Study on Project Bidding Risk Evaluation Based on BP Neural Network Theory

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Abstract By analyzing appraisable factors of engineering project bidding risk, a comprehensive evaluation model of engineering project bidding risk based on BP (back propagation) neural network is established to enhance the validity of evaluation in this paper. By learning of some effective samples given, the extraction and storage of experts' knowledge and experience are realized with this model. Two simulation examples show that the proposed comprehensive evaluation model of engineering project bidding risk based on BP neural network is reasonable and feasible. The purpose of this paper is to provide a scientific basis for the bidding decision-making.
Key words Engineering project; Neural network; Risk evaluation

1 Introduction

The purpose of engineering project's bidding is to lower cost and to improve project quality by winning the bid in competition. One of the important links is bidding risk appraisal, which is also tactics and technologies competition between bidding enterprises. Several researches on risk appraisal regarding engineering projects have been conducted at present, and some practical appraisal methods have been proposed at present. For example, the entropy method[1], projection pursuit(PP) method[2], Analytic Hierarchy Process(AHP) method[3], fuzzy comprehensive evaluation[4], etc. All these appraisal methods have their limitations. For instance, In the PP method realization process, projection direction, projection value and projection indicators' function, etc., need to be changed according to actual problems, and it is worth a further studying. The AHP method requires appraisal indicators to be independent, etc., but many factors in multi-level system are interrelated and influence each other, and their indicator systems are not independent structure. Therefore, this paper proposes an appraisal method of engineering project bidding risk based on artificial neural network technology, and establishes appraisal model of project bidding risk based on BP neural network. Its goal is to appraise project bidding risk effectively and to provide a scientific basis for the bidding decision-making.

2 Indicators System of Engineering Project Bidding Risk Appraisal

2.1 Construction of appraisal indicators

In order to analyze the project bidding risk comprehensively, firstly we should determine the project bidding risk influence factors. According to the roots where risk factors produce and some correlated domestic/foreign literature materials, based on some indicator appraisable principles of commensurability, representation, measurability and foresight, the risk factors in engineering project are given in Table 1. Appraisal indicators used to decide effectual factor are natural risk, political risk, economic risk, competition risk, scene risk, technical risk, equipment material risk, owner risk, contractor risk, overseeing mechanism, management mechanism and decision-making level. According to the appraisal rule, the key effect factors are obtained. A framework with 12 indicators is listed in Table 1, in which there are 4 indicators for 'External Environment', 3 indicators for 'Project Mainbody', 4 indicators for 'Project Owner' and 1 indicators for 'Management Decision-Making'.

2.2 Normalization of appraisal indicators

In order to eliminate the difference of magnitude and units, the original data should be normalized before Artificial Neural Network processing. Because the dimensions and quantities of different indicators differ greatly, they should be transformed to a certain range and in a non-dimensional form. Thus the comparisons would be meaningful. In this research, a normalization transformation method was utilized to transform all the parameters and variants to non-dimensional quantities. All indicators in project bidding risk are grouped into two kinds: positive and negative ones. If an indicator increases while bid risk appraisal result increases, it is grouped as positive ones. Vice versa, negative indicators refer to the opposite characteristics. The normalization processes of appraisal indicators are listed as follows:

(1) Positive indicators:

$$x_i = \begin{cases} 1(u_i \geq u_{i\max}) \\ \dfrac{u_i - u_{i\min}}{u_{i\max} - u_{i\min}}(u_{i\min} < u_i < u_{i\max}) \\ 0(u_i \leq u_{i\min}) \end{cases}$$

Table 1 Indicators and Influence Factors of Project Bidding Risk Appraisal

Risk categories	Specific indexes	Indicators describe
External Environment Risk	natural	Climate condition; Natural disaster
	policy	Policity environment; Profession policy
	economy	Society economy ; Profession economy; Contractor economy
	Status of competition	
Project Owner Risk	owner	Economy Status; Intelligence, prestige, achievement; Authorized tendency
	contractor	Intelligence, prestige, achievement; Construction technical technology; Management level
	Overseeing quality	
	Management mechanism	
Project Mainbody risk	Geology position and scene	
	Technology	New craft; Technology complex
	Equipment material	Special equipment; Equipment power; Material supply
Management Decision-maki	Tenderer's management Decision-making level	

(2) Negative indicators:

$$x_i = \begin{cases} 1(u_i \leq u_{i\max}) \\ \dfrac{u_{i\max} - u_i}{u_{i\max} - u_{i\min}}(u_{i\min} < u_i < u_{i\max}) \\ 0(u_i \geq u_{i\min}) \end{cases}$$

Where u_i represents the original data of any risk indicator, $i(i=1,2,\cdots,12)$ $u_{i\min}$ and $u_{i\max}$ are respectively the minimum and maximum data of indicator i in the standard framework in Table 1. By this way, we transform the original data into standardized values in the range of [0,1], and they are non-dimensional values.

