Forecasting Research on the Total Volume of Import and Export Trade of Ningbo Port by Gray Forecasting Model

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***Abstract*—Taking the total volume of import and export trade of Ningbo port in 2004-2011 as the original data, a mathematical model of gray forecasting is established for the total volume of import and export trade of port. The paper predicts the total volume of import and export trade of Ningbo port in 2012-2015 during the 12th Five-Year Plan in accordance with the posterior variance testing. The analysis results indicate that the fitting precision of forecasting model of gray system is satisfactory, offering a good idea for the development and reform of the Ningbo port and the port construction through the sustainable development overall in the future.**

***Index Terms*—gray forecasting; posterior variance test; foreign trade**

I. INTRODUCTION

Taking "To Thrive the City by Relying on the Port and to Boost the Port by Relying on the City" as the social-economic development strategy, the import and export trade of the Ningbo port and the physical distribution can supplement each other, and the trade development can promote the prosperity of cargo handling capacity, container inport and outport service, bringing the huge tax revenue, which makes the evident contribution to the overall economy of Ningbo[1]. The foreign trade volume of the port is an important indicator for the port competitiveness of a city. Therefore, the scientific forecasting on the import and export trade of the port plays a very important role in optimizing the structure of the port.

The factors influencing the import and export trade of the port are very complex, and the foreign trade system is a complex system with multiple influence factors, multiple layers and multiple targets. First, as both sides are located in different countries and regions, the course of dealing shall be influenced by such factors[2] as different systems, policies, economic forms, laws, conventions, etc. As the foreign trade system shows the uncertainty in terms of information, status, structure, etc., the model establishment through the gray system can be applied in forecasting the future foreign trade of the countries and regions.

The object that the gray system theory has been researching is the small sample of the uncertain system in "part of the information is known and the other part is unknown" [3]. In anyone system, known information and unknown one are distinguished by their colors with the white system for completely-known information, the black system for completely-unknown information and the gray system for partly-known and partly-unknown information. During the forecast of building a mathematical modeling for such a system, we are always trying to change the completely-unknown information, which is gray information originally, from "Gray" to "White" in color in order to make the forecasting could reach certain accuracy. As one of the important components in the gray system theory, the gray forecasting is a mathematical forecasting model system used to forecast the future by means of generating irregular original data, building a model, combining and seeking the inherent law of the system.

The gray system theory, founded by Professor Deng Julong in 1980s, has been widely applied in many fields, such as industry, agriculture, society, economics, energy, petroleum, geology, ecology, environment and medicine and so on. For example, Professor Xu Zhongxiang and others [4] complete a gray comprehensive forecasting on Xinjiang' s Tarim Basin oil and gas traps, solving the geological problems in oil and gas exploration and becoming an important branch of mathematical geology-gray mathematical geology. And on the other side, Lin Changrong [5] completes the gray forecasting on oil and gas reserves distribution on the west of the South China Sea and achieves an outstanding economic benefit by virtue of its high accuracy in predicting oil and gas by taking advantage of seismic data. Jiang Zhongxin and others [6] complete a gray forecasting on debris flow variation trend after a series of research on the comprehensive terrain index of debris flow development

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in debris flow cleugh longitudinal profile morphology characterization.

Many countries, regions and organizations as well as many famous scholars in the world are engaged in researching and applying the gray system, such as the application of gray system in hydraulic system proposed by Renn Jyh-chyang [7] in the Untied States compensates for ahead and delayed responses efficiently by the position signal of the hydraulic cylinder. And residual correction stepping model proposed by Yen-Tseng Hsu and others [8] by using studies of the gray theory in terms of cramping is used in cramping images. While Hiuh-JerHuang and others [9] apply the gray forecasting model into inverted pendulum control with the ability to point out the swing center and give the inverted pendulum control robustness.

The paper takes the total volume of import and export trade of Ningbo port over the years as the object of study and forecasts the total volume of import and export trade of Ningbo port in 2012-2015, which will provide the scientific theory for the task and policy of speeding up to build an internationally strong port and developing the strong city in marine economy stipulated in the Outline of the "12th Five-Year" Plan of Ningbo city.

