Research and Application of Construction Cost Forecasting System Based on BP Neural Network

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Abstract

With the steady development of the construction market, the scale of investment in fixed assets gradually increased, and thus reasonable control of construction investment is particularly important. In the whole life cycle of the construction project, the impact of the early stage on the investment control is higher than the construction stage, but the construction enterprises do not pay enough attention to the pre-investment decision-making stage. At present, the traditional project cost estimation method adopted in the investment decision stage cannot adapt to the development trend of the market economy. The accuracy of the investment estimation becomes the key factor of the investment control of the construction project. Therefore, the rapid and accurate estimation of project cost for the construction project investment control is of great importance. Firstly, the engineering characteristic factors influencing the construction cost of the main sub-project are sorted and extracted according to the main factor analysis method, and the hierarchical model is established to calculate the weight of the influence factors of the project factors on the project cost. The main factors are selected according to the primary and secondary factors, and the influence mechanism of construction engineering factors on the project cost is analyzed, and it is taken as the input vector of the estimation model. Secondly, according to the learning process of standard BP neural network and the relevant knowledge of gray number in gray theory, the initial connection weight between the hidden layer and the input layer is set by the interval gray number. Through the process of adjustment, the optimal value of the weighted BP neural network is improved, and the initial weight and coefficient of the model are improved by genetic algorithm, which improves the accuracy of the model. The results show that the applicability and reliability of BP neural network model are optimized by comparing the estimated value of the estimated model and the calculation result according to the investment estimation index.

Keywords: Construction Cost Forecasting System, BP Neural Network, Construction Investment, Genetic Algorithm.

1. INTRODUCTION

For a planned project, not only the country's economic development needs to consider, but also need to take into account the feasibility of technology, the most important is whether the economy is reasonable (Kim et al., 2004). The estimate cost of the construction project prepared in the pre-investment decision-making stage is one of the key documents to test the economic rationality of the project.

Through the research on the forecasting methods and estimation models at home and abroad, it can be seen that the current forecasting methods and the estimation models have their own advantages and applicability, but there are also some defects and limitations. The accuracy of the project reasoning method to estimate or predict the project cost depends largely on the degree of similarity between the proposed project and the typical project. For the typical project with the similarity degree, the larger the available value is, and the smaller the similarity of the case, it will completely lose the value of reference (Zhang et al., 1998; Maier et al., 2000). This will lead to the final establishment of the case library needs to include various types of projects, the establishment of the case library has become a difficult point. For the case-based reasoning, most of the work of the estimation process is focused on the selection of cases and the establishment of case libraries (Paliwal et al., 2009). In this process, a large number of different types of projects need to be selected, and the number of projects can not be selected, this choice for the human body is a huge and complex work. But the case-based reasoning method is easy to understand, it is more convenient for the user. The fuzzy mathematics method to estimate the cost of engineering or forecasting is to determine the degree of membership of the project characteristics, proximity and adjustment coefficient, and this work is more difficult, the form of membership function is also too subjective,
so the model is a high demand (Chau et al., 2007). It can be seen from the literature that the gray system theory generally adopts the GM (1,1) model in the prediction, that is, the first order differential equation with only one variable. For the construction project, the factors that affect the project cost are often multifaceted, and the construction cost of the project cost is also complex and diverse, so GM (1,1) model cannot be used for multi-factor project cost estimates.

It can be seen from the research that neural network is becoming more and more mature. Many of the characteristics of artificial neural network show that neural network is very suitable for engineering cost estimation, and many scholars have already studied it. BP neural network is error back propagation neural network. In order to improve the deficiency of BP neural network, this work proposes a gray system theory to improve the BP neural network algorithm, so as to improve the BP neural network. In this work, we propose a method to improve the BP neural network by using the gray system theory to improve the BP neural network (Dharia et al., 2003; Huang et al., 2004).

2. BP NEURAL NETWORK COST AND ESTIMATION OF CONSTRUCTION ENGINEERING

2.1 The composition of the total investment of the construction project

The total investment of the construction project is the sum of the expenses of the project used in the construction project during the construction period, which consists of the construction investment, the interest of the construction period loan and the working capital (Öztaş et al., 2006). According to the asset attributes, the total investment of construction projects can be divided into fixed assets investment and investment in current assets (Wanous et al., 2003). Liquid investment is an integral part of the investment of liquid assets. The investment in fixed assets includes the interest of construction investment and construction period. Static investment means that the construction project does not take into account the time value of price fluctuation and construction period loan interest. The construction project to estimate the construction investment, the general will set a price calculation of the base year. In contrast, the dynamic investment is to consider the estimated value of capital investment in the case of construction investment, generally including the construction period of loan interest and the cost of preparation costs in the preparation fee, other investment costs can be regarded as time-independent static investment. Construction investment refers to the project implementation period for the construction of all project costs, often related to the project design. Construction investment can be further split into engineering costs, construction and other costs and preparation costs.

