, it is necessary to carry out consistency test. Let R be intuitive fuzzy preference [20], then R be an acceptable integral consistent intuitive fuzzy preference. If there is $d(R, R') < \tau$, where τ is the consistency threshold, $d(R, R')$ is the distance measure from intuitive fuzzy preference R to its corresponding perfect integral consistent intuitive fuzzy preference R, and:

$$d(R, R') = \frac{1}{2(n-1)(n-2)} \sum_{i=1}^{n} \sum_{j=1}^{n} (|\mu_{ij}^{-} - \mu_{ij}|) \tag{6}$$

When $j = i + 1$, $r_{ij}^{-} = r_{ij}$; When $j < i$, $r_{ij}^{-} = (\upsilon_{ij}^{-}, \mu_{ij}^{-})$; It is only necessary to calculate the difference of the upper triangular elements, and the number of upper triangular elements is $(n-1)(n-2)$.

(4) The priority vector of fuzzy logic model is derived

After establishing a reasonable intuitive fuzzy preference relationship, it is necessary to derive the priority weight of the dynamic control indicators of project cost at each evaluated construction stage from the intuitive fuzzy preference relationship and then sort the factors [21]. The priority is a group of n dimension weight vectors $w = (w_1, w_2, \cdots, w_n)^T$ obtained from the preference relationship.

Calculate the priority vector with the indirect calculation method of the normalized sequential summation method: Converting the intuitionistic fuzzy preference relationship into the corresponding interval fuzzy preference relationship $\hat{R} = ([\mu_{ij}, 1 - \upsilon_{ij}])_{n\times n}$; Then, the priority expression of the interval fuzzy preference relationship $\hat{R}$ is calculated as follows:

$$\hat{w}_i = \frac{\sum_{j=0}^{n} \hat{r}_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} \hat{r}_{ij}} \tag{7}$$

(5) Ranking scheme of influence degree coefficient

Compare the intuitionistic fuzzy numbers $\alpha_i = (\mu_{\alpha_i}\upsilon_{\alpha_i})$ and $\alpha_j = (\mu_{\alpha_j}\upsilon_{\alpha_j})$ of the dynamic control index of project cost in the two construction stages: if $S(\alpha_i) < S(\alpha_j)$, then $\alpha_i < \alpha_j$. If $S(\alpha_i) = S(\alpha_j)$, there are two situations as follows: if $L(\alpha_i) = L(\alpha_j)$, then $\alpha_i = \alpha_j$; if $L(\alpha_i) < L(\alpha_j)$, then $\alpha_i < \alpha_j$. The sequence obtained by the above process is a complete sequence but the scalar product is not closed. On the basis of this scheme, the scheme of comparing any two intuitionistic fuzzy numbers is adopted.

A scheme for comparing the sizes of two intuitionistic fuzzy numbers $\alpha_i = (\mu_{\alpha_i}\upsilon_{\alpha_i})$ and $\alpha_j = (\mu_{\alpha_j}\upsilon_{\alpha_j})$ is obtained by using the similarity function $H(\alpha) = \frac{1-\upsilon_a}{1+\pi_a}$ of the intuitionistic fuzzy number $\alpha = (\mu_\alpha, \upsilon_\alpha)$:

If $H(\alpha_i) < H(\alpha_j)$, $\alpha_i < \alpha_j$. If $H(\alpha_i) = H(\alpha_j)$, there are two situations as follows: if $L(\alpha_i) < L(\alpha_j)$, then $\alpha_i < \alpha_j$; if $L(\alpha_i) = L(\alpha_j)$, then $\alpha_i = \alpha_j$. Using the above process, we can not only ensure that the results obtained are still consistent with people's intuition when the parameters of intuitionistic fuzzy numbers change slightly, but also obtain the total order of intuitionistic fuzzy numbers. The fuzzy logic analysis model constructed through the above process is used to calculate the influence degree coefficient of the project cost control index in the construction stage, and select the input neuron of the BP neural network in the fuzzy neural network according to the obtained influence degree coefficient.

