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Research on Selection and Evaluation of Strategic Material Suppliers Based on Fuzzy neural network

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Abstract: In the process of purchasing goods in power enterprises, strategic materials occupy a more important position. Therefore, how to solve the selection and evaluation of the suppliers of strategic materials in power enterprises is particularly important. Starting from the actual situation of material purchasing in electric power enterprises, this paper mainly studies the problems of the procurement of strategic materials and the selection of suppliers in electric power enterprises. Firstly, the Indicator system of supplier selection and evaluation is constructed. Secondly, fuzzy theory and neural network theory are used to construct the fuzzy neural network model for supplier evaluation. Finally, an example is given to demonstrate that the model has strong supplier classification and sorting ability, which can provide the theoretical basis for the selection and evaluation of strategic material suppliers.

Keywords: The strategic materials; supplier selection; fuzzy neural network.

1. Introduction

Strategic materials represent products and services of high-risk and high-purchase amount. Such materials play an important role in ensuring the market competitiveness of enterprises, efficient and sustainable production and operation. The purchase amount of such materials is high, the lack of supply or the unsatisfactory supply, and the inferior quality will bring considerable risks, resulting in the failure of the company to operate normally. Therefore, how to select strategic suppliers and form strategic cooperative relationship with key suppliers is of great significance.

Domestic and foreign scholars have done many typical researches on supplier selection. Bai Chunguang and Sarkis Joseph (2012) combine grey system theory and rough set theory to evaluate supplier performance [1]. Zeydan Mithat and Colpan Cuneyt et al. (2011) proposed a new method to improve the quality of supplier selection. Firstly, the Fuzzy Analytic Hierarchy Process (F-AHP) was used to determine the weight of supplier indicators, and the Fuzzy Technique for Order Preference by Fussy TOPSIS (F-TOPSIS) sorted suppliers and then used the Data Envelopment Analysis (DEA) method to select suppliers [2]. Soroor and Tarokh (2012) combine Fuzzy Logic method, Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD) to design an intelligent module to automatically select the best supplier. The validity of the intelligent module is verified by the application in practical cases [3]. Buyukozkan Gulcin and Cifci Gizem (2012) proposed a combined model based on Fuzzy Decision Making and Decision Making Trial and Evaluation Laboratory Technique (DEMATEL), The Analytic Network Process (ANP) and Technique for Order Preference by TOPSIS, and used it to evaluate and select suppliers of a company [4]. Gu Guoai (2011) used The Grey Correlation Analysis method in the selection and evaluation of suppliers, and gave the specific steps of the method [5]. Wang Liqin (2011) put forward the precautions for establishing the evaluation indicator system of power grid material suppliers, and discussed the evaluation and selection of power grid material suppliers based on Grey Relational Analysis [6]. Peng Cong (2012) applied grey system theory and AHP to establish grey multi-level evaluation model for the uncertainty of supplier selection, and studied the selection of strategic suppliers [7]. Yuan Yu, Guan Tao et al. (2014) used the VIKOR method based on mixed information to assemble evaluation values to overcome the incommensurability of data types and information loss caused by data conversion [8]. Chen Jiajia and Huang Dongbin (2017) use the weighted multi-objective to achieve degree as the effectiveness, and combine with the multi-objective mixed integer programming model to form the practical MAUT mixed integer programming model. At the same time, the weight trial algorithm is used to provide decision makers with the optimal solution set underweight uncertain scenarios for decision makers to make judgments [9]. From the research status at home and abroad, the methods of supplier selection and evaluation mainly include AHP, TOPSIS method, Fuzzy Comprehensive Evaluation method, and Gray Comprehensive Evaluation method. These methods have certain advantages, but they are cumbersome and less extensible. Therefore, in accordance with the characteristics of strategic materials such as high technical requirements and few qualified suppliers, this paper studies the qualifications of their suppliers and optimizes the indicator system from the actual situation of electric power enterprises. It combines the Fuzzy theory with the method of Neural Networks to construct an evaluation model, which provides a new way of thinking and method for supplier selection of strategic materials.