II. Research Method

A. GM(1,1) Model Principle

The gray forecasting carries out the forecasting on some uncertain information systems, or some time-related gray processes which have some changes within a certain range. As the core of the gray forecasting, GM (1, 1) model is a first-order differential equation model of forecasting a single variable quantity, whose discrete time response function is similar to the law of index number. The mathematic model is a model way to build possible full original data by utilizing sufficient information through weakening the randomness of original data, generating the data model, making the disordered original data showing regularity and building and developing the changing model by processing the generated data sequence at last. [10]

B. Research Data

Data were obtained from statistical yearbook of Ningbo in 2011, the paper selects the data of the total volume of import and export trade of Ningbo port in 2004-2011, and the data is shown in Table Ⅰ, the trend is shown in Figure 1. The paper adopts the DPS(data processing system)7.05 software to process the data.

III. Establishment of Model

A. Determination of Raw Data Sequence and Accumulation of Generated Data Sequence

Suppose $X^{(0)}$ as the raw data sequence:

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), ..., x^{(0)}(N)\right\}$$

TABLE I.
TOTAL VOLUME OF IMPORT AND EXPORT TRADE OF NINGBO PORT FROM 2004 TO 2011 (MILLION US DOLLARS)

Year	2004	2005	2006	2007
Handling Capacity of Port	515.76	674.95	864.93	1117.60
Year	2008	2009	2010	2011
Handling Capacity of Port	1401.85	1169.23	1613.44	2004.4

Figure 1. The trend of the import and export trade of Ningbo in 2004-2011

According to 6 numerical values from 2004 to 2009 in Table Ⅰ, the raw data sequence is constituted and the mathematical model is established. The total volume of import and export trade in 2010 and 2011 is used to forecast the testing accuracy and testing feasibility of the numerical value. That is:

$$X^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), ..., x^{(1)}(N)\right\}$$

$$x^{(1)} = \sum_{j=1}^{k} x_j^{(0)} (k = 1, 2, ..., N) \quad (1)$$

The accumulated and generated data sequence can be derived from (1):

$$x^{(1)} = \left\{515.76, 1190.71, 2055.64, 3173.24, 4575.09, 5744.32\right\}$$

B. Constructing Accumulated Matrix B and Vector Y_N(Constant Term)

The accumulated data matrix B and the vector (constant term) Y_N can be established through the accumulated and generated data sequence.

$$\mathbf{B}=\begin{bmatrix} -\frac{1}{2}(x^{(1)}(1)+x^{(1)}(2)) & 1 \\ -\frac{1}{2}(x^{(1)}(2)+x^{(1)}(3)) & 1 \\ \cdots & \cdots \\ -\frac{1}{2}(x^{(1)}(N-1)+x^{(1)}(N) & 1 \end{bmatrix}$$

$$=\begin{bmatrix} -853.24 & 1 \\ -1623.18 & 1 \\ -2689.44 & 1 \\ -3874.17 & 1 \\ -5159.71 & 1 \end{bmatrix}$$

$$y_N=\left[x^{(0)}(2),x^{(0)}(3),...,x^{(0)}(N)\right]^T$$

$$=\left[674.95,864.93,1117.60,1401.85,1169.23\right]^T$$

C. Establishment of GM (1, 1) Forecasting Mdel

The gray generation model -- whitening equation can be established with the generated data sequence as the basis:

$$\frac{\mathrm{dx}^{(1)}}{\mathrm{dt}}+\mathrm{ax}^{(1)}=\mathrm{u} \tag{2}$$

a is the gray number for development, u is the gray number for endogenous control, and the least square method shall be adopted to solve the gray parameter.

$$\hat{a}=\begin{bmatrix} a \\ u \end{bmatrix}=\left(B^TB\right)^{-1}B^TY_N \tag{3}$$

Then obtain from (3) that

$$a=0.055,u=3.066$$

$$\hat{a}=\begin{bmatrix} 0.055 \\ 3.066 \end{bmatrix},\frac{u}{a}=57.75$$

can be generated from (3).