2.2.3. Prediction of construction cost based on BP neural network

After the input neuron of BP neural network is determined by the fuzzy logic model, the project cost in the construction stage is predicted by the BP neural network method. Neural network simulates the thinking mode of human brain to process relevant information quickly and effectively. At present, there are BP neural network and cerebellar model neural network in practical use, and the most frequently used are BP neural network and other variations. BP neural network is a forward multi-layer neural network learning algorithm with backward error transmission [22–25]. It is composed of input layer, hidden layer and output layer. Nodes between layers are fully interconnected, and nodes in the same layer are not connected. Theory and practice have proved that the neural network with only one hidden layer can approach any continuous function at will [26–28], which is more conducive to problem processing and solution. Therefore, the three-layer BP neural network system is adopted as the prediction model of the fuzzy neural network.

The input neuron of the neural network determined by the fuzzy logic network is selected as the input vector of the BP neural network, and the connection weights and thresholds of each layer are given initial values. Through the forward transmission of information, sample errors often occur, and the errors are transmitted in the reverse direction. In the process of reverse transmission [29], the error is allocated to each node. By calculating the node error, each weight and threshold are adjusted, and so on until the set desired error is reached.

Let the input vector of the input layer of BP neural network to predict the project cost in the construction stage be $X = (x_1, x_2, \cdots, x_n)^T$, the output vector of the hidden layer be $T = (t_1, t_2, \cdots, t_m)^T$, and the output vector of the output layer be $Y = (y_1, y_2, \cdots, y_p)^T$. l_k and y_k are used to represent the weight matrix of input layer hidden layer and hidden layer output layer respectively. The expected value of each node of the output layer and the actual output of each node of the output layer of the BP neural network are represented by and respectively. When the BP neural network predicts the project cost at the construction stage, the error expression of the output layer is defined as follows:

$$E = \frac{1}{2}\sum_{k=1}^{p}(l_k - y_k)^2 \tag{8}$$

When BP neural network is used to predict the project cost in the construction stage, the error calculation formulas of the hidden layer and the input layer can be expanded accordingly.$U(n)$ and $W(n)$ respectively represent the node weights of the output layer and the hidden layer of the BP neural network, x_j and y_t respectively represent the input and output of the BP neural network, η and δ respectively represent the adjustment factor and the learning factor. The modified expression of the node weights of the output layer and the hidden layer of the BP neural network for the project cost prediction in the construction stage is as follows:

$$U(n+1) = U(n) + \eta\delta y_t \tag{9}$$

$$W(n+1) = W(n) + \eta\delta x_j \tag{10}$$

The node threshold $\theta(u)$ correction expression of BP neural network for project cost prediction in the construction stage is as follows:

$$\theta(n+1) = \theta(n) + \eta\delta \tag{11}$$

In the above formula, p is the number of samples and n is the number of iterations.

The transformation functions used in BP neural networks are usually differentiable monotonically increasing functions, such as purelin linear functions and sigmoid functions. Combined with the analysis of the characteristics of purelin function and sigmoid function, the tangent sigmoid function is used for the transmission of neurons in the hidden layer of BP neural network, and the purelin function is used for the transmission of neurons in the output layer. The determined transformation function [30] is introduced to obtain the hidden layer node output expression of BP neural network for project cost prediction in the construction stage as follows:

$$k_j = f(net_j - \theta_i) \tag{12}$$

Where $net_j = \sum_{i=0}^{n} W_{ij}x_i$ and θ_i are the node thresholds of the hidden layer, $j = 1, 2, \cdots, m$ and f are the nonlinear action functions. The node output expression of the output layer of BP neural network for project cost prediction in the construction stage is as follows:

$$y_t = f(net_t - \theta_j) \tag{13}$$

Where, $net_t = \sum_{j=0}^{m} U_{jt}y_j$ and θ_j are node thresholds of the output layer, and $t = 1, 2, \cdots, p$.

BP neural network is used to output the project cost results at the construction stage and complete the cost prediction.