The project cost refers to the total cost of the construction project in accordance with the construction content, scale, standard and the use function and requirements of the construction project to complete acceptance until the delivery process. At present, the cost of construction in our country often includes the purchase cost of equipment and equipment, the cost of construction and installation, the other costs and preparatory expenses of construction, the interest of construction period loan, that is, the so-called fixed assets investment.

In the construction project investment, by analyzing the composition of investment in construction projects, combined with the current market and social reality, you cannot consider the purchase of equipment and equipment costs, and other costs in the construction of land-related costs are land users through the government of the public auction or other means, cannot be used to predict the cost of the model, construction period loan interest and reserve costs are related to the total investment, not an independent fee. Therefore, this work chooses to estimate the cost of construction and installation as the main research object (Kim et al., 2004).

2.2 Estimation of Construction Cost

In different stages of construction, the cost of construction project is not the same, for example, in the project proposal stage and feasibility study stage, the cost of the construction is the investment estimate, the project cost in different stages of the form is shown in Figure 1
In the research of this work, the main function of the model is to forecast the cost of the residential project, and to make reference for the investment estimation. Therefore, the estimation of the investment project is the investment estimate of the construction project in the beginning of the construction project.

In the stage of the project and feasibility study of the traditional construction project, most of the cost of the proposed project is estimated by using the estimated index. The so-called project cost estimation index refers to the economic price of the construction and installation project of the production unit (such as m2, m3 or block, seat, etc.) and the consumption standard of labor, materials and construction equipment. The preparation process is to select the representative, in line with the direction of technological development, the number of sufficient and has the possibility of repeated use of the design drawings and engineering quantities of the project pre-billing information, the classification of screening, statistical analysis after the comprehensive determination. The use of engineering cost estimates can be roughly derived from the proposed project investment estimates and engineering materials consumption and so on.

In addition to use the traditional investment estimation indicators to calculate the investment estimates of the construction project, you can also use quantitative exponential smoothing, regression analysis and qualitative brainstorming, etc, or use fuzzy mathematics, genetic algorithm and other theories to model solution. The investment estimation of construction project can not only provide reference for the selection of technologically advanced and economically rational architectural design scheme, make the design of construction drawings more rational and influential, and have an irreplaceable influence on the investment decision in the early stage, which will affect the design of the subsequent stage budget and cost management and control in the implementation of the project (An et al., 2007).

3. BP NEURAL NETWORK

BP neural network is a multi-level feed forward neural network. The gradient descent method is used to adjust the weights and thresholds of the network by continuous error learning to achieve the minimum square sum of errors. BP neural network is a multi-layer feed forward neural network based on signal supervisor and error inverse algorithm. BP algorithm uses a relatively simple network structure, the algorithm is easy to understand, and the adjustment of the error is small, the entire network of high precision, can be used in many areas, "generalization" ability, making the BP algorithm to train artificial nerve, one of the main algorithms of the network.

3.1 BP neural network structure

BP neural network is generally set to three or more layers of the neural network, the middle of the hidden layer is set to one or more layers, the network structure shown in Figure 2:
The number of input neurons is equal to the number of input signals, the number of layers of hidden layers and the number of neuron nodes need to be set according to the actual situation, there is no definite method. The number of neuron nodes in the output layer is equal to the number of output signals. In the neural network model, the learning process consists of two steps: The forward propagation of the signal and the reverse propagation of the error. When a group of learning data is input from the input layer into the network neurons are activated, the neuron activation value from the input layer through the middle layer to the output layer to the output of the network output, and then reduce the expected output and network output are Square error method, starting from the output layer and then by the middle layer by layer to correct each connection weight. Continuously repeating such a learning and adjustment process, and ultimately can make the error signal close to the set target, then the network to stop training, in this process the least mean square error is learned.

