

# Evaluation of Ability to Supply Water Based on GRNN Neural Network Model: Case of Beijing

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**Abstract.** Water supply capacity is an important index for evaluating a city. In this paper, AHP (Analytic Hierarchy Process) is used to establish an index system and evaluation standard of the ability to supply water, and 15 evaluation indicators are put forward from 4 aspects of the relationship of supply and demand, the geographical factors, the economic factors and the environmental factors. Evaluation model for ability to supply water is established by the principle of GRNN (General Regression Neural Network) theory and methods. And then the model is used to comprehensively evaluate the water supply capacity of Beijing in 2005-2015, which is proved that the established GRNN evaluation model and evaluation method are reasonable and feasible.

## 1. Introduction

Water is vital for all kinds of life living in the earth. The human body, myriad ecological system and the big biosphere of our entire planet, all of these can't live without sufficient water. However, the shortage of water resources is the main obstacle for the development of many regions and countries.

Due to the water resources evaluation system is complex and the evaluation index is numerous, simple selection and weighting have obvious subjective components [1].

In order to provide an objective assessment of water supply capacity, this paper establishes the evaluating indicator system of the ability to supply water which consists of the target layer, the principle layer and the indicator layer. GRNN algorithm is used to find the corresponding relationship between principle layer and indicator layer. Using the value of 15 indicators, the model can get a city's capacity to supply water.

## 2. Water Supply Capacity Evaluation Model

### 2.1 The Selection of Principles and Indicators Based on AHP

Based on the existing water resources evaluation index, this paper applies the analytic hierarchy process component to the index system of water resources development and utilization in Beijing.

We divide the evaluating system into three layers. The first layer is our target layer, setting up comprehensive index to evaluate ability to supply water which is computed by the principle layer. Next is the principle layer and we set four indexes consisting of the supply and demand of water, the geographic factor, the economic factors and the environmental factors. Finally, the third layer consists of detailed indicators of four principle layers.

In order to measure accurately ability to supply water, this paper puts forward standard values, as is shown on the Table 1, corresponding to different levels based on the following principles [2]:

Refer or analogy to standard values corresponding to different levels according to relevant references

Adopt existing national or international standard values.

The standard values should be consistent with the plan of national and local water resource development.

**Table 1 The different level and its corresponding specific standard values**

The target layer	The principle layer	Indicator	The indicator layer					range
			1	2	3	4	5	
Ability to water supply	The relationship of supply and demand	The relationship of supply and demand	≥1.5	≥1.3	≥1	≥0.5	<0.5	0.1~2
		The amount of precipitation	≥1500	≥1200	≥1000	≥800	<800	400~3000
	The geographical factors	The proportion of surface water and groundwater	≥90	≥85	≥75	≥60	<60	20~100
		The density of water resource	≥80	≥60	≥40	≥20	<20	10~160
	The economic factors	The proportion of external water	≥20	≥10	≥6	≥2	<2	0~30
		The water demand quota of agricultural irrigation	≥2000	≥1500	≥1000	≥500	<500	100~3000
		The water demand of a unit industrial added value	≤30	≤50	≤100	≤200	>200	10~300
		The proportion of recycled water	≤3000	≤4500	≤6000	≤7500	>7500	1500~10000
		The processing ratio of sewage	≤10	≤40	≤55	≤70	>70	5~100
		The per capita water resources	≥40	≥30	≥20	≥10	<10	2~50
		The water demand of a unit GDP	≥90	≥80	≥40	≥20	<20	0~100
	The environmental factors	The proportion of water demand for environmental protection	≤10	≤15	≤25	≤30	>30	6~100
		The qualification rate of aquifer	≤5	≤10	≤20	≤25	>25	1~30
		The per capita amount of sewage produced	≥45	≥30	≥20	≥10	<10	5~50
		The sewage produced of a unit GDP	≥90	≥75	≥60	≥40	<40	20~100

In order to evaluate the ability to supply water, there are 5 levels. For example, if the value of evaluating result is between 1 and 2, the level is best. From 1 to 5, the situation gets worse successively.

