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The Forecasting of Humanitarian Supplies Demand Based on Gray Relational Analysis and BP Neural Network

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Abstract

This paper analyzes the characteristics of humanitarian supplies demand in the context of flood and discusses the disasters associated factors which influence the demand of humanitarian supplies. Then we choose the severe flooding whose grades is more than fifty year return period between 2004 and 2016 as the analysis objects, which are illustrated by the example of the Red Cross Society of China whose demand for relief tent in the flood. Finally, we set up gray relational analysis and BP neural network.

Key words: The forecasting of humanitarian supplies; Gray relational analysis; BP neural network

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INTRODUCTION

Flooding is one of the major and frequent disasters in the world today. China is one of the countries affected by flooding and about 2/3 of the land area has different types and different damage degree of floods (2006). The relief work which is headed by the government and the army has become increasingly outstanding, which received the attention of the public. The forecast of emergency supplies demand is also becoming a hot spot of experts and scholars to study.

Guo and Zhou (2011) adopts BP neural network algorithm for estimating the casualties in earthquakes, and utilizes the knowledge about inventory management to estimate the demand of emergency materials; Liu and Zhu (2013) use the case of fuzzy reasoning to forecast emergency supplies demand. The similarity between cases was calculated to find the best similar case. Case-fuzzy reasoning method solves the materials demand forecasting model. Song, Liu and Chang (2010) propose to switch the original data list to make it obey exponential law, breaking the re-stricted zone of the conventional GM(1,1) model with an exponential law，which is used to predict emergency material demand. Luo and Zhou (2012) use the grey metabolism model GM(1,1) to predict the trend, then use the prediction method of the Markoff chain state probability transition matrix to do the second fitting for the predicted value. Zhao, Gao and Feng (2013) use the support machine vector regression and inventory management model to predict the earthquake casualties, then the emergency materials were estimated by the inventory model. Kang (2012) established an emergency supplies demand forecast model based on PSO-BP neural network. Fu and Chen (2009) propose the best similar source cases by normalization of the Euclidean algorithm and determined the key factors in the source case, and then established case -based reasoning-the key factor model to forecast emergency material demands for objective case. Above all, the forecast of emergency supplies was focused on the algorithms and being supported by case study in the earthquake was more.

The Red Cross society of China is the assist department of civil administration and army rescue. Humanitarian supplies consist of relief supplies and rescue supplies. Rescue supplies usually come from the social donation, customs donation, etc.. Relief supplies are purchased by the Red Cross society of China. Compared with civil administration and army rescue, there are few species of relief supplies of Red Cross society of China, which has its own characteristics. The forecasting of supplies demand in major disaster will directly affect the purchase of the Red Cross society of China and have respect to the efficiency of relief. The traditional forecasting of humanitarian supplies demands subject to experts' experienced judgements. Therefore, it's necessary to make systematic and targeted predictions about humanitarian supplies demand.

1. CHARACTERISTICS ANALYSIS OF HUMANITARIAN SUPPLIES DEMAND

1.1 The Poor Predictability of Humanitarian Supplies Demand

The randomicity of rainstorms determine the paroxysm of flood. There is often a heavy intensity and a wide range of heavy rain in the eastern part of China. The risk coefficient of flood disaster caused by the typhoon and storm surge is also great. The phenomenon of drought-flood abrupt alternation frequently occurred in some areas. The flood, debris flow caused by heavy rains is sudden, which makes people often have no time to escape, such as the 2010 Gansu Zhouqu mudslide caused 1,765 deaths. Floods are characteristic of suddenness, high uncertainty and involving a wide range, which caused accurate prediction of material demand difficult. Moreover, it can't usually reserve all the supplies needed, which leads swelling supplies demand in a very short time, that is, demand for emergency materials is not predictable.

1.2 The Timeless of Humanitarian Supplies Demand

Floods cause a high degree of disaster and last a long time, which puts forward higher requirements on relief supplies. Humanitarian supplies are crucial for the victims' life and property safety. The characteristics of flood disaster lead to a short period of rapid growth of material demand, and the material demand has a strong timeliness, and timely supplies can be related to the disaster may cause loss. Supplies cannot be met in time will be related to the damage caused by the disaster. Floods hit southern China in July 2016, the Red Cross Society of China unified family box's standard process, which improves the efficiency of disaster relief.