Therefore, the single variable can be derived, and the response function of discrete time of model forecasted by the first order differential GM (1, 1) shall be as follows:

$$\hat{x}^{(1)}(t+1)=(x^{(0)}(1)-\frac{u}{a})e^{-at}+\frac{u}{a},(t=1,2,...,n) \tag{4}$$

a and u shall be substituted in the (4), the fitting residual error of GM (1, 1) model includes the partial dynamic effective information, and the original model can be revised through the establishment of the residual error GM(1,1) model to eliminate the error[11]. After the revise of the residual error, the forecasting model of the total volume of import and export trade of Ningbo port shall be as follows:

TABLE II.
GRADE OF EXAMINE PRECISION

Grade of precision	Average relative error	Accuracy	small error probability	Posterior error
Good	1%	99%	>0.95	<0.35
Qualified	5%	95%	>0.80	<0.50
Reluctantly	10%	90%	>0.70	<0.65
Unqualified	20%	80%	≤0.60	≥0.80

$$\hat{x}^{(1)}(t+1)=460.01e^{-0.055t}+55.75$$

The calculated value of $\hat{x}^{(1)}(t+1)$ shall be regarded as the accumulate reduction, thus the estimated value of raw data shall be as follows:

$$\hat{x}^{(0)}(t+1)=\hat{x}^{(1)}(t+1)-\hat{x}^{(1)}(t) \tag{5}$$

D. Model Testing

Fitting residuals in the GM (1, 1) model usually has some dynamic and effective information and the original model can get amended to eliminate its error through the establishment of residual GM (1, 1) model.

Certain methods and ways must be adopted in testing to find whether the predicted value is credible or not, and generally a posterior variance testing will be adopted[12].

(1) Residual test

Residuals and relative errors are:

$$\begin{aligned} &\varepsilon^{(0)}(t)=x^{(0)}(t)-\hat{x}^{(0)}(t), \\ &e(t)=\varepsilon^{(0)}(t)/x^{(0)}(t) \end{aligned} \tag{6}$$

Wherein $\hat{x}^{(0)}(t)$ is the predicted value calculated from the model with a relative error within 5%, and the relative error data are shown in Table Ⅲ.

Average relative error:

$$\overline{e}(t)=\frac{1}{n}\sum_{i=1}^{n}\left|e(t)\right|=0.0017<1\%$$

the grade of accuracy testing is good Accuracy:

$$p^0=(1-\overline{e}(t))\times 100\%$$
$$=(1-0.0017)\times 100\%$$
$$=99.83\%>99\%$$

the grade of accuracy testing is good.

(2) Posterior variance testing:

the average value and the dispersion of the residuals are:

$$\overline{\varepsilon}^{(0)} = \frac{1}{n}\sum_{i=1}^{n}\varepsilon_i^{(0)},$$
$$S_1^2 = \frac{1}{n}\sum_{i=1}^{n}(\varepsilon_i^{(0)} - \overline{\varepsilon})^2 \quad (7)$$

Then obtain from (7) that

$$\overline{\varepsilon}^{(0)} = 0.003, S_1^2 = 0.0487$$

The average value and the dispersion of the raw data are:

$$\overline{x}^{(0)} = \frac{1}{n}\sum_{i=1}^{n}x_i^{(0)}(t),$$
$$S_2^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i^{(0)}(t) - \overline{x}_i^{(0)}(t))^2 \quad (8)$$

Then obtain from (8) that

$$\overline{x}^{(0)} = 957.37,$$
$$S_2^2 = 91919.75$$

Posterior variance testing:

$$c = \frac{S_1}{S_2} = 0.0045 < 0.35$$

The smaller the indicator c is, the better the result will be, showing that when the variance of original data is large, the degrees of dispersion will be large, while the variance of residual error is small, the degrees of residual error dispersion will be small. Although the original data are much dispersed, the difference between the models calculated value and the actual value is not too dispersed. On the other side, the larger the indicator p is, the better the result will be, showing that the existing more points whose difference between residual error and average value of the residual error are lower than the fixed value$0.6745S_2$. The larger the relative errors of the model are, the lower the accuracy will be and the model gets residual error amendment. Refer to forecasting accuracy judging standard, as shown in Table Ⅱ. In the researching model, the relative error *e(t)* and the accuracy p^0 are up to the second level; and the posterior difference ratio C and the small error frequency *p* are up to the first level, showing that the accuracy of the model is relatively high so that it can be used to predicate and analyze the total volume of import and export trade in Ningbo port. The model fitting result are shown in Table Ⅲ.