2.3. Dynamic control of project cost in construction stage based on critical chain method

According to the idea of the critical chain method, in order to effectively control the project cost in the construction stage, part of the subdivisional works in the project cost increased due to conservative estimation are calculated according to a guarantee rate, and the cost difference under this guarantee rate is arranged into the basic reserve in the reserve according to the cut and paste method or the root variance method, that is, it is set as a buffer [31]. Since the basic reserve fund is for unforeseen expenses that may occur during the implementation of the project, there will be no expenses that will not be paid. Therefore, this characteristic is used to arrange the cost difference into the basic reserve fund and control the project cost through the reserve fund during the implementation of the project [32]. By applying the critical chain method, potential errors in the process of project cost can be overcome.

Consider all divisional and sub divisional works in the whole project construction stage as a system, and establish a network diagram of divisional and sub divisional works and costs of divisional and sub divisional works. In the network diagram, each construction period of the construction stage is changed to the predicted cost of the construction stage project output by the fuzzy neural network, and the total construction period is changed to the total predicted cost of the construction stage project. Find the sub divisional and sub divisional stages that restrict the total predicted cost of the project cost in the construction stage through the network diagram. According to the project cost prediction cost in the construction stage output from the fuzzy neural network, the most optimistic cost, the most probable cost and the most pessimistic cost of the budget cost of the divisional and subdivisional works in the construction stage are determined by using the method of dynamic control of project cost using the key chain. The project buffer and input buffer are calculated by using the most optimistic cost, and the uncertainty factors of the whole project are absorbed.

The specific implementation steps of the dynamic control method of project cost with the key chain are as follows:

(1) Find out the divisional and sub divisional works that restrict the total project cost in the construction stage, and determine the key chain, that is, determine the bottleneck of project cost control in the project construction stage.

The bottleneck of the project cost is the key chain of the dynamic control of the project cost in the construction stage. The heuristic operator is used to find out the key chain, which is the bottleneck of the project cost in the construction stage.

(2) The item buffer and input buffer are calculated by the root variance method.

According to the characteristics of the project cost in the construction stage (people often take a conservative attitude when estimating the cost), the project cost risk in the construction stage is integrated, and the cost of all divisional and sub divisional projects in the construction stage is replaced by the most optimistic cost among the three estimates of the most optimistic cost, the most probable cost and the most pessimistic cost of the budget cost of the divisional and sub divisional projects in the construction stage, so as to dynamically control the project cost through the most optimistic cost. First, two methods are used to estimate the execution time of each divisional project. The traditional method is used to estimate the execution cost of the divisional project j as s_j, and the key chain method is used to estimate the execution cost of the divisional and subdivisional project j as a_j (the most optimistic cost). The difference between the two is $\delta_j = s_j - a_j$. Then the expressions of the project buffer Ψ and the input buffer Φ of the key chain of the dynamic control project cost in the construction stage are as follows:

$$\Psi = \sqrt{\sum_{j=c} (\delta_j)^2} \tag{14}$$

$$\Phi = \sqrt{\sum_{j=1} (\delta_j)^2} \tag{15}$$

In the above formula, c is the project set of key chain parts; I is the set of partial projects in a non critical chain.

(3) Make other decisions subject to or subordinate to the above decisions.

In order to make the non critical chain obey the key chain, input buffer is added between the non critical chain and the key chain. In the process of project implementation, pay close attention to the implementation of each divisional and sub divisional project of the construction project on the key chain, and use the use of each buffer to control the project cost at the construction stage.

3. Results

In order to verify the dynamic control method of project cost in the construction stage based on fuzzy

Table 2. Details of construction projects.

Number of Construction project	Total construction area /m^2	Standard floor area /m^2	The height/m	Layer/layer	Structure type
A	8564	567	3.1	11	brick
B	6584	758	3.3	6	The framework
C	7845	586	3.3	10	The framework
D	4455	469	3.3	8	brick
E	6285	786	3.2	6	The framework
F	7054	845	3.3	8	Frame shear wall
G	9452	2315	3.1	4	brick
H	8526	1352	3.1	5	The framework

Table 3. The weight of the dynamic control index of the project cost in the construction stage.