2. Construction of Indicator System for Strategic Material Suppliers

Strategic materials refer to materials in which the market price of some raw materials has large fluctuation, or the future price is expected to increase greatly and the supply is expected to be short in the future. Its main features are as follows:

Less varieties and larger purchase amount;

Long manufacturing cycle and poor substitutability;

Material technical requirements are high, and have a great impact on the core business;

Qualified suppliers are few and the market is in a semi-monopoly environment.

Based on the basic characteristics of strategic materials, this paper selects and constructs the supplier selection indicator system as shown in Table 1. The indicators are divided into two grades, and the first grade indicators are six. The second grade indicators are the decomposition based on the first level indicators, that is, the indicators that can explain the first level indicators and are closely related to them. Generally, each primary indicator corresponds to about three secondary indicators. The secondary indicator generates a primary indicator by weighting or other forms of conversion. The six first-level indicators generated form the input part of the subsequent supplier evaluation and selection model.

In order to facilitate operation all secondary indicators are converted to standard data between 0-1. Then, the second-level indicators are given a certain weight through the expert opinion method or the historical experience method, and the data of the first-level indicators are weighted (the weighting coefficients of the second-level indicators corresponding to each first-grade indicator are added to 1), so that the first-level indicators are also standard data between 0-1.

Table 1 Supplier Selection Indicator System

Total indicator	First level indicator	Second level indicator
Comprehensive evaluation of strategic material suppliers(U)	Service(U_1)	Historical transaction satisfaction(u_1)
		Flexibility(u_2)
	Price(U_2)	Product price(u_3)
		Quantity discount(u_4)
		Transportation costs(u_5)
	Credit(U_3)	On-time delivery rate(u_6)
		Order completion rate(u_7)
	Quality(U_4)	Products qualification rate(u_8)
		Re-return the return rate(u_9)

	Production capacity(U_5)	Rated production rate(u_{10})
		Total production equipment(u_{11})
	Prospects(U_6)	Market share(u_{12})
		R&D Investment ratio(u_{13})

3. Construction of Supplier Selection Model

3.1 Normalization of Sample Matrix and Standard Indicator Matrix

There are n suppliers to be evaluated, and there are m evaluation indicators (here $m=6$), and $X_{m\times n}=(x_{ij})_{m\times n}$ is the measured indicator matrix.

Note $Y_{m\times c}=(y_{ih})_{m\times c}$ as the standard indicator matrix, where: c represents the standard level to which the m indicator belongs, $c(c=5)$ is the number of standard categories; The standard value of h-level standard category indicator is expressed by y_{ih}, and h represents the type number of standard category matrix, $h=1,2,,...,c$.

The concept of the supplier's pros and cons is ambiguous and continuously changing, there is excessive ambiguity in it. Therefore, the Subordinative degree Function is used to determine the degree of a supplier's superiority and inferiority: The Subordinative degree of the fuzzy concept that specifies the supplier's " superiority " corresponds to the first-level standard value of the index i in the standard matrix, which is recorded as 1; The Subordinative degree of the fuzzy concept that specifies the supplier's " inferiority" corresponds to the c-level standard value of the indicator in the standard matrix, which is recorded as 0; Relative Subordinative degree the h-level standard value corresponding to the index between level 1 and level can be calculated by Eq.(1):

$$s_{ih}=1-(y_{ih}-y_{i1})/(y_{ic}-y_{i1}) \tag{1}$$

In this paper, we label the c levels. When $c=5$, the 1, 2, 3, 4 and 5 levels correspond to the five labels of excellent, good, qualified, poor and very poor respectively, which are used to evaluate the quality of suppliers.