E. Extrapolation Forecasting and Verification Model

The established GM (1, 1) Model has the high fitting by model testing, which can conduct the extrapolation forecasting on the total volume of import and export trade in 2010 and 2011 and compare it with actual value, thus to verify the accuracy rating of the predicting data of this model, and inspect the feasibility of conducting forecast by using gray forecasting mathematical model in this study.

Substitute *t*=7,*t*=8 into the models established by formula (4) and (5) and calculate the following:

$$\hat{x}^{(0)}(7) = 1584.16,$$
$$\hat{x}^{(0)}(8) = 1985.68$$

relative errors are:

$$e(7) = 1.8\%,$$
$$e(8) = 0.9\%$$

respectively, while the relative error is less than 1% and the forecasting accuracy is high.

IV. ANALYZING OF FORECASTING RESULT

Model analysis on the total volume of import and export trade of Ningbo port in 2004-2011 is conducted and the calculated result is shown in Table Ⅲ, while the variation tendency of the forecasting model is shown as

TABLE III
FITTING RESULT OF GM(1,1) MODEL

Category	Year					
	2004	2005	2006	2007	20008	2009
Actual value	515.67	674.95	864.93	1117.60	1401.85	1169.23
Forecasted value	517.59	673.94	862.23	1117.601	1404.14	1168.86
Forecasted error	-1.83	1.01	2.70	-0.001	-2.29	0.37
Relative error %	-0.35	0.15	0.31	0.0	-0.16	0.032
Forecasting model	$\hat{x}^{(1)}(t+1) = 460.01e^{-0.055t} + 55.75$					
Forecasted grade	c=0.0045 Perfect p=1.0000 Perfect					

TABLE IV
FORECAST RESULT OF THE TOTAL VOLUME OF IMPORT AND EXPORT TRADE OF NINGBO PORT FROM 2012~2015 (MILLION US DOLLARS)

Year	Forecast value of GM（1，1）
2012	2491.03
2013	3127.71
2014	3932.42
2015	4954.23

Figure 2. It can be seen from Table Ⅱ that the predicted value and actual value are basically consistent with each other. By accuracy testing of the model, the predicted maximum relative error is 0.35% and the average relative error is 0.0017%. The result meets the requirement that general error should be less than 1%, while the accuracy of model is higher and the predicting effect is satisfactory. The extrapolation forecasting under the conditions of accurate model is carried out, and the total volume of import and export trade of Ningbo port in 2010 ad 2011 is forecasted. The forecasted average error of 1.35%..

The total volume of import and export trade of Ningbo port in 2012-2015 shall be forecasted in accordance with the forecasting model, and the forecasting results are shown in Table Ⅳ, the trend is shown in Figure 3. The result shows that during the 11th Five-Year Plan (2006-2010), the average annual increase of the total volume of import and export trade of Ningbo port is about 13%; and during the 12th Five-Year Plan (2012-2015), the average annual increase is predicted to be about 15% through the established gray forecasting model. Taking the economic development trend of our country and the world in the current and future period of time and the expansion form