1.3 The Uncertainty of Humanitarian Supplies Demand

Floods often cause traffic and communication facilities damaged, which make traffic, communication interrupt. This result in the information is not timely and accurate and Humanitarian Material Distribution can't accurately grasp the disaster situation, so we are unable to accurately estimate all material demand. For example, typhoon Longwang caused 96 urban residential powers cut and 81 highway lines outage. The train stations were idle, railroads were suspended, highways were flooded, which leads to a high degree of uncertainty in the demand of disaster relief supplies.

2. THE ANALYSIS OF HUMANITARIAN SUPPLIES INFLUENCE FACTORS

Flood is one of the most serious natural disasters in China. The severity of flood is mainly reflected in two aspects: the frequency of flood is the top of all kinds of natural disaster; the direct economic loss caused by flood is the most, as shown in Figure 1. This paper carries on the empirical analysis about the 2000-2015 national floods in China.

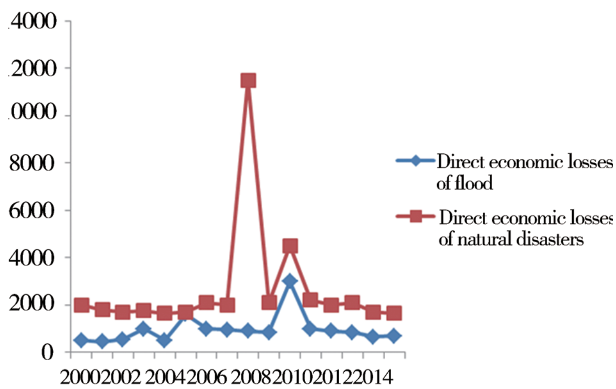

Figure 1
Natural Disaster and Flood Disaster Loss From 2000 to 2015

According to the existing theory and empirical research, this paper mainly analyzes the influence factors of humanitarian supplies demand from four points of view: supplies demand region, time, type and quantity. The factors that affect the humanitarian supplies demand are summarized as follows:

2.1 The Flood Season

Since China is affected by the monsoon climate, intra-annual precipitation is seasonal variation. The rainfall can be accounted for 60%-80% in the flood season which is about 4 months of the year. The duration of rainfall focus on July and August, which can be accounted for 50%-60%, but the months of precipitation will bring a few times heavy rain. The emergency supplies providing local residents with guarantee in the flood should be based on seasonal climate, such as unlined tent, woolen blanket, family box and other supplies will be in demand in the flood.

2.2 Disaster Area

Flood in China occurred in seven large river basins, the Yangtze River, the Yellow River, Huaihe River, Haihe River, Liaohe River, Songhua River, the Pearl River Basin. Flood happens almost every year with strong repeatability, but different from scale and type. There will be different climate, different population density and different economic development in different regions, which will cause different life and poverty losses after disaster, which has generated great influence on the type and quantity of humanitarian supplies demand. For example, autumn floods occurred in Jilin Province, which needs warm supplies such as quilts, cotton-padded jacket etc.. Summer floods occurred in the south of China, the need of which are T-shirt, shorts and dissipating heat materials. According to the regional characteristics of flood, it is conducive to the types of humanitarian supplies and the number of reserves for scientific decision-making.

2.3 The Affected Population

The population information of the disaster area can be obtained from the population database after the flood, including the local resident population, migrant workers and local tourism population etc.. After a comprehensive analysis and calculation, we can estimate the number of local affected people, that is, the demand population. Humanitarian relief supplies are used to help the victims, which are closely related to the number of victims. Therefore, demand population has a very important impact on the needs of humanitarian supplies. Figure 2 shows the change of the population in the flood in China during 2000-2015.