Convert $X_{m\times c}$ and $Y_{m\times c}$ into corresponding indicator relative membership matrix standard indicator relative membership matrix $S_{m\times c}=(s_{ih})_{m\times c}$, Defining sample j with relative membership degree u_{hj} belonging to level $h(h=1,2,,...,c)$, then there is category relative membership matrix $U_{c\times n}=(u_{hj})_{c\times n}$, and the matrix satisfies the constraint conditions.

$$\sum_{h=1}^{c}u_{hj}-1=0, 0<u_{hj}<1, \forall h, \forall j \tag{2}$$

3.2 Establishment of Fuzzy neural network Model

In order to select high quality suppliers, a Fuzzy neural network is constructed and trained to obtain the corresponding membership matrix, as shown in Eq.(2), In Fuzzy neural network model for supplier selection and evaluation, we construct a three-layer network consisting of an input layer, an implicit layer, and an output layer. There are six supplier evaluation indicators in this paper, so the number of input neurons is six, and the level of supplier is five, Therefore, the number of output neurons is five. The number of implicit layer neurons is calculated by the following formula: The number of neurons in the implicit layer = (number of neurons in the input layer × number of neurons in the output layer) 1/2, It can be determined that the number of neurons in the implicit layer is five. The specific structure of the Fuzzy neural network is shown in the Fig.1.

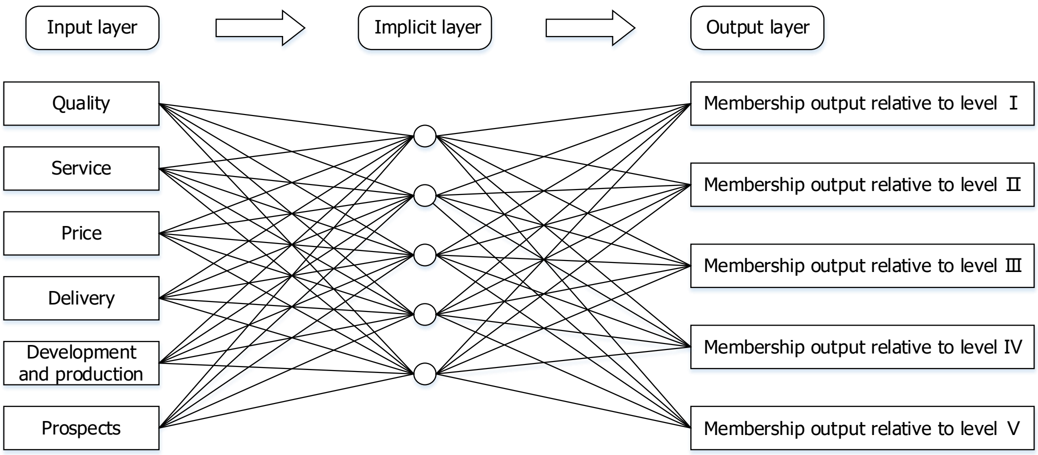

Fig. 1 Structural sketch of Fuzzy neural network

In the forward propagation of network learning, the basic information of the training sample is input, while the error and adjustment information are transmitted in the reverse propagation. In the training process of FNN, the activation function plays a crucial role. It determines how to continuously adjust the weights of the neurons in the process of error reverse propagation so as to make the FNN continuously optimized.

Generally, there are two kinds of activation functions. Sigmoid function and Radial Basis function, considering the application of sigmoid function is more extensive, here the activation function is chosen as sigmoid Fig.2., the function formula can determined by Eq.(3), and its image is shown in Fig.2.