Primary control index	The weight	Secondary control index	The weight
Manual control	0.35	The allocation of resources	0.22
		Human configuration	0.19
		Material resources configuration	0.17
		Comprehensive configuration	0.25
		schedule	0.08
		Site management	0.09
Material control	0.29	Purchase way	0.35
		Supply way	0.29
		Material way	0.08
		Warehouse management	0.28
Mechanical control	0.36	The construction technology	0.54
		Construction process	0.46

neural network and the effectiveness of dynamic control of project cost in the construction stage, the project cost in the construction stage of residential building construction projects with different construction projects in a city is selected as the research object, and the construction projects in the same area are selected. The geological types, climate conditions and other external environmental parameters are relatively similar, so the comparability is high. The construction of the selected 8 construction projects is shown in Table 2.

The method in this paper creates control indicators for the dynamic control of project cost in the construction stage, selects the input neurons of BP neural network using fuzzy logic method, builds an intuitive fuzzy judgment matrix according to the steps of fuzzy logic method, verifies its consistency, derives the priority vector, and finally calculates the influence degree coefficient. According to the importance of each index, the dynamic control index of project cost in the construction stage is used to construct a comparative construction factor table, a judgment matrix, and the consistency of the constructed judgment matrix is checked. The weight calculation results of each index are shown in Table 3.

From table 3, the indexes with index weight higher than 0.1 are selected as the important indexes for dynamic control of project cost in the construction stage and the input neurons of BP neural network.

The dynamic control index of construction cost in the construction stage is obtained by using fuzzy logic method as the input of BP neural network. The prediction results of construction cost in the construction stage predicted by BP neural network are shown in Figure 4.

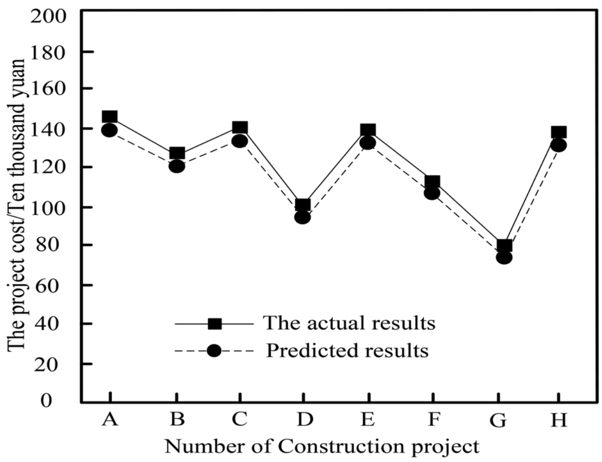

Figure 4. Project cost prediction results in the construction stage.

It can be seen from the experimental results in Figure 4 that the project cost results in the construction stage predicted by the method in this paper using BP neural network have a high degree of coincidence with the actual project cost results in the construction stage, which verifies that the method in this paper can effectively obtain the project cost prediction results in the construction stage by using the fuzzy neural network method, and the obtained project cost prediction results in the construction stage have high prediction accuracy, It can be used as the basis of project cost control in the construction stage and improve the performance of project cost control in the construction stage.

In order to further verify the prediction performance of the fuzzy neural network constructed by this method on the project cost in the construction stage,

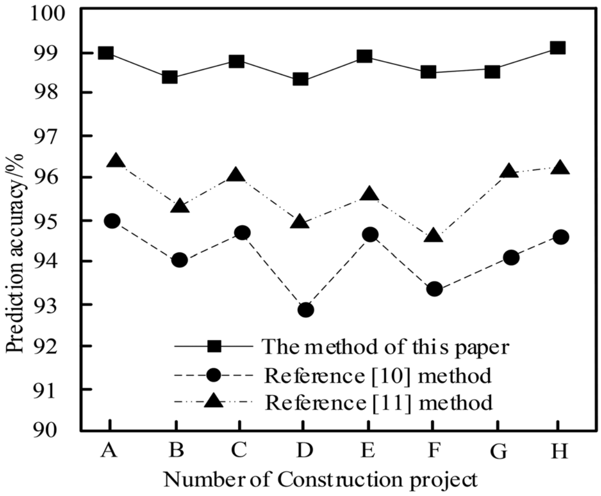

Figure 5. Comparison of project cost prediction accuracy in construction stage.

