

## Research Article

# Prediction of China's Express Business Volume Based on FGM (1, 1) Model

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Received 17 June 2021; Accepted 6 August 2021; Published 16 August 2021

Academic Editor: Lifeng Wu

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With the continuous development of the economy, people's lifestyle has changed greatly, online shopping has become a better choice for many people, and the express business volume is also increasing. Forecasting express business volume is of benefit to the healthy development of the logistics industry. Based on the data of China's express business volume from 2015 to 2019, this paper uses the improved Particle Swarm Optimization algorithm to calculate the fractional-order  $r$  of the FGM (1, 1) model and forecasts China's express business volume from 2020 to 2023. The results indicate that in the next few years, China's express business volume will show a large growth trend, indicating that the express delivery industry still has a lot of room for development.

## 1. Introduction

Since the Internet has become widely available, people get accustomed to shopping online. Online shopping is convenient and time-saving, which has facilitated the development of China's express business volume in recent years. It can be predicted that the express business volume will continue to grow in the future. The following content will do specific research on the growth of China's express business volume. Figure 1 shows the data of China's express business volume from 2015 to 2019.

The rapid growth of express business volume brings about the development of the whole logistics industry. At the same time, the unreasonable allocation of various resources leads to the disorderly development of the logistics industry. Therefore, predicting the express business volume will help related personnel to make scientific decisions, and then promote the healthy development of the whole logistics industry. At present, some scholars have done relevant prediction research. Li and Zhang have established a support vector machine model based on trend adjustment and seasonal adjustment to predict and analyze the monthly express business volume [1]; Zhou Yang et al. used the  $R$

language software to establish a sliding window model and SARIMA model based on time series analysis. The residual of the model was fitted linearly, and then the daily express business volume of express enterprises was predicted [2]; Tang and Deng used GM (1, 1) model to forecast the express business volume [3].

Grey prediction is a systematic prediction method containing uncertainty, which identifies different degrees of development trends among system factors and then establishes corresponding differential equation models according to certain rules to predict the future development trend of things. GM (1, 1) model is the core model of grey prediction theory, which is often used in the prediction of short-term data [4]. After the model was put forward, scholars have studied the GM (1, 1) model from the perspectives of accumulation generation method, initial value optimization, background value optimization, parameter estimation method, model properties, and so on [5–8]. For the poor accuracy of GM (1, 1), Wu Lifeng et al. proposed the fractional-order FGM (1, 1) model [9, 10]. In FGM (1, 1) model, each sequence is multiplied by different fractional-order and then accumulated. At present, FGM (1, 1) model has been applied to predict solid waste treatment capacity,

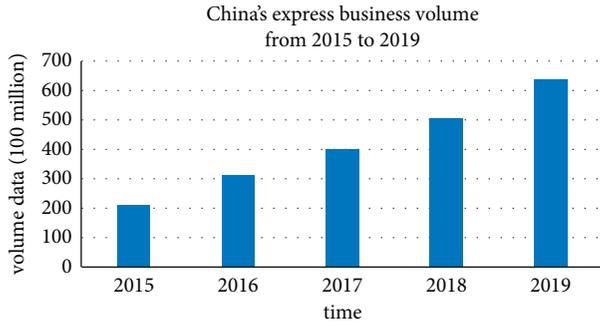


FIGURE 1: The data of China's express business volume from 2015 to 2019.

natural gas consumption, high-tech industrial added value, and so on [11–13].

Particle Swarm Optimization (PSO) algorithm has been proposed in 1995 by Kennedy and Eberhart [14, 15] based on the behavior of birds foraging, which is widely used in various calculations [16–18]. According to the data from China's express business from 2015–2019, this paper uses the improved particle swarm optimization algorithm to solve the fractional-order  $r$  of the FGM (1, 1) model and then predicts the express business volume of China in the coming years through the FGM (1, 1) model.

## 2. Modeling Process of FGM (1, 1) Model and Particle Swarm Optimization Algorithm

**2.1. Modeling Process of FGM (1, 1) Model.** For the deficiency of the traditional GM (1, 1) model, FGM (1, 1) model obtains more accurate results by selecting the appropriate cumulative order and reducing the relative error. The modeling process is as follows:

- (1) The original sequence is given according to the original nonnegative data.

