

## Predication Method for China's Civil Aviation Fuel Consumption

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### Abstract

With the China's civil aviation industry gradual market-oriented and the rapid development of China's economy, China's civil aviation transportation fuel consumption has grown significantly in nearly past three decades. Therefore, it's a very important strategic significance of the prediction of China's civil aviation transportation fuel consumption. In this paper, gray system and neural network approach, combined with China's civil aviation industry 1980-2010 total traffic volume of the data, we establish gray system GM (1,1) model and BP neural network model for civil aviation transport volume. Training and simulation of the back propagation neural network model and the gray system GM(1,1) used MATLAB. BP neural network modeling takes into account in three factors: the number of aircraft aviation industry, flight hours and total turnover. The fitting precision of the gray system GM(1,1) model is 64.2% while the fitting precision of the back propagation neural network model is 90.16%. Thus, the back propagation neural network model is better for estimating Civil aviation fuel consumption.

**Key words:** China's civil aviation industry; Fuel consumption; BP neural network; GM(1,1)

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DOI: <http://dx.doi.org/10.3968/j.css.1923669720130906.2976>.

### INTRODUCTION

China's civil aviation industry separate from the military jurisdiction and gradually return to the market since 1980, has more than 30 years. In three decades of market-oriented process, China's civil aviation industry has experienced rapid development. We can say that China's rapid economic development has effectively led the aviation industry. In this process, China's civil aviation industry has grown, the number and size of civil aviation enterprises expanding. There are six state-owned airlines in China's aviation industry, and it was 43 in the end of 2010. The categories include state-owned airlines, private airlines and joint venture airlines. At the same time, China's civil aviation industry fuel consumption is also increasing. Therefore, the aviation fuel consumption forecast is even more important.

Fuel consumption in itself is a non-linear, complex and open system, is the result of interaction of many factors. Some factors, such as political and economic factors, and some unexpected events (such as natural disasters, disease and terrorist attacks, etc.) and other factors. Because of the unpredictable nature of these factors, or the absence of such information, while the predictive modeling work to bring a certain degree of difficulty, which affects the prediction accuracy of the results.

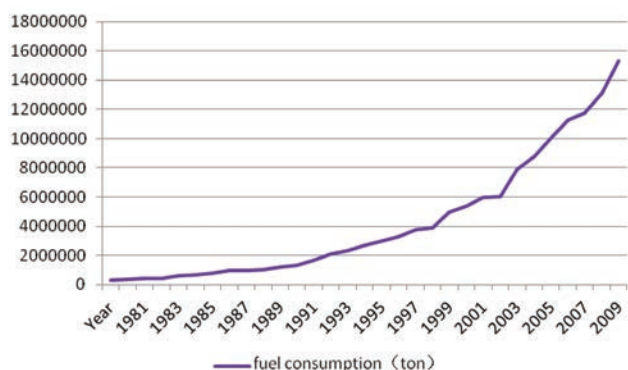
Grey prediction method is the 1980s Professor Deng Julong gray system theory proposed prediction method. For the information is incomplete or imperfect situation has good applicability. One single sequence of first-order GM (1,1) dynamic model has fewer samples, modeling and simple, widely used in the country. BP (back propagation) neural network is Rumelhart and McClelland 1986 by a team of scientists led by proposed is a method of error back propagation algorithm to train multi-layer feedforward neural networks, is currently the most widely used one neural network model. BP neural network can learn and store a large number of input - output mode mappings without prior description of this mapping

reveals the mathematical equations. BP neural network with non-linear, parallel distributed processing, self-learning, self-organizing, adaptive, etc., can accurately simulate the real demand for aviation fuel.

In this paper, China's civil aviation 1980-2010 fuel consumption data for 31 years, the use of gray system and neural network approach to build China's civil aviation fuel consumption of Grey System GM (1,1) model and BP neural network model. Study fuel consumption prediction method can predict the future of aviation fuel consumption for business decisions and provide reference for government policy makers to realize the sustainable development of civil aviation.

### 1. DATA

According to the China Air Transport statistics from published annually by the Civil Aviation Authority, we get from 1980 to 2010 aviation fuel consumption data from the "Statistical data on Civil Aviation of China 2010."



**Figure 1**  
1980-2010 China's Civil Aviation Transportation Fuel Consumption

### 2. GREY SYSTEM GM (1,1) MODEL

The fuel consumption of China's civil aviation transportation from 1980 to 2010 as GM (1,1) model of the original series  $x^{(0)}$ . Forecast 2011-2020 total turnover. Modeling process includes generating a cumulative sequence, using the mean cumulative number of solved column parameters using the least square method for solving gray, gray parameters into the differential equations for modeling and prediction of the original sequence.

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)) \tag{1}$$

Where  $n$  represents the number of samples of the original series, Here  $n=31$ .

