ISSN: 2688-9323

Forecast of China Railway Express Development Demand based on GM (1,1) Model

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Abstract

As an important part of the initiatives of "One Belt and One Road", China Railway Express will play a major role in promoting the interconnection and development along China and Europe. The prediction of the future development demand of China Railway Express will help to provide ideas for development and management of the China Railway Express in operation organization and transport organization, and to clarify the development goals. Considering the actual situation, the average weakening buffer operator of the original sequence is used to generate the first-order buffer sequence, and then the GM (1,1) model is used to build the dynamic prediction model of the number of China Railway Express trains. This results show that the average relative error of GM (1,1) model is more accurate, which can be used to predict the number of China Europe trains. Using this model to predict the number of China Railway Express trains in the next five years, it is found that the number of trains is growing rapidly, so the future transportation management of China Railway Express should focus on the quality of trains, so as to achieve the all-round development of China Railway Express.

Keywords

China Railway Express; Grey model; the Belt and Road Initiatives; forecast.

1. Introduction

CHINA RAILWAY Express (CR Express) is the China - Europe block train ferry, which is organized by the China Railway Corporation, has characters of fixed trips, route, schedule and transport time, operated in the international railway container inter-modal transportation mode in China-Europe alone the “The Belt and Road”. In October 2016, the national development and Reform Commission of the people's Republic of China issued the CR Express construction and development plan (2016-2020). The plan proposes to build CR Express into a world famous logistics brand with international competitiveness and good reputation, and also marks CR Express became the important achievements and main trading platform of strategic construction in "one belt and one road". In recent years, with China's increasing opening-up and in-depth implementation of the Belt and Road Initiatives, CR Express has developed rapidly. Since the opening of CR Express in 2011, by the end of 2019, China Europe train has accumulated more than 21 thousand trains, reaching 18 countries and 57 cities in Europe. Among them, in 2019, China Europe trains opened 8225 trains, with a year-on-year growth of 29%, shipping seventy-two point five Million TEUs, a year-on-year increase of 34%, and the comprehensive heavy box rate reached 94%[1].

As a stabilizer to promote international trade, CR Express is an indispensable role in the Belt and Road Initiatives. Therefore, it is of great significance to study the future development trend of CR Express in terms of operation and management. The future development trend of CR Express can be reflected by railway freight volume, but considering that CR Express has no comprehensive statistics of freight volume in the early stage. At present, the number of trains

ISSN: 2688-9323

is the main indicator to measure the development of CR Express. Therefore, this paper will reflect the freight volume of CR Express through the number of trains, so as to predict the future development demand of CR Express and find the future development focus of CR Express.

2. Literature References

At present, there are many forecasting methods for freight volume. Some scholars based on the system dynamics model, freight traffic rate model, input-output model to predict the freight volume or cargo demand. And some scholars make predictions based on the existing freight volume trend and time series. For example, Xiaoming Liu et al. forecast regional air passenger flow based on Rough Set Theory[2]; Cheng Zhou et al., use optimized BP neural network to weaken the interference between linear and nonlinear components in freight volume[3]; Li Xu et al. used the GM (1,1) residual quadratic correction model to predict the railway freight volume[4]; Zhenggang He et al. predicted the railway freight volume based on the FPSO grey Verhulst model[5]; Qinqin Li et al. predicted the regional freight volume using the optimal variable weight combination prediction model[6]; and Jianyou Zhao et al. predicted the highway freight volume based on the fuzzy linear regression model[7].

The system dynamics model can simulate the interaction between regional freight system and economic development, and improve the time series prediction model, but the system dynamics model does not cover enough space and network details, and the system parameters are difficult to carry out statistical tests. Regional freight traffic rate method is also easy to use, but the data collection of freight traffic rate needs a lot of statistical investigation, which costs a lot. In addition, when the environmental facilities, land use, industrial composition and other changes, the traffic rate may also change. The input-output model can not only consider the economic relationship, but also consider the factors of policy influence through the elastic coefficient. However, because the input-output model is non spatial, there is no endogenous calculation of trade flow, and it is not sensitive to the change of freight transportation cost; and based on the assumption of fixed input-output coefficient, it is not flexible; at the same time, the input-output model is used to calculate the regional generated and attracted freight volume The need for cross regional input-output table, which requires a lot of data, but there is no provincial and municipal cross regional input-output table in China, which limits its application[8]. Traditional forecasting methods based on current trends and time series mainly include time series method, regression analysis method, input-output balance method and elastic coefficient method. These linear trend models are faced with the problem of using approximate data to replace the data of logistics industry in the research process, that is, using data with certain gray level to analyze and calculate, which leads to prediction results are not accurate enough.

