Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

Guangzhou Port Throughput Prediction Based on Grey Metabolism Model and GM (1,1) Model

Weiguo Li
Nanfang College Guangzhou, Guangzhou, China

Abstract:

As the cargo throughput of Guangzhou port keeps increasing in recent years, the metabolic model was used to accurately forecast the port capacity data in the next few years, and the forecast results were compared with the forecast results of the GM (1,1) model. It was found that the metabolic model can achieve higher forecast accuracy. The metabolic model was also selected to forecast the cargo throughput of Guangzhou port from 2021 to 2025. The study is intended to accurately predict the data.

Keywords: *GM (1,1), Metabolism, Port capacity*

I. INTRODUCTION

Eighty percent of the world's cargo transport is realized through ports. Guangzhou port is the largest comprehensive hub port and the container trunk port in South China. Guangzhou port consists of harbors and inland river ports. Guangzhou port includes the inner harbor district, Huangpu harbor district, Xinsha harbor district, Nansha harbor district and the anchorage of the Pearl River, with a cargo throughput of 636 million tons in 2020. Since the reform and opening up, Guangzhou is the first to open its port to the outside world, and the shipping industry goes global first. At present, Guangzhou port construction has realized the comparative advantage of the whole industry chain and the whole factor, and the technological level is No. 1 in the world, which provides a strong guarantee for the import and export of goods.

The cargo throughput of Guangzhou port keeps increasing in recent years, and the requirements for the port hardware equipment and the software management are raised. As COVID-19 broke out in 2020, the global demand for products made in China keeps increasing, and the port cargo throughput increases rapidly. In order to improve the port management level and the operation efficiency, it is necessary to accurately predict the port cargo throughput.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

II. LITERATURE REVIEW

The common prediction methods include the methods that are based on the neural network, such as the trend curve model, the extended neural network algorithm, BP neural network algorithm. In addition, it also concerns the regression model, grey theory and the combined prediction model which considers the characteristics of actual data. Among the above methods, the grey forecasting method is one of the widely used forecasting methods. Many researchers have used this method to predict the cargo throughput of the port. Tian Xue et al. (2018) applied GM (1,1) model to predict the cargo throughput of Caofeidian port, analyzed the predicted values of different types of cargo[1], and concluded that the relative predicted error was relatively low, but some error levels reached Level III. Li Nan (2021) applied the grey GM (1,1) model to collect the data of the cargo throughput at Beihai port from 2015 to 2019[2] and forecast the data in the next five years. By optimizing the GM (1,1) model, Huang Yuehua (2019) predicted the time sequence data of the port throughput with the periodic oscillation characteristics and obtained the better prediction accuracy[3]. Zhu Nian et al. (2017) predicted the logistics of Guangxi Beibu Gulf port based on the grey GM (1, N) model, and compared the results with GM (1,1) model[4]. The predicted residual error was within 10%. The grey prediction model was all used to predict the port capacity data in the above papers, which can obtain the reasonable prediction accuracy. However, the data changes were not timely reflected in the prediction, so the result was not accurate enough. The metabolic model was used to predict the cargo throughput of Guangzhou port by replacing the old data with the new data. In this way, the prediction result can be controlled in a more reasonable range.

III. THEORETICAL MODEL

3.1 GM (1,1) Model

① The level ratio of the sequence calculated from the original data column $x^{(0)}=(x^{(0)}(1),x^{(0)}(2),\cdots,x^{(0)}(n))$ is as follows:

$$\lambda(k)=\frac{x^{(0)}(k-1)}{x^{(0)}(k)},k=2,3,\cdots,n. \tag{1}$$

②The original data $x^{(0)}$ is added up once.

$$x^{(1)}=(x^{(1)}(1),x^{(1)}(2),\cdots,x^{(1)}(n))=(x^{(0)}(1)\ ,\ x^{(0)}(1)+x^{(0)}(2),\cdots,x^{(0)}(1)+\cdots+x^{(0)}(n)).$$

Establish the model:

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

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

③ Construct the data matrix B and the data vector Y

$$B=\begin{bmatrix}-z^{(1)}(2) & 1\\ -z^{(1)}(3) & 1\\ \vdots & \vdots\\ -z^{(1)}(n) & 1\end{bmatrix}, Y=\begin{bmatrix}x^{(0)}(2)\\ x^{(0)}(3)\\ \vdots\\ x^{(0)}(n)\end{bmatrix} \tag{3}$$

Where, $z^{(1)}(k)=0.5x^{(1)}(k)+0.5x^{(1)}(k-1), k=2,3,\cdots,n.$

④The estimated value $\hat{a}$ and $\hat{b}$ are obtained from

$$\hat{u}=\begin{bmatrix}\hat{a}\\ \hat{b}\end{bmatrix}=(B^TB)^{-1}B^TY \tag{4}$$