The advantages of BP neural network: (1) Nonlinear; artificial neurons can be designed either linearly or non-linear in design, and when all neurons are designed as non-linear neurons, the neural network composed of each other is nonlinear, and the nonlinearity of the neural network is global. (2) Mapping function; neural network in essence can be achieved according to the input data mapping to the output data function, especially after the training and learning of neural networks, can be completed by the input to the output of the various maps. This combination of mapping and non-linearity makes the neural network a very good task of solving various nonlinear problems. (3) Adaptability and learning; BP neural network error back propagation to adjust the weight of the process, making the neural network can adapt to the environment with the external skills, which is the adaptability of neural networks. And learning is the neural network in the training process through continuous adjustment and transformation, you can get from the data in the knowledge and information stored in the network, and slowly accumulate experience and rules. (4) Generalization ability; the so-called generalization ability refers to the neural network after training encountered new data and knowledge can learn the knowledge of the flexible use, that is, it can attack the mountain stone. The generalization ability is an important index to evaluate the practicability of neural network (Cheng et al., 2009).

3.2 Learning of Improved BP Neural Network

In the three-layer feed forward network, the weight between the input layer and the hidden layer is $m \times n$, and the output value of the output layer is often modeled by the three-layer BP neural network. As a result of the prediction, if the output value is two gray numbers, the whitening number is also whitened. Therefore, the weight matrix between the input layer and the hidden layer is set to the gray number, and the weight matrix between the hidden layer and the output layer should be white. Use $V_{ij}$ to represent the weight matrix between the input layer and the hidden layer, that is $V_{ij} = [V_{i1}, V_{i2}, ..., V_{in}]$; Where column vector $V_{ij}$ is the weight vector of the jth neuron of the hidden layer. The subscript $\oplus$ indicates that the weight is the interval gray number, the weight matrix between the hidden layer and the output layer is represented by $W$, $W = [W_1, W_2, ..., W_j, ..., W_k]$, where the column vector $W_j$ is the weight vector corresponding to the kth neuron of the output layer.

When the error is propagated back to the input layer, the weight $w_{ij}$ between output layer and hidden layer and the weight $v_{ij}$ between hidden layer and input layer are adjusted according to the adjustment formula, and the value adjustment formula between output layer and hidden layer is (Adeli et al., 2006):
\begin{equation}
    w_{ij}(t+1) = w_{ij}(t) - \Delta w_{ij} = w_{ij}(t) - \eta o_k (d_i - o_k) (1 - o_k) y_{i,j}
\end{equation}

And the weight \( V_{ij} \) between the hidden layer and the input layer is the number of gray, the adjustment should be of its interval. Since the value range of this paper is \([-1.1]\), in order to ensure the gray interval, the number of intervals gradually reduce the approximation of the optimal value, should be based on the weight adjustment of the positive and negative to determine the adjustment of the gray interval, namely:

\begin{equation}
    v_{ij}(t+1) \in [v_{ij}(t+1), v_{ij}(t+1)]
\end{equation}

When \( \Delta v_{ij} > 0 \),

\begin{equation}
    v_{ij}(t+1) = v_{ij}(t) + \Delta v_{ij}
\end{equation}

\begin{equation}
    v_{ij}(t+1) = v_{ij}(t) - \Delta v_{ij}
\end{equation}

When \( \Delta v_{ij} < 0 \),

\begin{equation}
    v_{ij}(t+1) = v_{ij}(t) - \Delta v_{ij}
\end{equation}

\begin{equation}
    v_{ij}(t+1) = v_{ij}(t) + \Delta v_{ij}
\end{equation}

### 3.3 Fusion of Grey Theory and BP Neural Network

The fusion of gray system theory and BP neural network can be divided into simple fusion and combinatorial fusion according to the degree of fusion. Simple fusion can be further subdivided into weak integration, series fusion, etc., combination of fusion in accordance with the fusion of different ways there are two types.

Weak convergence generally refers to a part of the system in which some of the gray features can be resolved by gray theory, while the gray features are not obvious part of the use of BP neural network solution. This weak way of integration is generally simple, the two theories are independent of each other, do not interfere with each other. Tandem fusion refers to the connection of a theory with another theory in series, which is equivalent to the input value of a theoretical model that can be used as another theoretical model. The numerical values of the gray prediction model GM (1,1) model are used as the input signals of the neural network model, input to the neural network, and then trained and learned by the neural network to get the final output value with less error. In turn, we can also use the neural network to enhance the gray system. By constructing the BP neural network, the parameters of the gray differential equation are approximated. When the training of the neural network reaches the required progress, the parameters that have been whitened are extracted from the training results, so that we can obtain a high degree of accuracy of the differential equation, a simplified solution.