$$S(x) = \frac{1}{1+e^{-x}} \tag{3}$$

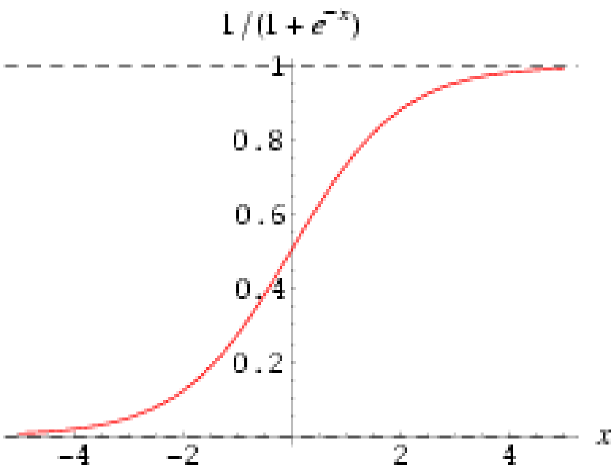

Fig.2 Activation Functions

3.3 Generation of Training Samples

From the criteria of supplier selection, we can see that all kinds of indicators have upper and lower limits. We construct the standard supplier data set corresponding to five levels (excellent, good, medium, poor, very poor), In the case of five levels, we construct the training data by interpolation, and the corresponding Subordinative degree value is calculated by Eq. (1). Interpolation method (or random sampling) is used to process the supplier evaluation criteria. Through this method, enough training samples can be obtained to meet the model's requirement for data volume, One thousand training samples are generated by interpolation and then in this set of samples, five hundred samples were taken as training samples, and the remaining five hundred samples were used as test samples and test samples. The standard Subordinative degree training samples and corresponding Subordinative degree values are shown in Table 2.

Table 2 Standard Category Indicator for Training and Their Corresponding Subordinative Values

Supplier evaluation criteria category	Training samples generated by $S_{m\times c}$ (m indicators)				Sample corresponding subordinative value				
	1	2	…	m	Grade1	Grade 2	Grade 3	…	N
Grade 1	s_{11}	s_{21}	…	s_{m1}	1	0	0	0	
1/2 interpolation	$(s_{11}+s_{12})/2$	$(s_{21}+s_{22})/2$	…	$(s_{m1}+s_{m2})/2$	0.5	0.5	0	0	0
1/4 interpolation	$(3s_{11}+s_{12})/4$	$(3s_{21}+s_{22})/4$	…	$(3s_{m1}+s_{m2})/4$	0.75	0.25	0	0	0

…	…	…	…	…	…	…	…	…	…
Level 2	s_{12}	s_{22}	…	s_{m2}	0	1	0	0	0
…	…	…	…	…	…	…	…	…	…
Level c	s_{1c}	s_{2c}	…	s_{mc}	0	0	0	0	1

3.4 Flow chart of fuzzy neural network model

According to the above principles, the flow of the corresponding calculation program is shown in Fig. 3.

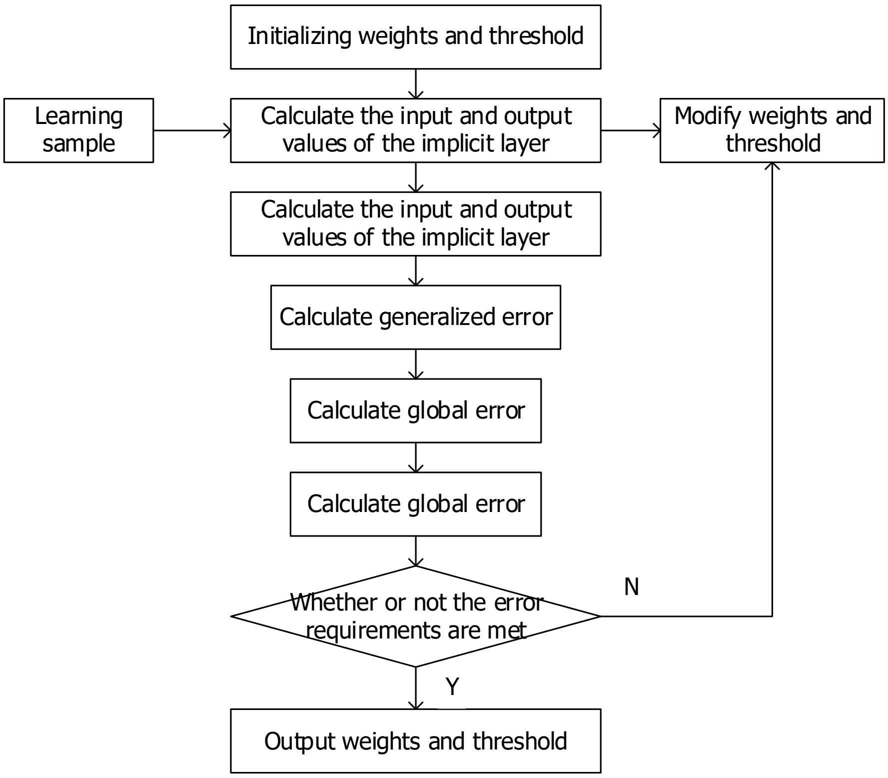

Fig.3 Program block diagram of fuzzy neural network

3.5 Determination of supplier Evaluation results

Suppose there are n suppliers, each supplier includes m evaluation indicators. When the matrix is inputted into the trained neural network, we obtain a matrix of evaluation results like $U_{n\times c}$. Formula (4) is a method of determining the level of the n suppliers.