⑤According to differential equation (1), the predicted value of the generated sequence is as follows.

$$\hat{x}^{(1)}(k+1)=\left(x^{(0)}(1)-\frac{\hat{b}}{\hat{a}}\right)e^{-\hat{a}k}+\frac{\hat{b}}{\hat{a}},\ \ \mathrm{k}=0,1,\cdots,n-1,\cdots, \tag{5}$$

And then the reducing value of the model is as follows.

$$\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}, k=1,2,\cdots,n-1,\cdots. \tag{6}$$

⑥Precision test and prediction

Residual error

$$\varepsilon(k)=x^{(0)}(k)-\hat{x}^{(0)}(k), k=1,2,\cdots,n, \tag{7}$$

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

Relative error

$$\Delta = \frac{|\varepsilon(k)|}{x^{(0)}(k)} \tag{8}$$

Table I is relative error precision accuracy grade.

Table I. Table of relative error precision class

Precision class	**Level 1 (Excellent)**	**Level 2 (Good)**	**Level 3 (Passing)**	**Level 4 (Failed)**
Relative error	0.01	0.05	0.1	0.2

3.2 Grey Metabolic Model

The GM (1,1) model uses the least square method to calculate the estimated parameters a and b based on the original data sequence. In this case, the calculated values of a and b are fixed, and this constant value is used to predict the data. In the future environment, various interference factors will inevitably appear, so the later prediction will cause the greater the gap between the predicted value and the true value and the prediction accuracy will continue to decrease. Therefore, the general GM (1,1) model is only suitable for the short-term prediction, and the error of the prediction value will become greater.

Compared with the GM (1,1) model, the metabolic model can not only give full play to the advantages of the traditional GM (1,1) model, in which only a small amount of data can achieve the higher precision accuracy, but also reflect the change trends of the data. Therefore, the accuracy of the prediction results is further improved. The limitation is that: the model is suitable for predicting sequences with strong exponential law and it can only describe the process of monotonic changes.

Calculation procedures

① Establish the metabolic data sequence

In the original data sequence, the latest information is used to replace the original data. In this way, the metabolic data sequence is obtained.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

② The specific calculation procedures are the same as those in GM (1,1) model.

③The latest calculation result of is used to replace the original information and obtain the repeated steps of the new sequence. Similarly, the calculation result is tabulated and analyzed.

IV. CASE ANALYSIS

4.1 GM (1,1) Model Used to Predict the Cargo Throughput of Guangzhou Port

The cargo throughput data of Guangzhou port over the years are collected to obtain the following Table II.

Table II. Cargo throughput of Guangzhou port (unit: 10,000 tons)

Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Throughput	44770	45125	47200	50008	52096	54437	59012	61313	62687

Data source (2020 Guangzhou statistical yearbook)

Step 1: establish the original data sequence

$X^{(0)}$=(44770,45125,47200,50008, 52096,54437,59012,61313,62687)

Step 2: add up the original data to obtain the cumulative generation sequence

$X^{(1)}$=(44770,89895,137095,187103,239199,293636,352648,413961,476648)

Step 3: construct the data matrix *B* and the data vector *Y*

$$B=\begin{bmatrix} -67332.5 & 1 \\ -113495.0 & 1 \\ -162099.0 & 1 \\ -213151.0 & 1 \\ -266417.5 & 1 \\ -323142.0 & 1 \\ -383304.5 & 1 \\ -445304.5 & 1 \end{bmatrix} \quad Y=\begin{bmatrix} 44770 \\ 45125 \\ 47200 \\ 50008 \\ 52096 \\ 54437 \\ 59012 \\ 61313 \\ 62687 \end{bmatrix}$$

Step 4: determine the values of the parameters a and b

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

The formula is applied to obtain the following results. $\hat{u} = \begin{bmatrix} \hat{a} \\ \hat{b} \end{bmatrix} = (B^T B)^{-1} B^T Y$

$\hat{a}$=-0.05 $\hat{b}$=41870.24

Step 5: Based on the differential equation (1), the predicted value of the sequence is calculated as follows.

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{\hat{b}}{\hat{a}} \right) e^{-\hat{a}k} + \frac{\hat{b}}{\hat{a}}$$
$$= 897694.7\, e^{0.05k} - 852924.7$$

Step 6: Based on the formula of Step 5, k=0 to 5 is substituted into the formula to obtain the predicted value. The following Table III is obtained.

Table III. Predicted cargo throughput of Guangzhou port (unit: 10,000 tons)

2014	2015	2016	2017	2018	2019
50008	54647	57449	60395	63491	66746

Step 7: precision test and prediction

Formula 7 is used to calculate the relative error between the predicted value and the true value. The average relative error is 4.56%, and the accuracy grade reaches the good standard of Level 2.