3 Artificial Neural Networks Model of Project Bidding Risk Appraisal

3.1 Principle of the model of bidding risk evaluation Based on ANN

The principle of the model of engineering project bidding risk evaluation based on ANN(Artificial Neural Network) is: Through experts' successful experiences and data, we establish a multi-inputs and multi-outputs ANN comprehensive appraisal model. Firstly, ANN model takes the bidding risk indicators' normalization values as input value and the output is the appraisal value of the project. Secondly, ANN model will train the network through enough learning data and make different input vector obtain corresponding output vector and format experts experience, knowledge as well as indicator tendentious understanding of project bidding risk evaluation. As its simulation is very accurate, the trained ANN model can be used as one kind of effective tool to evaluate unknown project bidding risk, it can output the project bidding risk appraisal degree and realize a comprehensive evaluation of engineering project bidding risk.

3.2 BP network model structure

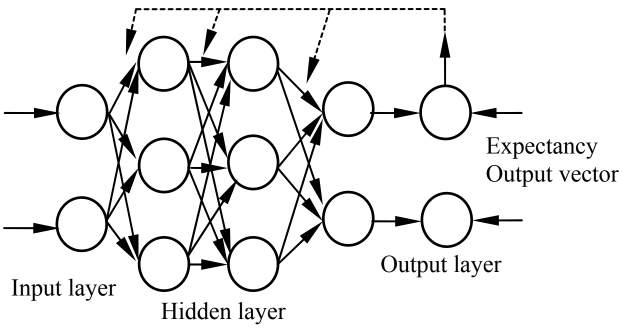

Figure 1 BP Network Model Structure

According to the comprehensive appraisal characteristics of project bidding risk, a 3-layers-structure back propagation (BP) neural network is proposed for multi-layer artificial neural network with sigmoid function. It is composed of input layers, hidden layers and output layers. In this research, input layers refer to project bidding risk indicators and output layers refer to appraisal result. Based on some correlated cases and literatures, input layer is composed of twelve input neural units, namely natural condition, political condition, current economic condition, competition risk, geology position, technology factor, equipment & material, owner factor, contractor factor, overseeing mechanism, management mechanism and decision-making level; output layer is composed of five output neural units, namely risk evaluation degree very high, higher, medium, lower and very low; hidden layer is determined by probe and experience, here we select 25 hidden neural units. The BP net model structure is pictured in Figure 1.

3.3 BP network learning method

BP neural network learning method is divided into two stages: In the first stage, BP network calculates each neural units' input and output values from input layers to output layers, which belongs to fore transmission; in the second stage, BP network calculates each neural units' output errors from output layers to input layers and then adjusts each layer's weigh-value as well as neural units' threshold value by error gradient drop principle, which belongs to back transmission. We suppose input sample space is $X = (x_1, x_2, \cdots, x_i)^T$, output sample space is $Y = (y_1, y_2, \cdots, y_j)^T$, where T denotes numbers of the sample, weigh-value between input layer and output layer is w_{ki} , deviation value is b_k, weigh-value between hidden layer and output layer is w_{jk} , deviation-value is b_j . Then the BP network learning steps are as follows:

Step 1: Initialize weigh-value w_{ki} 、 w_{jk} and deviation-value b_k 、 b_j, in order to establish small random numbers to avoid network saturate and unusual situation;

Step 2: Input learning data and calculate network output values, we have

Hidden layer: $o_{pk} = f(x_i) = f(\sum_i w_{ki} x_i - b_k)$

Output layer: $o_{pj} = f(o_{pk}) = f((\sum_{ki} w_{jk} x_i - b_k) - b_j)$

Where $f(x)$ can be taken as a sigmoid function, namely $f(x) = 1/(1 + e^{-x})$

Step 3: Calculate each layers' error signal, namely $E = \frac{1}{2}\sum_j (T_{pj} - o_{pj})^2$, where T_{pj} is a expect error, Here output layer error signal is $e_j = T_{pj} - o_{pj}$ then input layer error signal is $e_k = f^{'}(o_{pj})\sum_j e_j w_{jk} = (1 - b_k^2)\sum_j e_j w_{jk}$;

Step 4: Adjust weigh-value and deviation-value ; $w_{ki} = w_{ki} + \Delta w_{ki}$, $w_{jk} = w_{jk} + \Delta w_{jk}$, $b_k = b_k + \Delta b_k$, $b_j = b_j + \Delta b_j$, $\Delta w_{ki} = \eta \cdot e_k \cdot x_i$, $\Delta w_{jk} = \eta \cdot e_j \cdot o_{pk}$,

$$\Delta b_k = \eta \cdot e_k, \Delta b_j = \eta \cdot e_j$$

Where η refers to learning rate.

Step 5: Repeat the learning process (step 2 to 4) for n times to get a normal distribution and the average value.