## 2.2 Model Implementation Based on GRNN

### 2.2.1 The Analysis of GRNN Model

The GRNN neural network consists of four layers, including the input layer, the model layer, the summation layer and the output layer.

The input layer

Firstly, we normalize all data in the Table 1, which is the input data. The input layer directly passes the input variables of 15 indicators to the mode layer. The number of neurons in this layer is the dimension of input vector. A 100 by 15 input matrix can be constructed according to the number of input vectors is 100 and the number of input vectors is 15.

The Model layer

The number of neuron in the model layer is the number of learning samples. Each neuron corresponds to its own sample, which is the transfer function of neuron in this layer can be represented as:

$$p_i = \exp \left[ - \frac{(X - X_i)^T (X - X_i)}{2\sigma^2} \right] \quad i = 1, 2, \dots, 15 \quad (1)$$

Where  $x$  is the input variables in the network, 15 is the number of the indicators.  $X_i$  is the learning sample of the  $i$ th neuron.  $\sigma$  is the smoothing factor.

The summation layer

This layer calculates the sum of two types of neurons using arithmetic summation and weighted summation respectively.

The result of arithmetic summation ( $S_D$ ) is the sum of the output of all neurons ( $P_i$ ) in the model layer. The formula can be shown as:

$$S_D = \sum_{i=1}^4 P_i \tag{2}$$

The result of weighted summation ( $S_{Nj}$ ) is the sum of all products of the output of all neurons ( $P_i$ ) in the model layer and its corresponding weights ( $y_{ij}$ )

$$S_{Nj} = \sum y_{ij} P_i \quad j = 1 \tag{3}$$

The output layer

The output of the network is the level of the economic factors. The number of neurons in the output layer is the dimension of the output vector in the learning sample. The output neuron(Y) is our evaluating result which can be shown as:

$$Y = \frac{S_{Nj}}{S_D} \quad j = 1 \tag{4}$$

### 2.2.2 The Training and Test of GRNN Network

First, we divide the 100 sets of data into two parts. The first 80 groups were trained as network, and the remaining 20 groups were used to test the quality of network's training.

Both learning speed and value of mean square error will directly affect the accuracy of network training. Through many attempts, we set learning speed and the maximum value of mean square error as 0.1 and 20, respectively.

As is shown by the results, the data resulting from network's training is great when the value of network's training is 0.1. The smaller the value of learning speed, the smaller the deviation between samples and network is.

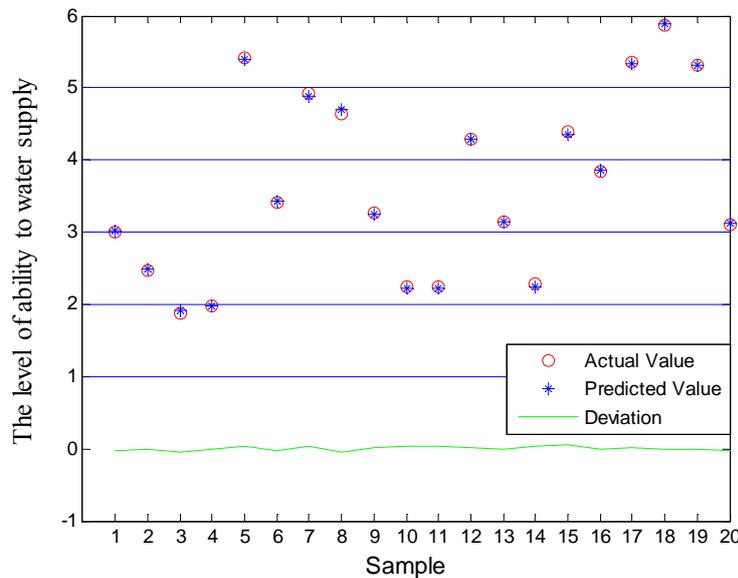


Fig.1 The test of the network's training

As is shown on Fig.1, 20 points represent 20 sets of data. The circle represents the actual value, and the asterisk represents the predicted value. From here we can see the level of water supply for each sample. At the same time, the green curve in the Figure 1 represents the deviation between actual value and predicted value of predicted value. The smaller the deviation is, the more robust the network is.