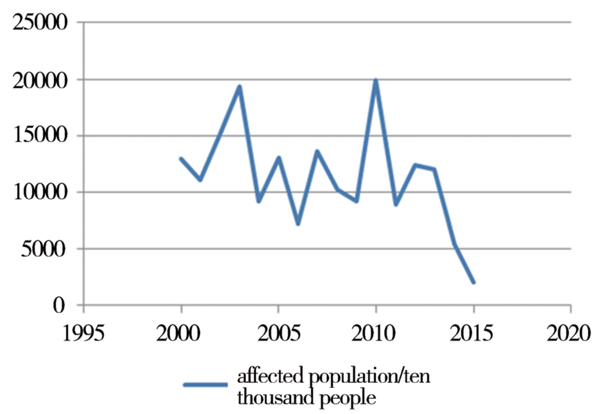

Figure 2
The Changes of the Affected Population in the Flood From 2000 to 2015

2.4 Flood Grade

According to the national standard *Hydrological Information Forecasting Standard* [GB/T 22482-2008], which was implemented on January 1, 2009, floods can be graded into small floods, medium floods, big floods, and extraordinary flood. These four grades are based on the recurrence interval of the flood, which is less than 5 years, 5-20 years, 20-50 years and more than 50 years. This paper selected the floods occurred from 2004 to 2016 with a recurrence period of more than 50 years as the objects of analyses.

Taking everything into consideration, the population density/square kilometer in the flood affected area, resettlement population/ten thousand people, death toll/person, collapsed houses/ten thousand rooms, affected area of crops/million hectares will be included as the index to evaluate the flood disaster. Those above factors will influence the demands of the humanitarian goods. The following Figure 3 and Figure 4 show us the damaged area of cops and the collapsed houses due to the flood waterlogging disaster respectively.

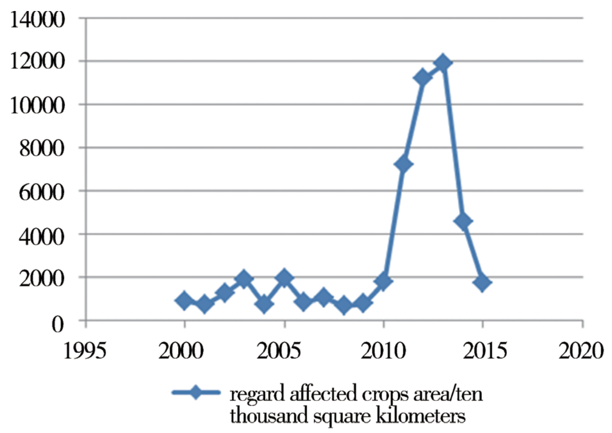

Figure 3
The Changes of the Regard Affected Crops Area in the Flood From 2000 to 2015

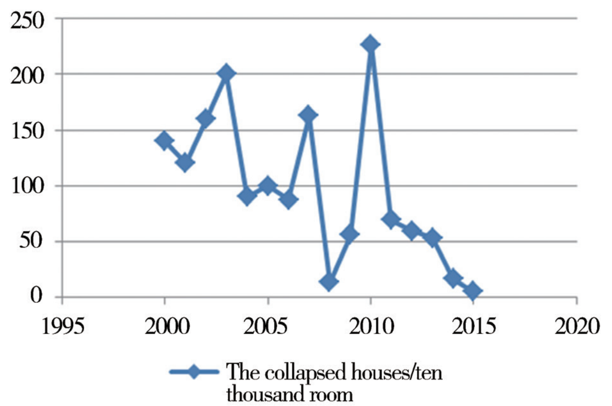

Figure 4
The Changes of the Collapsed Houses in the Flood From 2000 to 2015

3. GREY CORRELATION ANALYSIS (GCA) AND BP (BACK-PROPAGATION) NEURAL NETWORK

The present paper uses Grey Correlation Analysis (GCA) to analyze the major factor that affects the material demand in a flood disaster and then takes the major factor as the input of the BP (back-propagation) network and trains the BP (back-propagation) network with historical data. Finally, it is proved that this method can be used to predict the needs of humanitarian material as well as to improve the accuracy of prediction.

3.1 Grey Correlation Analysis (GCA)

Grey Correlation Analysis (GCA) is a multi-factor statistical method and it can be used to select the main factor of the influencing factors of a system. The basic idea is to judge the degree of correlation between the factors according to the degree of similarity between the curves. This method has no special requirements on the size of the sample and the analysis does not need a typical distribution; so it has very broad applicability.