4 Comprehensive Appraisal Model Training and Testing

Table 2 ANN Net-Training Input Value

No	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
1	1	0.8	1	1	0.8	0.8	0.8	1	0.653	0.580	0.436	0.135
2	0.6	0.6	0.4	0.6	0.6	0.8	0.2	0.8	0.385	0.688	0.498	0.092
3	0.6	0.6	0.8	1	0.6	0.8	0.2	0.8	0.597	0.433	0.125	0.642
4	0.6	0.6	0.4	0.6	0.4	0.8	0.6	0.6	0.784	0.236	0.119	0.076
5	1	0.8	1	1	1	1	1	1	0.467	0.512	0.236	0.074
6	0.4	0.6	0.6	0.6	0.8	1	0.2	0.6	0.374	0.605	0.337	0.057
7	0.4	0.4	0.4	0.4	0.6	0.4	0.2	0.2	0.315	0.677	0.503	0.189
8	0.8	0.6	1	0.8	0.8	0.8	1	1	0.605	0.275	0.452	0.248
9	0.6	0.6	0.4	0.6	0.8	0.6	0.4	0.6	0.652	0.351	0.228	0.115
10	0.2	0.2	0.4	0.2	0.4	0.6	0.2	0.2	0.362	0.655	0.477	0.189

Table 3 Factual Output and Expectation Output of ANN

No	Expectation Output					Factual Output				
1	0	0	0	1	0	0.0017	0.0035	0.0069	0.9474	0.0028
2	0	0	1	0	0	0.0038	0.0041	0.9524	0.0021	0.0072
3	0	0	0	1	0	0.0063	0.0034	0.0056	0.9643	0.0057
4	0	0	1	0	0	0.0008	0.0016	0.9266	0.0049	0.0065
5	0	0	0	0	1	0.0076	0.0049	0.0035	0.0027	0.9407
6	0	0	1	0	0	0.0074	0.0078	0.9713	0.0095	0.0018
7	0	1	0	0	0	0.0055	0.9547	0.0031	0.0047	0.0015
8	0	0	0	1	0	0.0069	0.0045	0.0057	0.9525	0.0048
9	0	0	1	0	0	0.0013	0.0062	0.9572	0.0045	0.0036
10	0	1	0	0	0	0.0036	0.9646	0.0038	0.0047	0.0058

To train BP neural network well, firstly we should determine learning data's input/output value. Learning data input-value can be obtained through a normalizing way. In terms of the actual situation of project bidding risk appraisal, output-value could be grouped into 5 levels, namely very high, higher, medium, lower and very low, in which vector (1,0,0,0,0) indicates risk very high, vector (0,1,0,0,0) indicates higher, vector (0,0,1,0,0) indicates medium, vector (0,0,0,1,0) indicates lower and vector (0,0,0,0,1) indicates very low. As analyzed above, we import the first 10 groups of data as training data in table 1 and the last one as testing data to model emulate by Matlab software, and run the emulate model to begin the train, we select overall error is 0.01, hidden layer's learning rate 0.8 and output layer's learning rate 0.6. Training input-values of ANN model are listed in table 2. By training 1100 times, ANN net-training error which precision is 3.2703×10^{-4}, but the goal precision is 1×10^{-4}, After net-training 2000 times, ANN net-training tends to be stable, which iteration is 0.001. BP network actual output-value comparison to expectation output-value is listed in Table 3. By comparing the training result in Table 3, BP net factual output-value is consistent with expectation output-value completely. In order to test BP net structure built above, now we import last group of data (In Table 2) to BP net model to examine its feasibility in terms of their output results. By calculating and training, the BP network factual output-value vector is (0.0037，0.9468， 0.0045 ， 0.0017 ， 0.0034), which is consistent with expectation output result(0,1,0,0,0). Therefore, project bidding risk evaluation method based on ANN can obtain satisfaction results.

5 Practical Applications

As discussed above, we utilize this ANN model to evaluate project bidding risk of Jingying highway in contract section A2. According to this project's correlated statistic data and some investigations of external environments risk, project main body risk, project owner risk as well as management decision-making risk, by normalizing these evaluation indicators, a quantification value vector will be achieved, namely (0.3758, 0.3150, 0.4081, 0.2162, 0.1932, 0.5421, 0.1817,0.0385, 0.2567, 0.3860, 0.2776, 0.4345). Inputting these vector data to ANN model established above, by calculating and training in ANN model, we get a output-value vector, namely (0.0014, 0.0046, 0.0065, 0.9453, 0.0085). Through ANN net output results, we know this project bidding risk degree is lower.

6 Conclusions

This paper constructs an indicator system of engineering project bidding risk appraisal and establishes a risk appraisal model based on ANN. Through real diagnosis research, the ANN model is capable of appraising project bidding risk comprehensively. When we appraise unknown projects bidding risk by ANN model, the ANN model can realize a direct and objective appraisal result through reappearing experts' knowledge and experience. Its goal is to provide a scientific basis for the bidding decision-making.

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