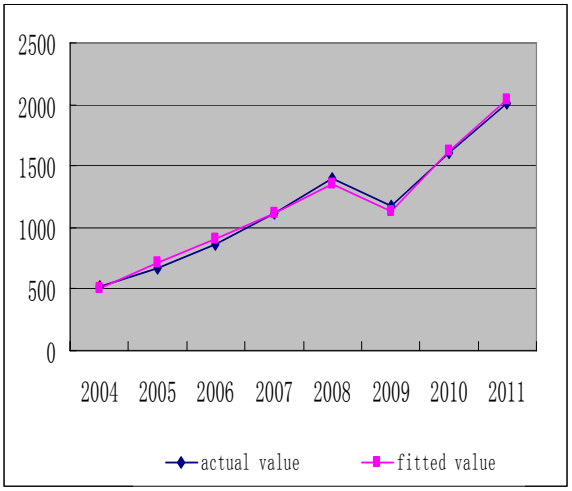

Figure2. Comparison of Actual Value and Fitted Value of Gray forecasting Model

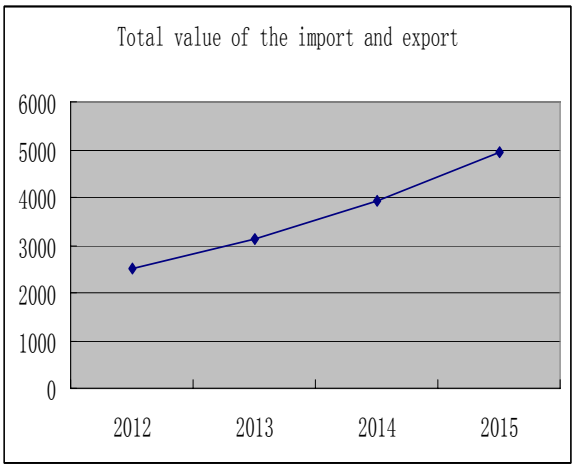

Figure3. The trend of the import and export trade of Ningbo in 2011-2015

of Ningbo port into consideration, it is possible to achieve the above forecasted level of handling capacity. The value of import and export trade of Ningbo port is growing year by year, and conforms with the development state and the objective law of import and export trade of Ningbo port over the past few years.

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V. CONCLUSION AND DISCUSSION

The research result shows that GM (1, 1) model is a univariate[13] and order linear model with an essence of using exponential curve fitting the raw data, and without strict requirements to the sample size and the probability distribution of the data. The model has strong adaptability and superior fitting degree, and has a better prediction effect on the time series data, so it is workable to forecast the total volume of import and export trade of Ningbo port by using the GM (1, 1) Model of Gray System. Under the condition of relatively stable model and satisfactory fitting effect, the model can be adopted to forecast the total volume of import and export trade in certain period in the future, which will provide Ningbo port with scientific thought for its sustainable development.

However, there are errors in research process and the analysis of the reasons is as follows:

(1) In this paper, the sample size in the sampling data is not homogeneous. The volume of import and export trade of Ningbo port from 2008 to 2009 decreased due to the financial crisis, which influenced the accuracy of the model to some extent.

(2) Each year's import and export trade volume prediction of the model is based on the import and export trade volume prediction of the last year, which magnifies the forecasted error. After the GM residual model analysis is adopted, the accuracy of the model is enhanced and the forecasted effect is more satisfactory.

(3) Due to various factors impacting the import and export trade in ports, it is hardly to find out the most effective and accurate way to predict the import and export trade in ports in the medium-long term at present. So, how to find out a way suitable to predict the handling capacity of container in the medium-long term will become a researching direction oriented in forecasting the handling capacity of container.

To sum up, the combination forecasting model result verifies that the fitting degree of predicted value and actual value is very high. The combination forecasting model possesses better stability and is able to reflect the changing trends of the total volume of import and export trade of Ningbo port, and it can be used as an effective prediction method to provide a scientific reference for the planning of Ningbo port.

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Scientific research project:

(1) Project of Education Department of Zhejiang Province: 《 Application and Research of Association Rules in Relationship between Hemorheology and Apoplexy》, Project No.: Y20108569, ranking first.

(2) Soft science project of Science and Technology Ningbo Bureau: 《Thebresearch of combined forecasting model on grey forecast and tri-exponertial smoothing in the container throughput forecasting of Ningbo port 》, Project No.: 2011A1058, ranking first.

(3) Soft science project of Zhejiang association for science and technology: 《Resedrch on effect evaluation system of health care service in traditional Chinese medicine based on Factor Analysis》, Project No.: KX12E-10 ranking first.

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