At present, most of the research on freight volume is railway freight volume. Because the railway freight volume is affected by policy factors, it is easy to have sudden changes, so many scholars use various improved models to predict the railway freight volume. However, there is no such problem in the freight volume forecast of CR Express. Because the author found that the number of CR Express has been on the rise since 2011, and there is no oscillation. In addition, there are only nine years of data from 2011 to 2019, which conforms to the application background of grey system theory of "small sample" and "poor information".

Using GM (1,1) model to study freight volume does not need a lot of time series, nor does it need to analyze the factors affecting freight volume. The research process is simple, the results are relatively accurate, and it can effectively predict the future development trend of CR Express. When using GM (1,1) model to forecast, it is necessary to deal with the original data because of the impact disturbance factors in the data of the number of trains in CR

Express. Therefore, this paper uses buffer operator method, based on the trend of the original data series, to weaken the transformation, form a new data series, reduce the error of the prediction results of the number of rows. To sum up, the author establishes GM (1,1) model based on the actual statistical data of the number of CR Express trains, and forecasts the freight volume of CR Express in the next five years, so as to better understand the future development trend of CR Express, and puts forward relevant suggestions.

3. Research Method

3.1. GM (1,1) Model

GM (1,1) model is the basic model of grey system prediction and control. Its modeling principle does not depend on the distribution information of the original data, but uses the method of accumulation to make the sequence present the whole grey index law. On this basis, the grey differential equation is constructed and solved. Grey model can model and predict without large sample data, and the modeling process is simple and easy to operate, which has unique advantages in short-term prediction of small sample series. The grey model GM(1,1), i.e., a single variable first-order grey model, is summarized as follow [9]:

Step 1 For an initial time sequence

$$X^{(0)}=(x^{(0)}(1),x^{(0)}(2),\ldots,x^{(0)}(n))$$

where $X^{(0)}(k)$ the time series data at time k, n must be equal to or larger than 4.

Step 2 On the basis of the initial sequence $X^{(0)}$, a new sequence $X^{(1)}$ is set up through the accumulated generating operation in order to provide the middle message of building a model and to weaken the variation tendency. $X^{(1)}$ also known as the 1-AGO sequence.

$$X^{(1)}=(x^{(1)}(1),x^{(1)}(2),\ldots,x^{(1)}(n))$$

Where

$$X^{(1)}(k)=\sum_{i=1}^{k}x^{(0)},k=1,2,3,\ldots,n\,.$$

Step 3 The first-order differential equation of grey model GM(1,1) is then the following

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

and it is easy to get

$$\hat{a}=[a,b]^T=(B^TB)^{-1}B^TY$$

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

Step 4 The time response formula of GM (1,1) model becomes the following

$$\hat{x}^{(1)}(k)=(x^{(0)}(1)-\frac{b}{a})e^{-a(k-1)}+\frac{b}{a},k=1,2,\ldots,n\,. \quad (1)$$

Step 5 Equation (1) is generated by progressive reduction, and the reduction sequence is obtained as follows

$$\hat{x}^{(0)}(k)=(1\text{-}e^{a})(x^{(0)}(1)-\frac{b}{a})e^{-a(k-1)},k=1,2,\ldots,n\,. \quad (2)$$

ISSN: 2688-9323

3.2. Construction of Weak Buffer Operator

When using GM (1,1) model to predict, it is necessary to process the original data because of the impact disturbance factors in the original data of most research objects. Yaoguo Dang, Sifeng Liu and so on put forward the buffer operator method. Based on the trend of the original sequence, they can strengthen or weaken the transformation to form a new data sequence, which can effectively meet the modeling requirements of GM (1,1) model. The construction principle of weakening buffer operator is as follows[10]:

Step 1 For an initial time sequence

$$X = (x(1), x(2), \dots, x(n))$$

Step 2 A new sequence of modifications is as follows

$$XD = (x(1)d, x(2)d, \dots, x(n)d)$$

Where

$$x(k)d = \frac{1}{n-k+1}[x(k) + x(k-1) + \dots + x(n)], \quad k = 1,2,\dots,n.$$

3.3. GM (1,1) Model of CR Express

According to the principle of grey system GM (1,1) model, this study establishes the GM (1,1) model of the number of CR Express trains, in which R represents the variable of the number of China Europe trains, and r represents the specific value of the number of trains.

