Security status evaluation of tunnel construction based on the fuzzy evalution-neural network

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Abstract. In this paper, a fuzzy evaluation-neural network tunnel construction safety and environmental evaluation model was constructed, according to the characteristics of tunnel construction. Firstly, the main characteristics of tunnel construction were analysed and the evaluation system was constructed. Then the weight of each set of construction factors was determined by using chromatography analysis method. Based on the realization of the system, the neural network was applied to train and test, and the model system was verified by engineering examples. The results show that the model system has better generalization ability and accurately evaluate the safety and environmental of tunnel construction.

1. Introduction

With the gradual acceleration of the pace of social modernization, more and more tunnels appear in the field of engineering construction, but the safety and environmental problem is also increasingly prominent. Various construction factors are constantly changing. The hidden dangers of unsafe factors in construction are varied, and these hidden dangers are often sudden, causing serious harm. It is necessary to carry out safety evaluation during tunnel construction.

The evaluation methods of tunnel construction safety and environmental state usually include expert scoring method, fuzzy evaluation method, analytic hierarchy process method, field investigation method and reliability evaluation method. In addition, there are some comprehensive evaluation methods developed recently. For example, PHA-LEC-SCL method, improved Analytic hierarchy process (AHP), Fisher discriminant Analysis (FDA), Fuzzy Analytic hierarchy process (FAHP), etc. [1, 2]. According to the characteristics of tunnel construction, this paper combines fuzzy evaluation with neural network, and constructs a fuzzy evaluation-neural network tunnel construction safety and environmental evaluation model. With a view to making tunnel construction safety and environmental evaluation method more reasonable and operable.

2. Construction of Safety Evaluation Index system for Tunnel Construction

The safety evaluation of construction tunnel is a typical multi-index and multi-attribute problem. It is very effective to apply the analytic hierarchy process (AHP) of system engineering. To form an orderly hierarchical structure, according to the tunnel construction plan and the actual situation of the site, in the model mainly consider the construction ventilation, environmental conditions, personal

protection, blasting and equipment, slag and transport, construction equipment, construction electricity, and safety management several factors [3,4,5]. Specific evaluation indicators are shown in Fig.1.
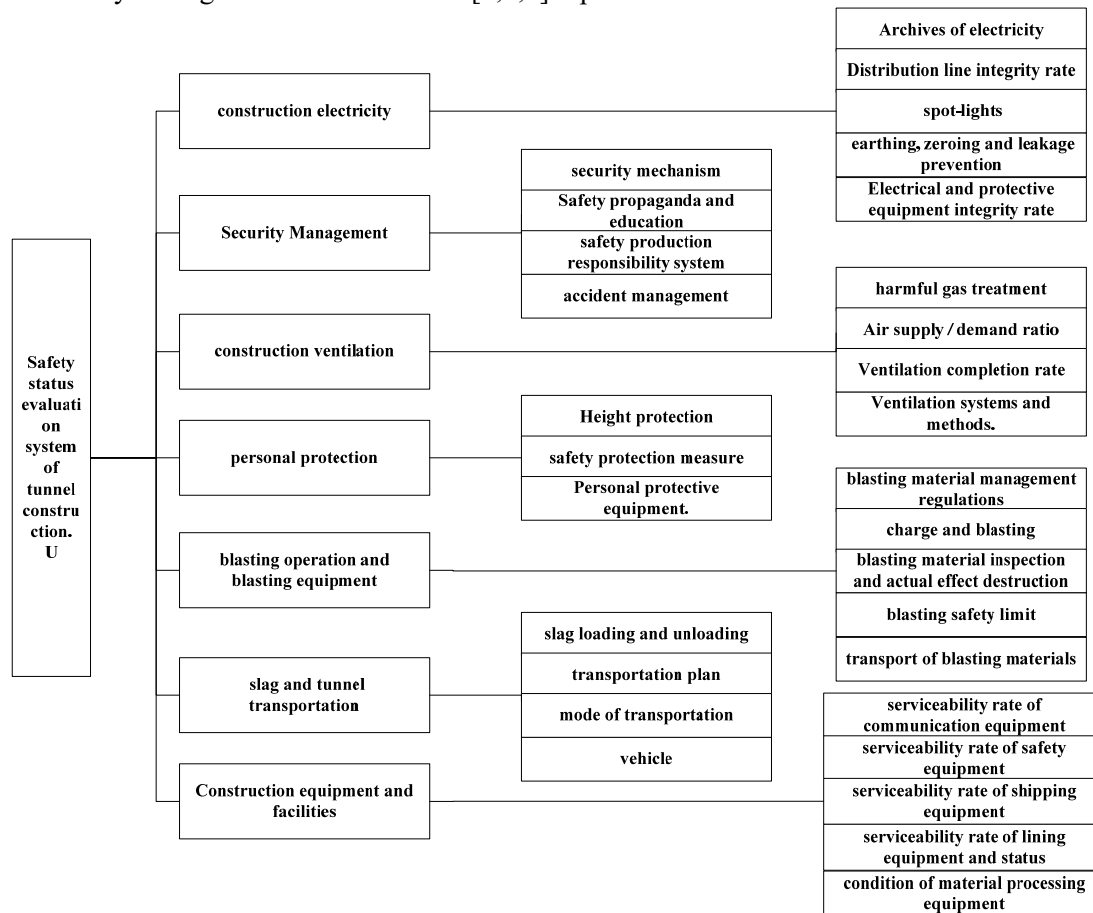