the prediction accuracy of the project cost in the construction stage predicted by this method is counted, and the prediction results of this method are compared with those of reference [10] and reference [11]. The comparison results are shown in Figure 5.

It can be seen from the experimental results in Figure 5 that the accuracy of this method in predicting the project cost in the construction stage by using the fuzzy neural network method is as high as 98%, which is significantly higher than the methods in reference [10] and reference [11]. The prediction accuracy of the reference [10] method in predicting the project cost in the construction stage is lower than 96%. The reference [10] method cannot take into account the uncertain factors that affect the explained variables when determining the form of functional relationship between the uncertain variables. The fuzzy neural network method used in this method can approach any form of functional relationship, especially non-linear functional relationship, because of its self-adaptive learning ability, and can better adapt to the dynamics and uncertainty of project cost. The prediction accuracy of the reference [11] method in predicting the project cost in the construction stage is lower than 97%. The reference [11] method has the defects of poor generalization ability and unstable computing performance; The method of reference [11] has high requirements for sample data. When there are sensitive points in the data, the network may fall into local minimum, and the number of data input vectors is too many, which will lead to overfitting. The fuzzy logic model combined with BP neural network method used in this method has the highest prediction accuracy among the three models, which improves the calculation speed and the generalization ability of the model.

The project cost control method in the construction stage of the key chain is used to control the project cost in the construction stage of the construction project.

Table 4. Construction cost of construction projects.

Number of Construction project	Most optimistic charge/Ten thousand yuan	Most likely charge/Ten thousand yuan	Most pessimistic charge/Ten thousand yuan
A	64.8	75.9	185.6
B	75.8	81.5	105.6
C	81.5	76.5	98.5
D	87.5	91.4	108.4
E	58.6	62.4	94.5
F	35.6	42.8	85.6
G	75.6	58.6	115.6
H	71.5	38.4	104.8

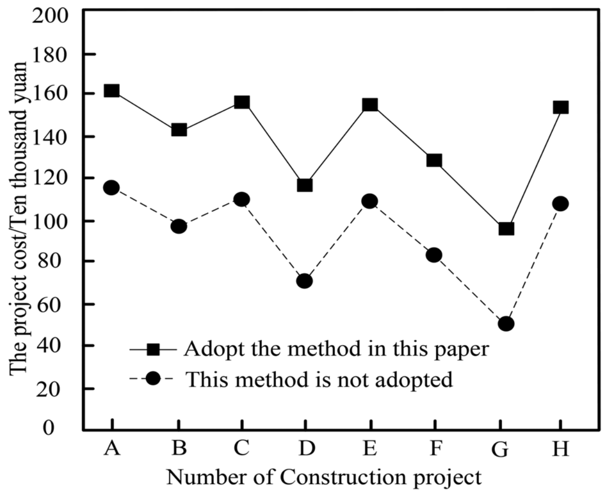

Figure 6. Project cost control results.

The output results of the most optimistic cost, the most probable cost and the most pessimistic cost of the eight projects are shown in Table 4.

During the implementation of construction projects, pay close attention to the implementation of each divisional and sub divisional project on the key chain, and use the use of each buffer to control the project cost, so as to effectively control the project cost. The key chain is used to analyze the project cost in the construction stage, and the optimistic cost, pessimistic cost and the most likely cost of the project cost in the construction stage are clarified. During the project implementation, the implementation of the construction work of each part on the key chain is closely followed, and the use of the buffer of the key chain is used to control the project cost in the construction stage of the construction project.