Step 1 the original sequence of the number of CR Express trains is:

$$D^{(0)} = (d^{(0)}(1), d^{(0)}(2), \dots, d^{(0)}(n))$$

Where

$$\mathrm{d}^{(0)} \geq 0, k = 1,2,\dots,n.$$

Step 2 The first-order buffer sequence generated by weakening the buffer operator on the original sequence is as follows:

$$R^{(0)} = (r^{(0)}(1), r^{(0)}(2), \dots, r^{(0)}(n))$$

Where

$$r^{(0)}(k) = \frac{1}{n-k+1}[d^{(0)}(k) + d^{(0)}(k-1) + \dots + d^{(0)}(n)], k = 1,2,\dots,n.$$

Step 3 The 1-AGO generation sequence of buffer sequence is

$$R^{(1)} = (r^{(1)}(1), r^{(1)}(2), \dots, r^{(1)}(n))$$

where $\mathrm{R}^{(1)}(k) = \sum_{i=1}^{k} r^{(0)}, k = 1,2,\dots,n$.

Step 4 The nearest mean value sequence of 1-AGO generation sequence is:

$$Z^{(1)} = (\mathrm{z}^{(1)}(2), z^{(1)}(3), \dots, z^{(1)}(n))$$

Where

$$z^{(1)}(k) = 0.5(r^{(1)}(k) + r^{(1)}(k-1)), \quad k = 1,2,\dots,n.$$

Step 5 According to the basic form of GM (1,1) model, the GM (1,1) model of the number of China Europe trains is as follows:

$$r^{(0)}(k) + az^{(1)}(k) = b, \text{ where } \hat{\mathrm{a}} = [\mathrm{a}, \mathrm{b}]^{\mathrm{T}} = (B^T B)^{-1} B^T Y,$$

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

Step 6 Therefore, we can get the time response formula of GM (1,1) model of the number of trains in China and Europe as follows:

$$\hat{r}^{(1)}(k)=(r^{(0)}(1)-\frac{b}{a})e^{-a(k-1)}+\frac{b}{a}, \quad k=1,2,\ldots,n \tag{3}$$

Step 6 Equation (3) is generated by progressive reduction, and the reduction sequence is obtained as follows:

$$\hat{r}^{(0)}(k)=(1-e^{a})(r^{(0)}(1)-\frac{b}{a})e^{-a(k-1)}, \quad k=1,2,\ldots,n \tag{4}$$

3.4. Average Relative Error Test

Step 1 For an initial time sequence

$$D^{(0)}=(d^{(0)}(1),d^{(0)}(2),\ldots,d^{(0)}(n)),$$

the prediction model sequence is

$$\hat{R}^{(0)}=(\hat{r}^{(0)}(1),\hat{r}^{(0)}(2),\ldots,\hat{r}^{(0)}(n)).$$

Step 2 From the above, we can get the residual sequence

$$\varepsilon^{(0)}=(\varepsilon(1),\varepsilon(2),\ldots,\varepsilon(n))=(r^{(0)}(1)-\hat{r}^{(0)}(1),r^{(0)}(2)-\hat{r}^{(0)}(2),\ldots,r^{(0)}(n)-\hat{r}^{(0)}(n))$$

the relative error sequence is

$$\Delta=\left(\left|\frac{\varepsilon(1)}{r^{(0)}(1)}\right|,\left|\frac{\varepsilon(2)}{r^{(0)}(2)}\right|,\ldots,\left|\frac{\varepsilon(2)}{r^{(0)}(2)}\right|\right)=\{\Delta_k\}_n^1;$$

The average relative error is

$$\overline{\Delta}=\frac{1}{n}\sum_{k=1}^{n}\Delta$$

Step 3 Given the accuracy as *a*, if $\overline{\Delta}\le a$, then the model is a qualified residual model.

4. The Practical Application of GM (1,1) Model in CR Express

4.1. The Application of GM (1,1) Model

In recent years, the development of CR Express has been rapid, and the number of banks can well measure the freight volume level of CR Express, and then predict the future development trend. Table 1 shows the specific number of trains to be opened in 2011-2019. According to the data released by China National Railway Group Co., Ltd., CR Express will open 8225 trains in 2019, with a year-on-year growth of 29%, and 725000 TEUs will be shipped, with a year-on-year growth of 34%.