In the case where the training samples are the same, if the different parameters are used to predict the results using the GM (1,1) model, the error between the output and the true value of the model can be minimized. It can be used with the neural network fusion model. First, we need to construct a number of different GM (1,1) prediction models. Through these prediction models, we can get multiple sets of predicted output values, and use the obtained multiple sets of forecast values as the input vector of neural network, and then construct the neural network. The output value of the neural network is the final output data closest to the true value. In this combination of fusion, the neural network structure selection is often used to use a wide range of BP neural network structure or RBF neural network structure, to quickly achieve the model to establish and solve, and high precision. The number of nodes in the input layer neurons of the network is the number of GM (1,1) prediction models, and the number of nodes in the output layer neurons is consistent with the output of the gray prediction model. The combination of its structure is shown in Figure 3.
In the BP neural network, the connection weights between the input layer and the hidden layer can often change the starting point of the training of the neural network on the error surface. Therefore, the weight of the initialization method can be a good way to reduce the training time of the neural network. In general, the weight of the connection is the value of the network will be in the [-1,1] between the value of the training process in the continuous adjustment. In practice, there are two ways to adopt, one way is to set the initial weight to an infinitely close to the number of -1, the other way is to set the number of roughly the same value of -1 and +1 initial Weight. It can be seen from the weight adjustment formula that when the value of the weight between the output layer and the hidden layer is too small, the weight adjustment between the hidden layer and the input layer is small, which leads to an increase in the number of training, so generally in the output layer and the implicit layer to set the initial weight between the latter method used more.

The weights between the hidden layer and the input layer and the weights between the output layer and the hidden layer are indeterminate between the [-1,1] intervals can be regarded as the interval gray number $\otimes$ and the number of gray $\otimes \in [-1,1]$, the amount of implicit layer weights can be adjusted as the interval of gray numbers when the error is propagated backwards. When the number of adjustments reaches a certain degree, the gray number interval will gradually shrink until the upper and lower boundary values of the gray number interval are equal, and the gray level $g' = 0$, the gray number of the hidden layer weights become white (Pendharkaret al., 2003).

4. ESTABLISHMENT AND OPTIMIZATION OF PREDICTIVE MODEL

The working principle of the neural network is to adjust the network weights according to the training process of the training samples, so that the neural network produces “memory” to the training samples, and such memory generally requires a large number of training samples to get. The training sample contains the rules extracted by the network. So the number of samples in each category is as large as possible. The selected training samples need to be selected by "egalitarianism", so that when the network training, the established model will be knowledgeable, no longer bias to a certain class of samples, and will not appear on the number of models, and the number of fewer new samples of the project in the field of construction engineering, different types of housing its unilateral cost and man machine consumption is not the same. In order to improve the accuracy of the neural network estimation model, this work collects and collates the cost data of 300 sets of residential projects, eliminating the redundancy of information and the uselessness of the categories in order to make the neural network can treat each category in the training process evenly. Information, and finally received 121 sets of available training samples.

Through the finishing of the residential project cost data contains quantitative indicators and qualitative indicators. The quantitative indicators include the total construction area, the number of layers, the eaves high and the engineering cost index, the qualitative index is the language variable described by the text class. When this language variable is used as the input vector of the neural network, the language value needs to be conversion to make it into a discrete number of values, so that the network can identify the input data. In order to transform the input data, this work selects the most commonly used linear normalization method:

$$x_i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}$$

(7)
In the establishment of the sample database, 121 sets of information were complete, involving a wide range of residential engineering sample data, the 121 groups of samples were divided into training samples and test samples. Among them, the training sample is 120 groups, used to train the established BP neural network model. The test samples are group 1, and the error and error percentage are calculated according to the network output vector and the expected output vector. The accuracy of the model and the network performance of the model are observed.

Through the training of 120 sets of samples, the training samples are finally obtained, as shown in Figure 4:

![Image of error curve](image_url)

**Figure 4.** Figure of error curve

It can be seen from the figure that when the number of training reaches 50 times, the mean square error E of the neural network estimation model has dropped to 0.0000993, reaching the set error range of 0.0001, and the training is stopped.