In order to verify the project cost control results of this method, the project cost control results of this method are compared with the project cost control results without this method. The comparison results are shown in Figure 6.

It can be seen from the experimental results in Figure 6 that the method in this paper can effectively control the project cost in the construction stage of building projects. After the method in this paper is adopted, the project cost control effect in the construction stage of building projects is obvious. Compared with not using the method in this paper, the construction cost of each construction stage is saved by more than 300000 yuan. In this paper, the key chain technology is used, and the project cost prediction results of the construction stage output from the fuzzy neural network are used as the control basis of the buffer set in the key chain, so as to obtain a good project cost control effect.

4. Discussion

4.1. Project cost control content in construction stage

In the project cost control in the construction stage of a construction project, the main work of cost control in the contract management stage includes controlling the number of engineering changes and claims.

(1) Cost control of engineering change.

The owner may establish a change application procedure for controlling project changes. Before the design change is issued to the construction unit for implementation, the application form must be submitted to the management of the company to ensure that the management understands in detail the expected impact of each design change on the budget and construction period, and compares the feasibility and cost of different schemes. It can be officially issued after approval, and there must be strict restrictions on major design changes. Since most of the design changes will constitute the reason for the construction unit to claim for compensation in terms of construction period and economy, and may greatly weaken the owner's control in all aspects, the number and amount of design changes have a great relationship with the success or failure of the construction project. Once the design change is determined, the owner needs to make a detailed estimate of the content of the change. Determine the changed items of the construction project according to the requirements of the design change, list the list of changed items, and then calculate the quantities according to the items in the list. When listing the bill of quantities, it shall be consistent with the list items in the contract, that is to say, the bill of quantities shall be determined according to the same project division standard, single work content and bill of quantities calculation rules. In case of any change caused by the contractor, the Contractor shall try to adjust the construction scheme by itself, speed up the construction progress and return to the construction period, and bear the corresponding increased costs; In case of any change caused by the engineer's instruction, the Contractor shall extend the construction period or negotiate with the contractor to take measures to speed up the construction and compensate the cost. The construction period not only involves the claim for construction period, but also involves the claim for expenses, rewards and penalties after the completion of the project. Reasonably handling the change of construction period can also control the project cost.

(2) Control of claims.

The construction project claim refers to the compensation demand that should be borne by the other party according to the contract for the actual losses suffered through no fault of the other party during the construction of the construction project. Due to the complexity of the construction of the construction project, it is difficult to avoid the occurrence of claim events, such as geological reasons and underground structures in excavation. In most cases, the claims are caused by subjective reasons, such as the engineer's instructions and the rework costs caused by design changes. Therefore, claim is also one of the key links of cost control in the construction stage. When a claim occurs, as the owner, we must first identify what the Contractor's claim application contains is a reasonable actual loss due to the needs of the project and what is an unreasonable request made by the contractor for pure profit. For the former, the actual losses incurred by the contractor should be reviewed and the corresponding claim funds should be provided in time, which not only meets the reasonable requirements of the contractor, but also keeps the project continuous and reduces the risk of the project. For the latter, the owner should hire professionals to explain the irrationality of these claims from a professional perspective and reject their claims. At the same time, we should strengthen the foresight of claims and try to avoid claims. For claims, neither the employer, the contractor nor the engineer want them to happen, because the handling of claims will involve the interests of all parties, and the workload of argumentation and negotiation is large, which requires more time and energy. It is beneficial for all parties to strengthen the forward-looking nature of claims and try to avoid claims. Of course, avoidance is not avoidance. Once claims occur, they should be taken seriously.

4.2. Cost control strategy in construction stage

The following two aspects can be taken into consideration to strengthen the control of project cost in the construction stage of construction projects:

(1) Strengthen project cost control and management.