Set the system behavior sequence:

$$X_0 = (X_0(1), X_0(2),\dots, X_0(n))$$
$$X_1 = (X_1(1), X_1(2),\dots, X_1(n))$$
$$\dots\dots$$
$$X_i = (X_i(1), X_i(2),\dots, X_i(n))$$

Steps of Grey Correlation Analysis (GCA) (2004):

(a) Find the initial image of each sequence, so as to eliminate the influence of different quantity level and to facilitate the calculation and comparative analysis

$$X'_i=X_i / x_i(1)= (X'_i(1), X'_i(2), \cdots, X'_i(n), i =0,1,2,\dots,n.$$

(b) Find the sequence difference

$$\Delta_i (k)=|x'_0(k)-x'_i(k)|$$

(c) Find the maximum and minimum

$$M=\max_i\max_k \Delta_i(k),\ m=\min_i \min_k \Delta_i(k)$$

(d) Find the number of associations

$$\gamma_{0i}(k) = \frac{m + \xi M}{\Delta_i k + \xi M},\ \xi\epsilon(0,1)$$

$$k=1, 2,\dots,n;\ i=1,2,\dots,m.$$

ξ is the identification coefficient and is used to adjust the size of the comparison environment.

(e) Calculate the degree of association

$$\gamma_{0i} = \frac{1}{n}\sum_{k=1}^{n}\gamma_{0i}(k);\ i = 1,2,\cdots m.$$

The total gray relational degree is the total degree of correlation $R=(r_{01}, r_{02},\cdots, r_{0n})$. The higher the gray correlation degree is, the closer the comparison sequence is the reference sequence.

3.2 BP (Back-Propagation) Neural Networks (2002), (1992)

BP neural network can be widely applied to functioning approximation, pattern recognition, data compression and other fields by implementing any nonlinear mapping between input and output, which is highly nonlinear and has strong adaptive learning ability. It is divided into input layer, hidden layer and output layer. There is no association between nodes at the same layer, and forward link between heterogeneous networks. The reduced parameter set is taken as the input variable of the BP neural network and N is the number of input neurons. The decision attribute of the system is taken as the output of the neural network and the neuron output characteristic function is set as the logical sigmoid type function which is, so the training samples can be used to train this network, the training weights and thresholds can be acquired and used for the output prediction of the multi-factor system.

4. ANALYSIS ON FORECAST OF HUMANITARIAN SUPPLIES DEMAND

According to the national policy，the service rate of Red Cross Society is 10%, it means that if the disaster needs 100,000 tents, the center needs to provide at least 10,000. In this paper, we select the floods with a return period of more than 50 years from 2004 to 2016 and consider the factors of tent's demand (population in need, flood disaster level, population density, collapsed buildings, crops disaster area, relocated population, number of deaths) by reviewing the paper, website, State Flood Control & Drought Relief Office and the ministry of civil affairs. We take the tent demand Y as the reference sequence and take population in need (X_1) , flood disaster level (X_2), population density (X_3), collapsed buildings (X_4), crops disaster area (X_5), relocated population (X_6) and number of deaths (X_7) as compare sequences. The specific data are as follows:

Table 1
Related Data About Flood From 2004 to 2016 in China

The affected population/ten thousand persons	Flood grades	Population density/square kilometers	Collapsed building/ ten thousand houses	The affected crops area/ten thousand hectares	Relocated population/ten thousand persons	Death toll/ persons	Tent/set
1299	100	484	6.4	39.2	46.8	188	8000
788	100	169	1.2	2.5	49	61	6500
402.79	100	287	0.94	13.079	53.7	103	6500
831	100	300	8.42	35.7	153	526	13000
742.23	100	342	3.35	23.352	26.78	62	4200
653.7	100	551	1.54	38.375	67.84	22	6300
177.9	50	169	1.3	9.85	22	23	2800
274.39	300	195	1.01	16.343	17.9783	52	3500
140	65	56	0.5508	0.0095	0.9852	1765	1000

To be continued

Continued

The affected population/ten thousand persons	Flood grades	Population density/square kilometers	Collapsed building/ ten thousand houses	The affected crops area/ten thousand hectares	Relocated population/ten thousand persons	Death toll/ persons	Tent/set
265.91	100	304	4.42	11.983	52.73	154	5500
57.6	100	197	0.2958	2.51196	9.93	53	1000
190	61	1261	0.8265	0.5	5.6933	79	2040
350	100	167	0.6	10.32	30	231	4000
812.15	100	315	1.67	63.94	43	45	7100

We use the grey system theory modeling software (GTMS3.0) to solve grey correlation and the relative correlation between the remaining sequences and reference sequences "r" is 0.8083, 0.6143, 0.9003, 0.8047, 0.8662, 0.6885, 0.9329 respectively. We can know that $r_7 > r_3 > r_5 > r_1 > r_4 > r_6 > r_2$ and the influence degree of the demand for tents is that number of deaths > population density > crops disaster area > population in need > collapsed buildings > relocated population > flood disaster level.