Figure 1. Specific evaluation indicators

The first layer is the target layer, which contains a target object that is U, the safe state of tunnel construction. The second layer is the criterion layer, which is composed of the factors which may affect the safety state of the tunnel construction, including construction electricity, safety management, construction ventilation, personal protection, blasting operation and blasting equipment, slag and tunnel transportation, and construction equipment and facilities, these seven factors constitute the criterion layer of tunnel construction safety state, which are expressed in U1~ U7 respectively. The third layer is the index layer, which is composed of the factors that may affect the criterion layer.

3. Construction of Fuzzy judgement Neural Network Model

3.1. General situation of Tunnel Engineering

The starting and ending mileage of a certain expressway is K274+200~ K285+000. The total length of tunnel is 10.8km. the length of tunnel No. 2 is about 1200m.The tunnel passes through the geomorphological unit of the structure erosion peak, which belongs to the low mountain geomorphology and the erosion hill geomorphology area, and the surface elevation is between 1140 and 1370m. The terrain in this area is characterized by steep terrain and more steep ridges. Vegetation is developed in most areas of the region. The data of base survey, drilling and geophysical exploration are used. There is no serious bad geological phenomenon in the tunnel area of this section. The main bad geological phenomena are karst, weak intercalation and soft rock.

3.2. Level analysis and fuzzy comprehensive evaluation
In the course of the tunnel construction, experts in tunnel engineering, safety engineering, safety evaluation, and geotechnical mechanics and so on are invited to evaluate the safety state of the tunnel under construction. Combined with the corresponding original data and data of the project. Through the expert scoring method, the scoring value of each parameter in the index system, that is, the sample value, is obtained.

According to the tunnel construction index system, the evaluation index of the second layer weight W and the third layer weight W1,W2,W3,W4,W5,W6,W7can be obtained by calculating the scoring values of each parameter according to the tunnel construction index system. Take the evaluation w1 as an example, according to the evaluation of relevant experts and the set of experience, the judgment matrix can be obtained according to the judgment value of the degree of impotence of the factors. After using AHP method to determine the weight of each index of the evaluation system, fuzzy comprehensive evaluation method is used to evaluate and quantify the influencing factors of tunnel safety construction. Thus, the input data and output data of the training BP network are obtained. The fuzzy evaluation set has been constructed V= {V1, V2, V3, V4, V5} = {excellent, good, medium, qualified and unqualified}. According to the expert scoring method, the membership weight matrix is established, in which each weight should satisfy the condition of normality and non-negativity.