Before the commencement of a project, sufficient preparations should be made and a correct fund utilization plan should be properly formulated according to the budget requirements. We should not only ensure that the project construction has sufficient funds, but also occupy as little funds as possible. We should also make careful arrangements for the number of workers, mechanical equipment, material supply, production or procurement of accessories, transportation conditions, etc. in combination with the nature and scale of the project. Determine the construction period of each sub project according to the actual situation, select the technically feasible and economically reasonable construction scheme, and organize the construction in an orderly manner. Make full use of existing equipment, promote efficient operation, ensure work quality, improve work efficiency and equipment utilization, shorten construction period and reduce project cost.

(2) Improve construction site management.

The construction process is changeable, so it is necessary to go deep into the site to obtain first-hand information, master the project progress, and find out the investment deviation in time. Take appropriate corrective measures, scientifically predict the unfinished projects, timely discover potential problems, take the initiative in cost control, and also provide a strong basis for completion acceptance. After the completion of the project, the whole project shall be subject to load or no-load joint test run according to the quality standards required by the design before acceptance. Problems found shall be rectified in time to avoid rework losses after putting into operation. The construction unit delays the promised construction period due to improper measures; In cross operation, if one party impedes the other party's normal work procedure due to untimely site cleaning, or damages the finished product of the project due to brutal construction, or uses new products not designated by the owner, resulting in increased project cost, the construction unit can make counterclaim. In order to do a good job of counterclaim, we need to have sufficient and powerful evidence, and make use of the role of the supervisor to keep the original data such as the site project images.

5. Conclusion

In the development of society, construction projects have gradually become more complex and large-scale, which also makes the construction cost of construction projects more difficult. The construction stage of the construction project is greatly affected by the internal and external environment, so it is necessary to effectively deal with the changes of the internal and external environment, so as to make the cost control of the project truly possible. In the construction stage, the external environment cost control is relatively important, which is of great significance to the cost control of the project. Therefore, in the construction stage, the cost analysis and summary should be carried out in time, the external cost estimate should be defined, and the unnecessary cost increase should be reduced on the basis of relevant coordination work, so as to achieve the cost control and achieve the goal of good benefits for the enterprise. The fuzzy neural network is used to realize the dynamic control of the project cost in the construction stage, and the project cost in the construction stage is dynamically controlled by the high-efficiency prediction performance of the fuzzy neural network method. The experiment proves that this method can effectively control the project cost in the construction stage and has good application performance.

Data availability statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

Authorship contributions

All authors are contributed equally to this work.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

[1] Tang Y, Chen Y, Hua Y, et al. Impacts of risk allocation on conflict negotiation costs in construction projects: does managerial control matter? Int J Project Manage. 2020;38(3):188–199.
[2] Rezahoseini A, Noori S, Ghannadpour SF. Integrated scheduling of suppliers and multi-project activities for green construction supply chains under uncertainty. Autom Constr. 2021;122(8):103485.
[3] Thesing T, Feldmann C, Burchardt M. Agile versus waterfall project management: decision model for selecting the appropriate approach to a project. Procedia Comput Sci. 2021;181(30):746–756.
[4] Li XM. Material price risk control in construction cost control. Mater Prot. 2020;53(10):175–176.
[5] Hn MK, Lker MV, Schmidt T. An algorithm for efficient generation of customized priority rules for production control in project manufacturing with stochastic job processing times. Algorithms. 2020;13(12):337–348.
[6] Gumbarevi S, Dunovic IB, Milovanovi B, et al. Method for building information modeling supported project control of nearly zero-energy building delivery. Energies. 2020;13(5519):1–21.
[7] Barber S, Schubiger A, Koller S, et al. A new decision process for choosing the wind resource assessment workflow with the best compromise between accuracy and costs for a given project in complex terrain. Energies. 2022;15(3):1110–1118.
[8] Hoseini E, Veen PV, Bosch-Rekveldt M, et al. Cost performance and cost contingency during project execution: comparing client and contractor perspectives. J Manag Eng. 2020;36(4):50–60.
[9] Kim J, Lotfaliei B. Debt recapitalization and value in waiting to finance a project. Oper Res Lett. 2020;48(4):421–427.
[10] Li X, Wang XY. A dynamic pre-control system for the projected cost of post-earthquake building groups in restoration and construction stages. China Earthq Eng J. 2019;41(06):1679–1684.