In order to improve the performance of BP neural network for intuitive analysis, the training model is trained by standard neural network model. The training results are shown in Figure 5:

![Image of error curve](image_url)

**Figure 5.** Error curve of standard BP neural network

It can be seen from the figure, the standard BP neural network performance gradient in the first three steps of training when the decline faster, from the third step backward error curve gradually tending, and reached the minimum performance gradient before a slight rise , and when the error reaches 0.4015, the error has stopped declining, which indicates that the BP neural network at this time in the training process error into the local minimum point, when the training reaches the minimum performance gradient target will stop training, and the error of this time still does not meet the required target, so the use of standard BP neural network to predict the cost of the project will lead to predict the actual results and the greater the error between the project decision-making have a negative impact. Compared with the standard BP neural network, the improved BP
neural network has the advantages of short training time, small training error and fast convergence speed. Therefore, the improved BP neural network estimation model is practical and reliable.

Genetic algorithm can be used to optimize the initial weights of neural networks, and it can also be used to determine the structure of neural networks. In this work, the basic structure of the improved BP neural network has been determined, and the initial parameters of the network include the whitening coefficient $\alpha$, the initial weight matrix of the neural network is given randomly, so it can be used to optimize the genetic algorithm, the obtained weights and whitening coefficients are taken as the initial weights and whitening coefficients of the neural network. Initializing and improving the BP neural network will randomly generate the weights of a set of BP neural networks. At the same time, the initial population will produce a set of random whitening coefficients. This group of weights and whitening coefficients are used as the chromosomes of the genetic algorithm for genetic manipulation. After the optimization of the above genetic algorithm, with the same set of training samples on the model training, the error curve obtained at this time as shown in Figure 6:

![Figure 6. Error curve of genetic neural network](image)

According to the optimized neural network training chart and the optimized neural network training chart, we can clearly see the training time and performance. We can compare the performance of the network training performance in Figure 4, Figure 5 and Figure 6.

### Table 1 Contrast training performances

<table>
<thead>
<tr>
<th>Neural network type</th>
<th>Training steps</th>
<th>Training time</th>
<th>Final error</th>
<th>Minimum performance gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard BP Neural Network</td>
<td>8</td>
<td>2s</td>
<td>0.4015</td>
<td>4.32e-7</td>
</tr>
<tr>
<td>Improved BP neural network</td>
<td>50</td>
<td>6s</td>
<td>9.93e-5</td>
<td>2.08e-5</td>
</tr>
<tr>
<td>Genetic BP neural network</td>
<td>35</td>
<td>4s</td>
<td>9.68e-5</td>
<td>5.43-5</td>
</tr>
</tbody>
</table>

Through the comparison of training performance and simulation results, it can be seen that when the training samples and parameters are the same, the improved BP neural network is more accurate than the standard BP neural network, and the training performance is better, and the improvement of genetic algorithm optimization BP neural network makes the model improve effectively in the training time, the number of steps and the final error, and the network performance is further improved compared with the improved BP neural network.

### Table 2 Comparison of cost forecast

<table>
<thead>
<tr>
<th>Serial number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual cost(Million yuan)</td>
<td>51.25</td>
<td>47.86</td>
<td>46.52</td>
<td>38.18</td>
<td>53.16</td>
<td>66.24</td>
</tr>
<tr>
<td>Predictive cost(Million yuan)</td>
<td>50.85</td>
<td>48.10</td>
<td>46.24</td>
<td>37.85</td>
<td>52.80</td>
<td>67.21</td>
</tr>
<tr>
<td>Relative error</td>
<td>-0.79%</td>
<td>0.5%</td>
<td>0.61%</td>
<td>0.86%</td>
<td>0.68%</td>
<td>1.46%</td>
</tr>
</tbody>
</table>
The use of genetic neural network trained to predict the 6 construction cost samples, the error is less than 2%, the combination of genetic algorithm and BP neural network in the project cost forecast can be used. As shown in table 2.

5. CONCLUSIONS

Genetic algorithm optimization based on the improved BP neural network, the initial weights and albatore locating coefficients of BP neural network are set as genetic populations, and the improved BP neural network is optimized by genetic algorithm. The optimized project cost is obtained. The optimization model is trained by the same set of training samples. The calculation results, error curves and training performance of the BP neural network estimation model and the improved BP neural network estimation model are compared and optimized. The reliability of the genetic algorithm in the optimal network parameters is verified. By comparing the calculated results of the traditional investment estimation index and the improved BP neural network, it is proved that the improved BP neural network estimation model can realize the project cost quickly and accurately.

REFERENCES