Table 1. Number of CR Express trains in 2011-2019

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of trains	17	42	80	308	815	1702	3673	6363	8225

Step1 For an initial time sequence

$$D^{(0)} = (17,42,80,308,815,1702,3673,6363,8225).$$

Step 2 The first-order buffer sequence generated by weakening the buffer operator on the original sequence is as follows:

$$R^{(0)} = (2358.3, 2651.0, 3023.7, 3514.3, 4155.6, 4990.8, 6087.0, 7294.0, 8225.0)$$

Step 3 The 1-AGO generation sequence of buffer sequence is

$$R^{(1)} = (2358.3,5009.3,8033.0,11547.3,15702.9,20693.7,26780.7,34074.7,42299.7).$$

Step 4 The nearest mean value sequence of 1-AGO generation sequence is:

$$Z^{(1)} = (3683.8,6521.2,9790.2,13625.1,18198.3,23737.2,30427.7,38187.2)$$

Step 5 According to the basic form of GM (1,1) model, the GM (1,1) model of the number of trains in CR Express is as follows:

$$r^{(0)}(k) + az^{(1)}(k) = b \text{, where } \hat{a} = [a, b]^{T} = (B^T B)^{-1} B^T Y \text{,}$$

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

The development coefficient *a* and grey action *b* of grey model are calculated, and the following results are obtained:

a=-0.2, b=1947.4.

Step 6 From equation (3), the time response formula of GM (1,1) model for the number of trains in CR express is as follows:

$$\hat{r}^{(1)}(k+1) = 9754e^{0.2k} - 9737, \quad k = 1,2,\ldots,n \tag{5}$$

Step 6 Equation (3) is generated by progressive reduction, and the reduction sequence is obtained as follows:

$$\hat{R}^{(0)} = (2358.3,2555.8,3026.3,3583.4,4243.1,5024.3,5949.2,7044.5,8341.4)$$

Using the software MATLAB, we can get the comparison diagram of the original sequence and the simulation sequence, as shown in Figure1.

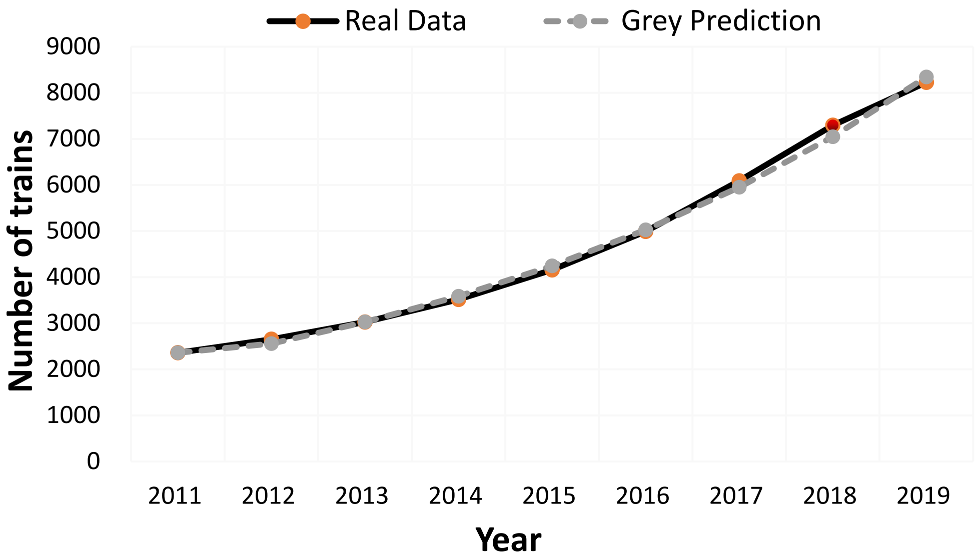

Fig. 1. Comparison of original sequence and simulation sequence

4.2. Average Relative Error Test

According to the above calculation, the grey prediction model of the number of trains in CR Express is as follows:

$$\hat{r}^{(1)}(k+1) = 9754e^{0.2k} - 9737, \quad k = 1,2,\ldots,n$$

Whether this model is valid, whether it can be used for prediction and the accuracy of prediction still need to be tested. If the test results show that the prediction accuracy is relatively high, it can be used to predict the number of CR Express trains in the future, otherwise it cannot be used for effective prediction. Next, the average relative error test method is used for verification, and the results of the error test refer to the accuracy test level reference table (see Table 2).

Table 2. Precision inspection level reference table

Accuracy Level	Level 1	Level 2	Level 3	Level 4
Relative Error	0.01	0.05	0.10	0.20

It can be seen from the above that the original sequence after buffering is:

$$R^{(0)} = (2358.3, 2651.0, 3023.7, 3514.3, 4155.6, 4990.8, 6087.0, 7294.0, 8225.0).$$

The predicted model sequence is:

$$\hat{R}^{(0)} = (2358.3,2555.8,3026.3,3583.4,4243.1,5024.3,5949.2,7044.5,8341.4).$$

The residual sequence of the model can be obtained as follows:

$$\varepsilon^{(0)} = (0,95.2, -2.6, -69.1, -87.5, -33.5, 137.8, 249.5, -116.4),$$

And the relative error sequence is:

$$\Delta = (0,0.036,0.001,0.02,0.021,0.007,0.023.0.034,0.014).$$

The average relative error of the model is as follows: $\overline{\Delta} = \frac{1}{n}\sum_{k=1}^{n}\Delta = 0.019$.