[11] Li Q, Li Y. Research on comprehensive cost management of highway engineering life cycle based on BIM. Highw Eng. 2019;44(03):264–269.
[12] Shi WL, Liu L, Xu Y. Cost control model of expressway project based on system dynamics. J Civ Eng Manage . 2020;37(05):62–67+76.
[13] Li YP, Li YF, Sun ZL, et al. Optimization method of engineering project resource balance based on SAGA. J Civ Eng Manage. 2020;38(03):84–87+94.
[14] Wang RJ, Wang CJ. Simulation of reliability prediction method for prefabricated construction period. Comput Simulat. 2019;36(12):468–471.
[15] Luo DM, Niu DT. Influences of water-to-cement ratio and curing condition on water absorption of internal curing concrete. J Build Struct. 2019;40(01): 165–173.
[16] Wu YJ, Huang FH, He Y, et al. Research on simulation method of construction cost based on uncertain network graph. Adv Power Sys Hydroelect Eng. 2019;35(07):10–17.
[17] Wang WJ. Simulation of software secret data loss prevention transmission based on mobile gateway. Comput Simulat. 2021;38(11):459–463.
[18] Rodríguez RM, Labella L, Dutta B, et al. Comprehensive minimum cost models for large scale group decision making with consistent fuzzy preference relations. Knowl Based Syst. 2021;215(1):106–115.
[19] Meng F, Pedrycz W, Tang J. Research on the consistency of additive trapezoidal fuzzy preference relations. Expert Syst Appl. 2021;186(3):115837.
[20] Gupta S, Patel N, Kumar A, et al. Adaptive fuzzy convolutional neural network for medical image classification. J Intell Fuzzy Syst: 1–17.
[21] Li J, Mi Y, Shi Y, et al. Fuzzy-based concept learning method: exploiting data with fuzzy conceptual clustering. IEEE Trans Cyber. 2020;42(1):1–12.
[22] Kalaivani K, Kshirsagarr PR, Sirisha Devi J, et al. Prediction of biomedical signals using deep learning techniques. J Intell Fuzzy Syst. 2023: 1–14.
[23] Chiranjeevi P, Rajaram A. A lightweight deep learning model based recommender system by sentiment analysis. J Intell Fuzzy Syst. 2023: 1–14.
[24] Cheng S, Wu Y, Li Y, et al. Twd-sfnn: three-way decisions with a single hidden layer feedforward neural network. Inf Sci (Ny). 2021;579(9):15–32.
[25] Babu PA, Rai AK, Ramesh JVN, … Dilipkumar S. An explainable deep learning approach for oral cancer detection. J Elect Eng Technol. 2024;19(3):1837–1848.
[26] Zekrifa DMS, Lamani D, Chaitanya GK, … Rajaram A. Advanced deep learning approach for enhancing crop disease detection in agriculture using hyperspectral imaging. J Intell Fuzzy Syst. 2024: 1–14.
[27] Shunmugasundaram M, Ahmad MO, Subha T, et al. An effective method for managing waste in smart cities based on deep residual neural network approach. J Environ Protect Ecol. 2024;25(2):420–429.
[28] Xie X, Zhang H, Wang J, et al. Learning optimized structure of neural networks by hidden node pruning with l_{1 regularization. IEEE Trans Cyber. 2020;50(3):1333–1346.
[29] Li X, Yuan C, Shan B. System identification of neural signal transmission based on backpropagation neural network. Math Probl Eng. 2020;2020(1):1–8.
[30] Dorogov AY. Stratified model of self-similar multi-layer neural network. Procedia Comput Sci. 2021;186(4): 685–692.
[31] Zhang JG, Ji F. Project buffer management based on activity resilience. Chinese J Manage. 2020;17(06): 924–930.
[32] Ji GD, Zhan YM. Method for determining critical chain project buffer based on information flow interaction. J Civ Eng Manage. 2022;39(01):35–42.