### 3. Beijing Case Study

Based on the values of parameters of Beijing from 2005 to 2015 according to relevant reference [3], we calculate the level of four principle layers, as is shown on Fig 2. At the same time, we get the evaluating results of the ability to water supply, as is shown on Fig 3.

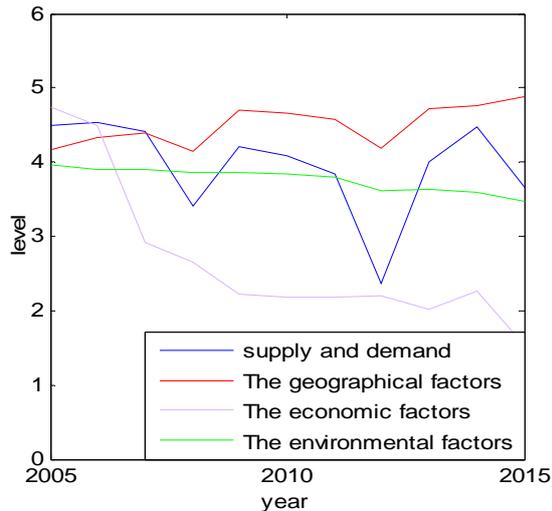


Fig 2 The evaluating results of four principle layers

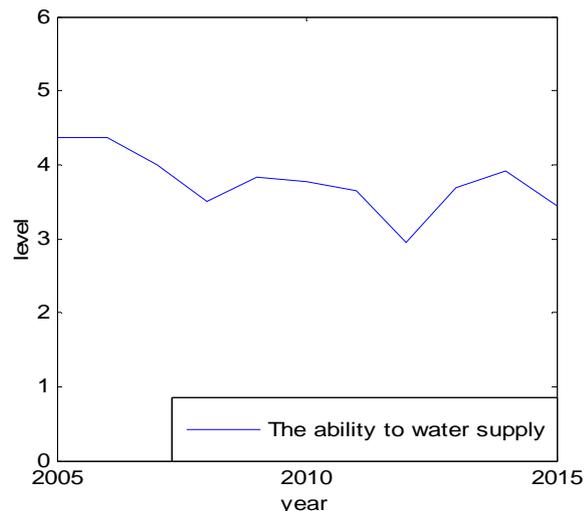


Fig 3 The evaluating results of the ability to water supply

According to relevant references, our evaluating results are consistent with objective facts.

In the past ten years, the situation of Beijing's geographical environment has increasingly become worse, which is the main factor affecting the water supply. On the contrary, economic factors have risen rapidly, reaching the highest level in 2015. It mainly resulted in the rapid development of water-saving technologies. The level of relationship between supply and demand has fluctuated significantly in 2008 and 2012, mainly due to the sudden increase in precipitation over the past two years. However, the remaining years are still worrying. Environmental factors gradually improve, but the speed of improvement is relatively slow because of the large base of population in Beijing.

#### 4. Conclusion

This model is more objective in the selection of indicators. And the status of water resources in Beijing can be easily seen through the rank evaluation. Through the long-term simulation results in Beijing, it is proved that the established GRNN evaluation model and evaluation method are reasonable and feasible.

GRNN network evaluation model has the characteristics of fast convergence, high prediction accuracy, less parameters adjusting, uneasy to fall into local minimums, and can predict and evaluate more quickly to meet the objective evaluation requirements of the ability to supply water.

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