1 number of times as cumulative is:

$$x^{(1)} = (x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)) \tag{2}$$

and

$$x^{(1)}(1) = x^{(0)}(1)$$

$$x^{(1)}(k) = x^{(1)}(k-1) + x^{(0)}(k)$$

Mean number listed is:

$$z^{(1)} = (z^{(1)}(1), z^{(1)}(2), \dots, z^{(1)}(n-1)) \tag{3}$$

and

$$z^{(1)}(k) = 0.5x^{(0)}(k) + 0.5x^{(0)}(k+1)$$

Whitening system differential equations is:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = d \tag{4}$$

Its time response function that is the solution of the differential equation is:

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - u/a)e^{-ak} + u/a \tag{5}$$

The solution to restore the original sequence simulation solution:

$$\hat{x}^{(0)}(k+1) = (1 - e^{-a})(x^{(0)}(1) - u/a)e^{-ak} \tag{6}$$

The gray parameters  $(a, u)$  which obtained by least squares method, using the equation is:

$$\begin{bmatrix} a \\ u \end{bmatrix} = (B^T B)^{-1} B^T Y_n \tag{7}$$

and

$$B = \begin{bmatrix} -z^{(1)}(1) & 1 \\ -z^{(1)}(2) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n-1) & 1 \end{bmatrix}$$

$$Y_n = [x^{(0)}(2), x^{(0)}(3), \dots, x^{(0)}(n)]^T$$

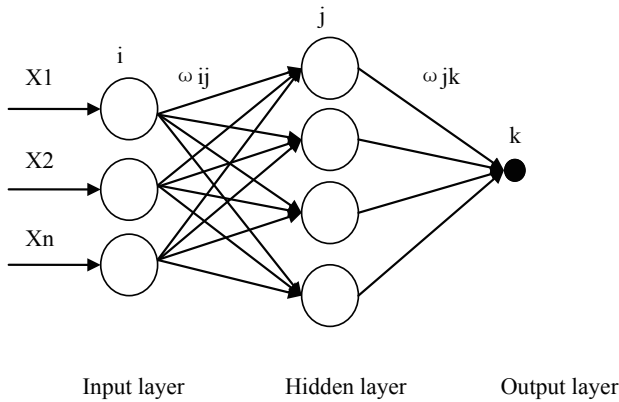
Meanwhile calculation model accuracy, which is calculated as:

$$s = 1 - \frac{1}{N} \sum_{i=1}^N \frac{|t_i - \hat{t}_i|}{t_i} \times 100\% \tag{8}$$

Wherein  $s$  represents the model accuracy, the number of samples  $N$ ,  $t_i$  is a sample value (actual value) of  $t_i$  analog values.

### 3. BP NEURAL NETWORK MODELING

BP neural network is a multilayer feedforward neural networks, the topology consists of three layers: the input layer, hidden layer and output layer.



**Figure 2**  
**Multi-Layer Structure of A Neural Network**

We make the fuel consumption as the output vectors, and the number of aircraft, flight hours, with a total turnover and airline mileage and other four factors be the impact on fuel consumption input vector. While the dimension difference exists input and output vectors are standardized, so that they have zero mean and a standard deviation of unity.

Here, we choose to contain a hidden layer of BP neural network. Nodes in the input layer dimension of

the input vectors determined input vector dimension is 4, so the input layer nodes identified as 4. Output layer nodes have determined the dimension of input vectors, where the output nodes is 1. Hidden layer node selection currently no theoretical guidance, too much will increase the network node network training time, will reduce the generalization ability of the network; But too little network nodes cannot effectively learn the training samples, modeling insufficient. Hidden layer nodes can refer to the following formula:

$$h = (m + n)^{\frac{1}{2}} + a \quad (9)$$

of which: number of nodes in the hidden layer, the input layer nodes for the output layer nodes, is an integer between 1 and 10. According to equation (9) hidden layer nodes initially identified through repeated training, and finally determine the hidden layer nodes is 8. Thus forming a 4-8-1 BP neural network.

The sample data from 1980 to 2000 as the training sample set 2001-2006 2010 sample data as the test sample set. Using Matlab software for data programming and analysis. While the use of the test sample data to test the model.