Given the accuracy as *a=0.01*, because $\overline{\Delta} = 0.019 \le a$, the model is a qualified residual model, and its accuracy is level 1. Therefore, the prediction model is established, which can be used to predict the number of trains in CR Express, and the prediction accuracy is very high.

4.3. Forecast of CR Express

It can be seen from the above that the grey GM (1,1) prediction model for the number of CR Express has passed the rate average relative error test and has a high accuracy, so the model can be used to predict the number of CR Express in the future. Now it forecasts the number of CR Express in the next five years.

From equation (5), we know:

$$\hat{r}^{(1)}(k+1) = 9754e^{0.2k} - 9737, \quad k = 1,2,\ldots,n$$

And

$$\hat{r}^{(0)}(k+1) = \hat{r}^{(1)}(k+1) - \hat{r}^{(1)}(k)$$

When k = 9,

$$\hat{r}^{(1)}(9+1) = 9754e^{0.2\times 9} - 9737 = 47271.26,$$

$$\hat{r}^{(0)}(10) = \hat{r}^{(1)}(10) - \hat{r}^{(1)}(9) = 10696.38.$$

In the same way:

when k=11, $\hat{r}^{(0)}(11) = \hat{r}^{(1)}(11) - \hat{r}^{(1)}(10) = 13064.59$;

when k=12, $\hat{r}^{(0)}(12) = \hat{r}^{(1)}(12) - \hat{r}^{(1)}(11) = 15957.13$;

when k=13, $\hat{r}^{(0)}(13) = \hat{r}^{(1)}(13) - \hat{r}^{(1)}(12) = 19490.08$;

when k=14, $\hat{r}^{(0)}(14) = \hat{r}^{(1)}(14) - \hat{r}^{(1)}(13) = 23805.24$.

Therefore, the forecast results of the number of CR express to be operated in the next five years are shown in Table 3:

Table 3. Forecast of the number of CR express in the next five years

Year	2020	2021	2022	2023	2024
number of trains	10696	13065	15957	19490	23805

5. Conclusions and Discussion

The GM (1,1) model of the number of trains in China and Europe has passed the average relative error test, and the accuracy is one level, so the model can be used to predict the future freight volume of CR express[11]. According to the forecast results, the number of CR express is expected to exceed 20000 in 2024, reaching the total number of current trains. The continuous increase of the number of trains is the future development trend of CR express. The scale of CR express continues to expand, which will gradually become an important support point for trade between China and Europe.

In addition, the forecast results also show that the number of trains is showing a good trend, so more attention should be paid to the improvement of the quality of the trains in the future, that is to say, in order to achieve long-term sustainable development, CR express must focus on meeting the demand of the quality of the trains. In October 2018, the national development and Reform Commission organized the on-site meeting and special coordination meeting of CR express construction in Chongqing, which clearly proposed that the operation of CR express should establish the concept of quality first and benefit first, and establish a quality oriented assessment and evaluation system. In February 2019, “one belt, one road” construction project leading group of CR express, held a special meeting on construction of CR express, and again put forward the principle of quality first.

It can be seen that the central government and the government of China attach great importance to the quality of the development of CR express. However, in order to occupy the position of "strategic fulcrum of the new Silk Road" in the actual operation process, the cities of CR express compete with each other for the source of goods, and repeat the construction of operation lines, which makes the domestic source of goods smaller and scattered, the full load rate of trains is not high, and the overall operation cost is high, resulting in uneconomical transportation. In this case, it is difficult for one train operator to promote the market-oriented operation of CR express in a short time by reducing freight rates, freight subsidies and other preferential means. Therefore, how to effectively coordinate the opening city of CR express, improve the overall efficiency and achieve the high quality development of CR express is the main research direction in the future.

Acknowledgments

This work was supported by National Social Science Foundation of China (18BGL007), Foresight and System Innovation Project of Chongqing Science and Technology Commission (cstc2019jsyj - zzysbAX0047), Humanities and Social Science Research Project of Chongqing Education Commission (18SKGH069), Graduate Innovative Research Project of Chongqing Technology and Business University (yjscxx2019-101-93).

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