Taking the first set of training samples as an example, the sample processing example operation:

$$Y_1 = \begin{pmatrix} 0.5 & 0.4 & 0.1 & 0.0 & 0.0 \\ 0.4 & 0.3 & 0.2 & 0.1 & 0.0 \\ 0.3 & 0.2 & 0.5 & 0.0 & 0.0 \\ 0.3 & 0.5 & 0.1 & 0.1 & 0.0 \\ 0.4 & 0.3 & 0.3 & 0.0 & 0.0 \end{pmatrix}$$

Calculated weight value

$W_1 = (0.5140, 0.0719, 0.0509, 0.1252, \text{ and } 0.2380)$

$B_1 = W_1 \times Y_1 = (0.4338, 0.3713, 0.1752, 0.0197, 0)$

The results of the fuzzy comprehensive evaluation of the sample are as follows:

$$Y = \begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \\ B_7 \end{pmatrix} = \begin{bmatrix} 0.4338 & 0.3713 & 0.1752 & 0.0197 & 0 \\ 0.3838 & 0.3732 & 0.1602 & 0.0269 & 0.0559 \\ 0.5027 & 0.3538 & 0.0697 & 0.0682 & 0.0055 \\ 0.2933 & 0.3892 & 0.1526 & 0.1000 & 0.0648 \\ 0.3892 & 0.3937 & 0.0791 & 0.0757 & 0.0623 \\ 0.3280 & 0.4211 & 0.1016 & 0.0430 & 0.1061 \\ 0.3588 & 0.2908 & 0.2615 & 0.0840 & 0.0050 \end{bmatrix}$$

The weight of the calculated set of factors U

W= (0.0246, 0.4108, 0.2478, 0.0792, 0.0520, 0.0353, 0.1504)

Two level fuzzy comprehensive evaluation vector for safety evaluation of tunnel construction.

$B = W \times Y = (0.4019, 0.3600, 0.1465, 0.0544, \text{ and } 0.0372)$

The resulting B is the program output for this group of samples.

3.3. Level analysis and fuzzy comprehensive evaluation
According to the above evaluation model, 30 of the 7 primary evaluation indexes of construction ventilation, environmental conditions and personal protection are evaluated by primary single factor, which will come from engineering design, construction and supervision. Experts from management and other units formed a judgment group to score the secondary index synthetically. The results were

divided into 15 groups and 12 groups were used as the training data of BP neural network. Three groups were used as data to test the neural network.

Based on the information table to determine the structure of the neural network, set the BP network input node for 7, after many experiments of the network convergence, set the number of hidden layer nodes for 15, output node set to 1. The learning rate of the network is 0.6and the global error is set to 1e-003.The fig.3 shows that the training network converges. It shows that the fuzzy evaluation-neural network evaluation model can extract the key factors automatically through data learning, and the error curve converges well after training the network input. In order to verify the prediction performance of the established BP network, the prediction value is compared with the target value to be forecasted, and the relative error is calculated. The result is shown in Fig.3 and Fig.4. The relative error fluctuates around 25%. The results show that the BP neural network can be applied to the evaluation of tunnel construction safety after effective training. It is proved that the fuzzy evaluation-neural network model has the storage experience after studying and training. The safety evaluation function of tunnel construction is evaluated. The Fig.4 shows the difference between the training error and the expected error. After training, the error decreases gradually, and finally within the range of the expected error, where the expected error is determined to be 0.001.
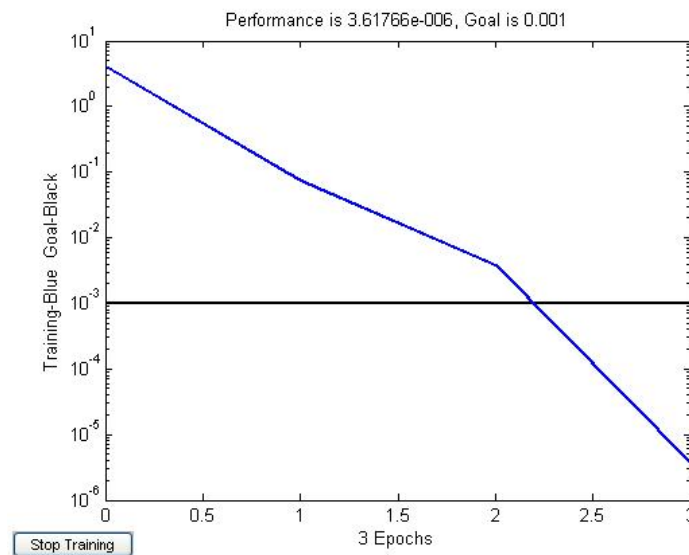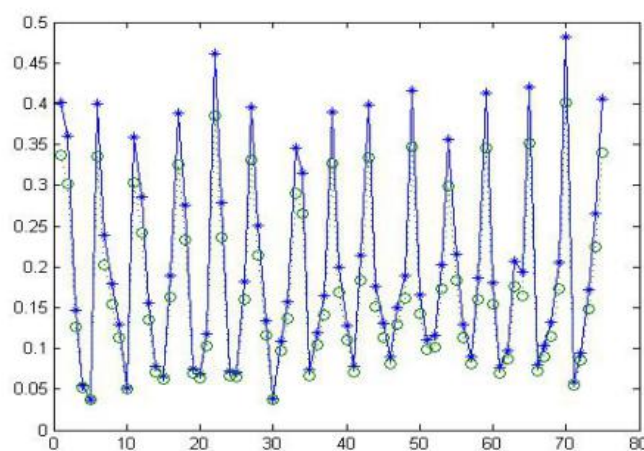