4.2 Grey Metabolic Model Used to Predict the Cargo Throughput of Guangzhou Port

The cargo throughput data of Guangzhou port from 2011 to 2015 are selected to establish the original data sequence.

X(0)=(44770,45125,47200,50008, 52096)

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

According to the calculation steps of GM (1,1) model, the predicted value of cargo throughput of Guangzhou port in 2016 is 548.18 million tons. Compared with the true value of cargo throughput of Guangzhou port in 2016, the relative error value of the calculation is 0.007, reaching the level of first-grade accuracy.

By replacing the cargo throughput data of 2011 with those of Guangzhou port in 2016, the new original data sequence (45, 125, 47, 200, 50008, 52, 096, 54437) is obtained, and then the predicted value in 2017 is 577. 33 million tons by using the above method. Similarly, the predicted values of 2018 and 2019 are 616.87 million tons and 652.12 million by means of deduction, respectively.

Finally, the predicted data sequence of Year 2015-2019 is (51964, 54437, 57733, 61687, 65212) based on the metabolic model. Through the comparative analysis of the predicted results between GM (1,1) model and the metabolic model, the error between the predicted data of the GM (1,1) and that of the metabolic model above is collected for the comparative analysis. The following Table IV is obtained.

Table IV. Comparison of predicted value errors between metabolic model and GM (1,1) model

year	**true value (10,000 tons)**	**metabolic model (10,000 tons)**	**relative error**	**GM (1,1) model (10,000 tons)**	**relative error**
2015	52096	51964	0.2534%	54647	4.8967%
2016	54437	54437	0.0000%	57449	5.5330%
2017	59012	57733	2.1674%	60395	2.3436%
2018	61313	61687	0.6100%	63491	3.5523%
2019	62687	65212	4.0279%	66746	6.4750%

As shown in the prediction of the metabolic model above, when it comes to Guangzhou port throughput from 2015 to 2019, the average relative error of the predicted value is 0.014, while the average error of the predicted value by the GM (1,1) model is 0.0456. By comparison, it can be seen that: the predicted value error of the metabolic model is much smaller than that of the GM (1,1) model. Therefore, the metabolic model is used to predict the port throughput data in the next five years.

The metabolic model is used to predict the throughput data of Guangzhou port from 2021 to 2025 by using the above method, and the predicted data sequence of Year 2021-2025 is (72604, 77309, 82198, 87396, 94162).

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2021 Page No. 380-387
Article History: Received: 22 July 2021 Revised: 16 August 2021 Accepted: 05 September 2021 Publication: 31 October 2021

V. CONCLUSIONS AND PROSPECTS

It is of great significance to accurately predict the throughput data of Guangzhou port in the next five years, which can not only promote the sustained and rapid development of Guangzhou cargo import and export but also facilitates the rational planning and layout of logistics industry. Based on GM (1,1) model, an improved five-dimensional prediction model—the metabolic model, is proposed. From the perspective of prediction, the prediction result of the five-dimensional metabolic model is more accurate than that of general GM (1,1) model, and the prediction error is smaller. After removing the old data and introducing the new data, the metabolic model can timely reflect the changes of data, so it improves the accuracy of prediction and is an ideal prediction model. In addition, it can be known from the prediction results that: in the next five years, the throughput of Guangzhou port will develop rapidly at an average annual growth rate of 6.7%. Although the metabolic model is more accurate than GM (1,1) model, it has its limitations. The model is only suitable for predicting sequences with the strong exponential law and can only describe the process of monotonous changes. The logistics of Guangzhou port is in the stage of rapid development, and it is growing every year. Therefore, it is appropriate to use the metabolic model to predict the throughput of Guangzhou port. However, according to the law of logistics development in developed countries, when the speed of logistics development has experienced a stage of rapid growth, it will enter a stage of slow growth. At the moment, although the whole logistics system is perfect and its operation efficiency is high, its development speed no longer shows the law of exponential growth, so the metabolic model will no longer be applicable. It is necessary to choose a new method for reasonable prediction by then.

REFERENCES

[1] Tian et al. Study on port throughput prediction based on grey model – a case study of Caofeidian port. Mathematics in Practice and Theory, 2018, 48(04): 280-284.
[2] Li, Sun & Chen. Study on the cargo throughput of Beihai port based on the grey prediction method. China Business and Market, 2021, (13): 6-8.
[3] Huang Yuehua & Chen Xiaolong. Cargo throughput prediction based on the optimized GM (1,1) model. China Shipping, 2019, 42(04): 136-140.
[4] Zhu et al. Logistics prediction study of Guangxi Beibu gulf based on the grey GM (1,1) model. China Shipping, 2019, 42(04): 136-140.