$$T = [1,2,3.,..\ .,c] \times (U_{n\times c})^T = [t_1, t_2, t_3, ..., t_n] \quad (4)$$

The value and the attribution level of t are both different. The value of t has a certain range of intervals. The methods for determining the attribution level are as follows: when $c-1 < t_j \le c$, rounding the value of t, and then judging if t belongs to class c-1 or class c.

4. Example study

4.1 Construction of training data set and training of Fuzzy Neural Network

Firstly five sets of standard vendor-grade data should be determined by analyzing historical data and discussing with experts (panels), and then a 5-6 matrix is obtained. Each row in the matrix represents an array of standard grades, that is, A, B, C, D, E.

$$Y_{5\times 6}=\begin{bmatrix} 0.8 & 0.75 & 0.9 & 0.9 & 0.85 & 0.9 \\ 0.7 & 0.7 & 0.8 & 0.8 & 0.75 & 0.8 \\ 0.6 & 0.65 & 0.7 & 0.7 & 0.65 & 0.7 \\ 0.5 & 0.6 & 0.6 & 0.6 & 0.55 & 0.6 \\ 0.4 & 0.55 & 0.5 & 0.5 & 0.45 & 0.5 \end{bmatrix} \Rightarrow \begin{Bmatrix} A \\ B \\ C \\ D \\ E \end{Bmatrix}$$

Then using interpolation method(including 1/2 interpolation, 1/4 interpolation, 3/4 interpolation, 1/8 interpolation, 3/8 interpolation, 5/8 interpolation, 7/8 interpolation.....) to construct about 1000 sets of training data, as shown in Table 3.

Table 3 Building table of training data set.

Supplier evaluation standard category	Training samples generated from S6×5 (6 indicators)						Sample corresponding membership value				
	1	2	3	4	5	6	1A	2B	3C	4D	5F
Class 1	0.8	0.75	0.9	0.9	0.85	0.9	1	0	0	0	0
1/2 Interpolation	(s11+s12)/2	(s21+s22)/2	(s31+s32)/2	(s41+s42)/2	(s51+s52)/2	(s61+s62)/2	0.5	0.5	0	0	0
1/4 Interpolation	(3s11+s12)/4	(3s21+s22)/4	(3s31+s32)/4	(3s41+s42)/4	(3s51+s52)/4	(3s61+s62)/4	0.75	0.25	0	0	0
…(interpolati-on)	…	…		…		…	…	…	…	…	…
Class 2	0.7	0.70	0.8	0.8	0.75	0.8	0	1	0	0	0
…(interpolati-on)	…	…		…		…	…	…	…	…	…
Class 3	0.6	0.65	0.7	0.7	0.65	0.7	0	0	1	0	0
...(interpolati-on)	...	...		...		...	...	...	...	...	...
Class 4	0.5	0.60	0.6	0.6	0.55	0.6	0	0	0	1	0
...(interpolati-on)	...	...		...		...	...	...	...	...	...
Class 5	0.4	0.55	0.5	0.5	0.45	0.5	0	0	0	0	1

Secondly, a 6-5-5 (6 input node, 5 hidden node, 5 output node) neural network is designed to bring the training data into the fuzzy neural network and get the trained fuzzy neural network. The training and iterative processes of neural networks are shown in Fig. 4.