Figure 2. Training error diagram

Figure 3. Training sample error

4. Conclusion

(1)According to the basic principles of safety system engineering, the comprehensive evaluation index system of tunnel construction safety state is established from the aspects of construction electricity consumption, safety management, and personal protection and so on, and 30 evaluation indexes are determined.

(2)According to the characteristics of tunnel construction safety state evaluation, a fuzzy evaluation-neural network evaluation model is established, and the evaluation value is processed by the method of AHP and fuzzy mathematics. It is used as the target value of neural network training to evaluate the safety state of tunnel construction.

(3)The model solves the complex nonlinear relationship between tunnel safety state evaluation results and evaluation elements, and has good generalization ability. Through engineering practice, it is verified that the model can get more accurate evaluation results.

(4)This comprehensive evaluation model can be applied to the safety evaluation involving multi-factors and multi-correlation problems, and provides reasonable suggestions for extending to the safety evaluation of other complex systems.

Acknowledgements

References

[1]   LIU Hui,ZHANG Zhichao,LIU Qiang. Study on safety assessment of highway tunnel construction based on PHA-LEC-SCL method [J].Modern Tunnelling Technology,2010, 47 (5):32-36.

[2]   ZHANG Hong,LI Jianhua,HUANG Hongyuan , et al. Safety evaluation method of the highway tunnel construction system based on fuzzy AHP [J]. Journal of Nanchang Institute of Technology, 2009, 2 8(3):60-67.

[3]   WANG Feiyue,DONG Longjun,BAI Yunfei. A FDA model for tunnel construction site safety evaluation and its application [J]. China Safety Science Journal,2008,18(1):160-164.

[4]   JIAO Xiaoyou, HU Zhaoguang, SONG Shouxin, et al. Intelligent power safety culture assessment model and simulation analysis[J]. Journal Of Beijing Jiaotong University,2008,32(2):48-52.

[5]   Ivo Duntsch, Gunther Gediga. Rough Set Data Analysis[J]. Encyclopedia of Computer Science and Technology,2000,43:282 -301.

[6]   Radzikowaka A M,Kerre E E.A Comparative Study of Fuzzy Rough Sets[J].Fuzzy Sets and Systems, 2002,126(1):137-149.

[7]   YANG Tao,LI Longshu. The application of rough set on selection of software test case[J]. Microcomputer Development,2005,15(2):12-14.

[8]   Wang Xinmin,ZHAO Bin,ZHANG Qinli. Mining method choice based on AHP and fuzzy mathematics[J]. Journal of Central South University: Science and Technology,2008,39 (5):875-880.

[9]   LI Zijun, SHI Dongping. Renovated security status evaluation system for tunnel construction based on the rough sets-fuzzy evaluation-neural network t[J]. Journal of Safety and Environment,2011,11(6):231-235.