Mathematic model is established by using BP neural network to predict tent demand. We select population in need, population density, collapsed buildings, crops disaster area and number of deaths as input variables X_1, X_3, X_4, X_5, X_7, whose correlation is 80% above and select tent demand as the output variable Y.

Firstly, the data are normalized to facilitate the training of BP neural network. In addition, the training result will be significantly decreased when near 0 or 1 and the number of training needs to increase a lot and may not be able to achieve the set goals. Therefore, the data are further standardized to the interval [0.15, 0.85].

In order to determine the number of neurons in the hidden layer, according to Kolmogorov theorem, the number of neurons in the input layer is 5 and in the hidden layer is 6 initially. Then, we set the number of neurons in the hidden layer as 6, 8, 10, and 12 respectively and compare the results after repeated training. Finally, we set the number of neurons in the hidden layer as 6 and determine the network structure parameters, which we could see from Table 2.

Table 2
Network's Structure and Parameters

Parameter	Name	Value
Tansig	Transfer function	—
Logsig	Output layer function	—
Traingdx	Training function	—
Epochs	Max training time	1000
Goal	Accuracy of training request	0.001
Ir	Learning rate	Adaptive changes

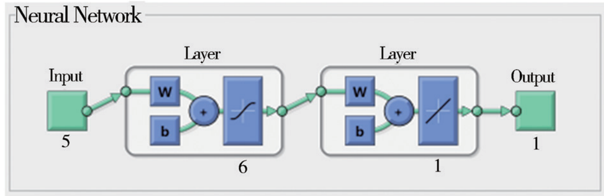

Figure 5
Training Structure of BP Neural Network

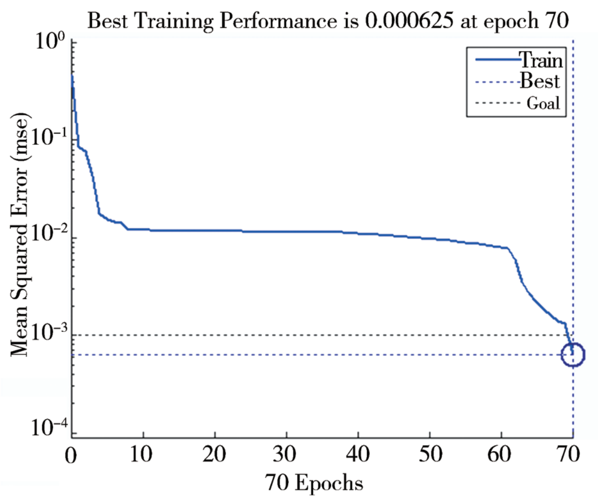

Figure 6
Training Results

We determine that the acceptable prediction error is about 15% according to the situation of the Red Cross. The predicted values are compared with the actual values, and the results obtained by this method are compared with those by other forecasting methods, which we can see the result from Table 3.

Table 3
Prediction Error Comparison

Forecast model		13	14
GM(1,n)	Actual value	4,000	7,100
	Predictive value	3,845.56	6,369.23
	Relative error percentage	-3.86%	-10.29%
Neural Network	Actual value	4,000	7,100
	Predictive value	3,869.5	6,779.4
	Relative error percentage	3.26%	4.51%

We find that the neural network model is better than the gray prediction model according to compare different prediction methods. The predictive value of neural network model is closer to the actual value and the maximum error is 4.51% which is an acceptable range. Therefore, using grey relativity and BP neural network to predict the demand, which meet the requirement in advance.

CONCLUSION

In this paper, the forecasting model is mainly aimed at the humanitarian goods with uncertain demand under the background of major disaster. Taking the tentative tents in the post-flood resettlement period as an example, select the influencing factors which can be easily obtained after the disaster, and using grey correlation and BP neural network to provide important reference significance for the forecast of the humanitarian supplies' demand. The sample data can be increased in practical application so as to enhance the stability of the prediction mode.

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