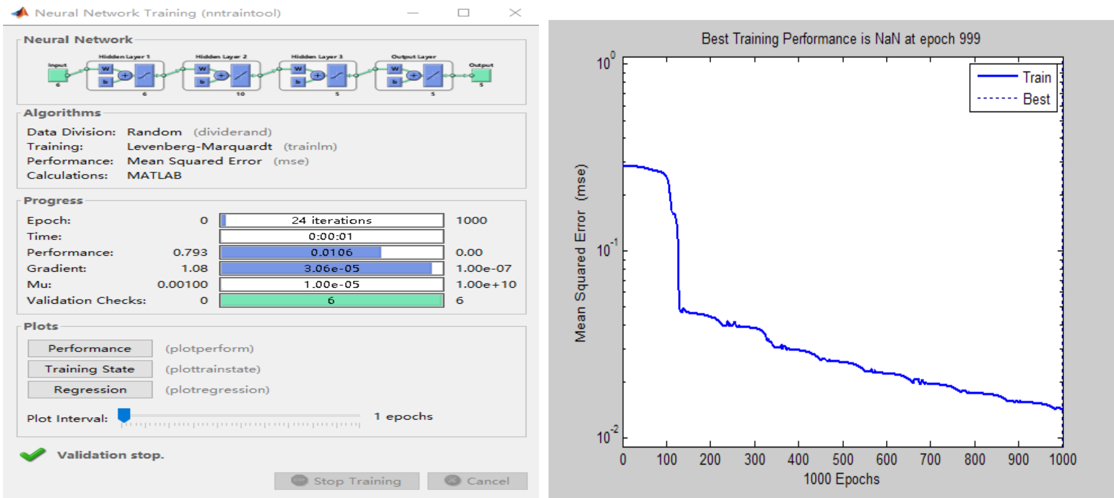

Fig. 4 left: neural network training; right: neural network achieve optimal through iteration

It can be seen that after iteration, the model quickly reaches the optimum.

The results of the mode are as follows.

Weight from input layer to hidden layer:

$$in = \begin{Bmatrix} -0.5111 & -0.008 & -0.7212 & 0.2798 & 0.123 & 0.0599 \\ 0.3162 & -0.7335 & 0.7762 & -0.0455 & 0.1016 & -0.0028 \\ 0.3117 & -0.3099 & -0.8968 & -0.7599 & -0.6678 & 0.0613 \\ -0.4972 & -0.3758 & 1.0607 & -0.3768 & -0.0592 & 1.0962 \\ -0.8501 & -0.6142 & 0.4514 & 0.6298 & 0.1821 & -1.3756 \end{Bmatrix}$$

Weight from hidden layer to output layer:

$$out = \begin{Bmatrix} -0.7596 & 0.3849 & 1.3366 & 1.4589 & 0.4217 \\ 0.6309 & -0.3751 & -0.5045 & -0.1641 & 1.5981 \\ -1.1325 & 1.1551 & 0.7053 & -0.2340 & 1.0107 \\ 0.8292 & 1.0693 & -1.0500 & 1.0614 & 0.2645 \\ -0.9901 & 0.9269 & -1.0990 & 0.4571 & -0.7077 \end{Bmatrix}$$

4.2 Verification of Fuzzy Neural Network

Vendor data about nine known vendor grade were given and then brought into the trained model to verify the model.

We first present a data sheet of thirteen secondary indicators for nine suppliers, as shown in Table 4.

Table 4 Data sheet of nine real vendors

Sup-plier	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	Expert evaluation
1	0.82	0.8	0.82	0.91	0.55	0.83	1.0	0.79	0.89	0.77	0.89	0.89	0.84	A
2	0.83	0.77	0.82	0.87	0.55	0.78	0.93	0.89	0.65	0.88	0.8	0.87	0.52	A
3	0.71	0.69	0.76	0.75	0.61	0.88	0.68	0.77	0.83	0.80	0.7	0.76	0.96	B
4	0.62	0.9	0.67	0.69	0.60	0.78	0.68	0.65	0.91	0.74	0.74	0.77	1.0	B