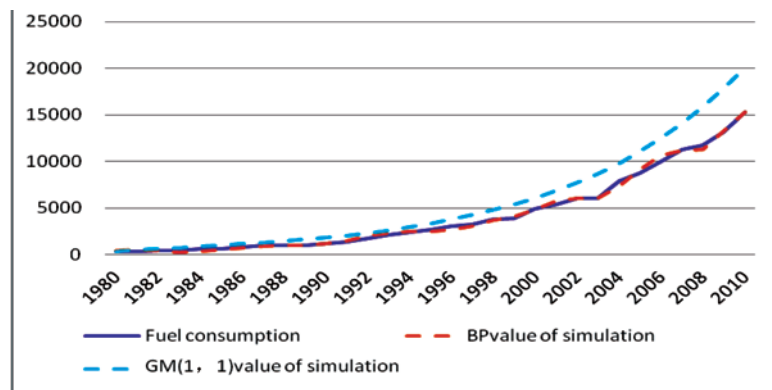
## 4. RESULTS

**Table 1**  
**Grey System GM (1,1) Model Simulation Results**

Year	Fuel consumption (10 <sup>3</sup> tons)	Value of simulation	Relative error	Year	Fuel consumption (10 <sup>3</sup> tons)	Value of simulation	Relative error
1980	340	340	0.07%	1996	3014	2710	24.90%
1981	376	555	47.70%	1997	3275	3097	29.52%
1982	413	625	51.36%	1998	3776	3704	26.62%
1983	445	705	58.48%	1999	3874	4043	39.12%
1984	602	895	48.58%	2000	4941	4844	22.92%
1985	660	1009	52.91%	2001	5356	5750	27.85%
1986	782	1137	45.46%	2002	6001	6076	28.60%
1987	970	1282	32.12%	2003	6049	6040	43.80%
1988	988	1445	46.29%	2004	7888	7308	24.29%
1989	1009	1628	61.35%	2005	8781	9131	25.85%
1990	1186	1835	54.67%	2006	10005	10582	24.49%
1991	1324	2069	56.24%	2007	11299	11142	24.25%
1992	1697	2332	37.40%	2008	11745	11302	34.72%
1993	2115	2628	24.28%	2009	13142	13203	35.72%
1994	2351	2962	25.96%	2010	15314	15313	31.28%
1995	2714	3339	23.01%	-	-	-	-

**Table 2**  
**BP Neural Network Model Simulation Results**

Year	Fuel consumption (10 <sup>3</sup> tons)	Value of simulation	Relative error	Year	Fuel consumption (10 <sup>3</sup> tons)	Value of simulation	Relative error
1980	340	467	37.45%	1996	3014	2710	10.07%
1981	376	501	33.33%	1997	3275	3097	5.44%
1982	413	463	12.13%	1998	3776	3704	1.90%
1983	445	281	36.83%	1999	3874	4043	4.37%
1984	602	341	43.39%	2000	4941	4844	1.97%
1985	660	544	17.56%	2001	5356	5750	7.36%
1986	782	759	2.90%	2002	6001	6076	1.25%
1987	970	868	10.55%	2003	6049	6040	0.15%
1988	988	954	3.42%	2004	7888	7308	7.35%
1989	1009	1021	1.19%	2005	8781	9131	3.99%
1990	1186	1181	0.46%	2006	10005	10582	5.76%
1991	1324	1417	7.01%	2007	11299	11142	1.39%
1992	1697	2062	21.49%	2008	11745	11302	3.78%
1993	2115	2346	10.94%	2009	13142	13203	0.47%
1994	2351	2452	4.28%	2010	15314	15313	0.01%
1995	2714	2527	6.90%	-	-	-	-



**Figure 3**  
**True Values and Simulated Comparison**

**CONCLUSION**

In this paper, we use gray system GM (1,1) model and BP neural network model for 1980-2010 China's civil aviation industry aviation fuel consumption simulation study. The results showed that: BP neural network model has a strong self-organizing, self-learning, adaptive capacity, superior gray system GM (1,1) model is better suited for the civil aviation industry aviation fuel consumption prediction. BP neural network model can be used in the future China's civil aviation industry development trend of aviation fuel consumption forecasts for government policy makers to provide a reference.

**REFERENCES**

Cai, J. B., Chen, H. B. (2010). Prediction research on China's R&D input intensity based on GM (1, 1) model. *Science and Technology Management Research*, (21).

Deng, J. L. (1989). Introduction to grey system theory. *The Journal of Grey System*, (1), 1-24.

Deng, J. L. (2005). *A primary methods of grey system theory* (2nd ed.). Wuhan: Huazhong University of Science and Technology Press. (in Chinese)

He, C. H., Shen, S. F., & Huang, Q. Y. (2012). Predication method for college and university enrollment scale. *The Journal of Tsinghua Univ (Sci & Tech)*, 52(1).

Liu, S. F., & Dang, Y. G., Fang, Z. G., & Xie, N. M. (2010). *Grey system theory and its applications* (5nd ed.). Beijing: Science Press.(in Chinese)

The Civil Aviation Administration of China Development and Planning Department. (2012). *Statistical data on civil aviation of China*. Beijing: China Civil Aviation Press. (in Chinese)

Yang, J., Liu, B., & Shang, M. L. (2006). Forecast of soybean import in China. *Systems Engineering Theory & Practice*, (6).