5	0.55	0.65	0.56	0.71	0.67	0.67	0.74	0.68	0.72	0.66	0.64	0.64	0.94	C
6	0.56	0.62	0.73	0.66	0.55	0.71	0.63	0.60	0.82	0.57	0.79	0.73	0.73	C
7	0.50	0.5	0.53	0.63	0.63	0.67	0.49	0.55	0.65	0.65	0.45	0.66	0.36	D
8	0.42	0.56	0.50	0.60	0.75	0.56	0.68	0.50	0.64	0.55	0.59	0.51	1.0	D
9	0.40	0.4	0.50	0.51	0.61	0.50	0.5	0.49	0.51	0.53	0.37	0.42	0.47	E

According to the description in the construction of the indicator system, the secondary indicator after weighting summation is converted to the first grade indicator. The data are as follows. The results of experts evaluation are given in the last column, which is used to compare the results obtained from the model and then validate, as shown in Table 5.

Table 5 Validation data set

Index	Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Grade
Supplier 1	0.81	0.74	0.91	0.84	0.83	0.88	Grade 1 (A)
Supplier 2	0.8	0.73	0.84	0.77	0.84	0.8	Grade 1 (A)
Supplier 3	0.7	0.7	0.8	0.8	0.75	0.8	Grade 2 (B)
Supplier 4	0.76	0.65	0.74	0.78	0.74	0.82	Grade 2 (B)
Supplier 5	0.6	0.65	0.7	0.7	0.65	0.7	Grade 3 (C)
Supplier 6	0.59	0.64	0.68	0.71	0.68	0.73	Grade 3 (C)
Supplier 7	0.5	0.6	0.6	0.6	0.55	0.6	Grade 4 (D)
Supplier 8	0.49	0.63	0.61	0.57	0.57	0.62	Grade 4 (D)
Supplier 9	0.4	0.55	0.5	0.5	0.45	0.43	Grade 5 (E)

The result matrix of the output $U_{5\times 9}$ is obtained after the model is brought into the model.

Calculating according to evaluation method of supplier in the model,

$$T = [1,2,3,4,5] \times (U_{9\times 5})^T$$

Then, the evaluation results of fuzzy neural network are obtained by rounding method, as shown in Table 6.

Table 6 The model evaluation results and comparison table of expert evaluation results

Supplier	Suppl-ier 1	Suppl-ier 2	Supp-lier 3	Supp-lier 4	Supp-lier 5	Suppl-ier 6	Suppl-ier 7	Suppl-ier 8	Suppl-ier 9
Evaluation results	0.9998	1.4012	2.008	2.382	3.064	3.4301	3.9089	4.4361	5.0610
Evaluation grade	Grade 1	Grade 1	Grade 2	Grade 2	Grade 3	Grade 3	Grade 4	Grade 4	Grade 5
Evaluation results	A	A	B	B	C	C	D	D	E
Result verification	√	√	√	√	√	√	√	√	√
Supplier sorting result	1	2	3	4	5	6	7	8	9

From the evaluation results, we can see that the evaluation grade of nine suppliers is correct, which proves that fuzzy neural network has high accuracy. Besides, we can sort according to the evaluation data to select suitable suppliers.
From the above results, it can be seen that it is a feasible method to use fuzzy neural network to evaluate and select suppliers. This evaluation method has characteristics of accuracy, extensibility, flexiblity and etc. For example, if the grade number of supplier evaluation need to be adjusted, the parameter c is only data that needs to be changed, and then the standard vendor grade data can be increased or reduced.

5. Conclusion

This paper studies the selection of suppliers model based on fuzzy neural network. Firstly, according to the characteristics of strategic materials, it constructs a evaluation indicator system of strategic material suppliers. Secondly, it describes the construction process of fuzzy neural network, and then constructs a 6-5-5 fuzzy neural network to evaluate and select suppliers. Finally, the training data set is constructed to train the neural network. It is used to evaluate actual supplier data is evaluated, which verify the validity and stability of the model. The application results of the model in supplier evaluation show that, it can not only determine the grade of suppliers, but also determine the difference of same grade-suppliers. Moreover, the model can sort the alternative suppliers which reflects the strong sorting ability and classification ability of the model.

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