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n-1), x^{(0)}(n)\}. \quad (1)$$

- (2) The  $r$ -order accumulation sequence is as follows:

$$X^{(r)} = \{x^{(r)}(1), x^{(r)}(2), \dots, x^{(r)}(n)\}, \quad (2)$$

where  $x^{(r)} = \sum_{i=1}^k C_{k-i+r-1}^{k-i} x^{(0)}(i)$ ,  $C_{k-i+r-1}^{k-i} = (k-i+r-1)(k-i+r-2) \cdots (r+1)r/(k-i)!$ ,  $C_{r-1}^0 = 1$ ,  $C_k^{k+1} = 0$ .

- (3) The whitening differential equation is as follows:

$$\frac{dx^{(r)}(t)}{dt} + ax^{(r)}(t) = b, \quad (3)$$

where “ $a$ ” is called development grey number, “ $b$ ” is called endogenous control grey number.

The solution of the equation is exponential as follows:

$$x^{(r)}(t+1) = \left[ x^{(0)}(1) - \frac{b}{a} \right] e^{-at} + \frac{b}{a}. \quad (4)$$

Using the least square method, the following results can be obtained:

$$\begin{bmatrix} \hat{a} \\ \hat{b} \end{bmatrix} = (B^T B)^{-1} B^T Y, \quad (5)$$

where

$$B = \begin{bmatrix} -0.5(x^{(r)}(1) + x^{(r)}(2)) & 1 \\ -0.5(x^{(r)}(2) + x^{(r)}(3)) & 1 \\ \vdots & \vdots \\ -0.5(x^{(r)}(n-1) + x^{(r)}(n)) & 1 \end{bmatrix}, \quad (6)$$

$$Y = \begin{bmatrix} x^{(r)}(2) - x^{(r)}(1) \\ x^{(r)}(3) - x^{(r)}(2) \\ \vdots \\ x^{(r)}(n) - x^{(r)}(n-1) \end{bmatrix}.$$

- (4) The time response function is as follows:

$$\hat{x}^{(r)}(k+1) = \left[ x^{(0)}(1) - \frac{\hat{b}}{\hat{a}} \right] e^{-\hat{a}k} + \frac{\hat{b}}{\hat{a}}, \quad (7)$$

where  $\hat{x}^{(r)}(k+1)$  is the value of time  $k+1$ .

- (5) The reduction sequence of  $\hat{X}^{(r)} = \{\hat{x}^{(r)}(1), \hat{x}^{(r)}(2), \dots, \hat{x}^{(r)}(n)\}$  is as follows:

$$\alpha^{(r)} \hat{X}^{(r)} = \{\alpha^{(1)} \hat{x}^{(r)(1-r)}(1), \alpha^{(1)} \hat{x}^{(r)(1-r)}(2), \dots, \alpha^{(1)} \hat{x}^{(r)(1-r)}(n)\}, \quad (8)$$

where  $\alpha^{(1)} \hat{x}^{(r)(1-r)}(k) = \hat{x}^{(r)(1-r)}(k) - \hat{x}^{(r)(1-r)}(k-1)$  so the predicted value is as follows:

$$\hat{X}^{(0)} = \{\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \dots, \hat{x}^{(0)}(n)\}. \quad (9)$$

- (6) Model test (mean absolute percentage error).

$$\text{MAPE} = 100\% \times \frac{1}{n} \sum_{k=1}^n \left| \frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)} \right|. \quad (10)$$

**2.2. Particle Swarm Optimization Algorithm.** The particle swarm optimization algorithm is an iterative-based optimization tool, where particles follow the optimal particle in the solution space to find the optimal solution. In each iteration, particles update themselves by tracking individual extremum ( $P_{\text{Best}}$ ) and global extremum ( $G_{\text{Best}}$ ). In addition, it is also possible to use only a part of the population instead of the whole population as the neighbors of the particle; then, the extremum in all the neighbors is the local extremum [14, 15].

Suppose there are  $N$  particles in a  $D$ -dimensional target search space to form a community, where the  $i$ -particle represents a vector of  $D$  dimensions, it is denoted by  $X_i = (x_{i1}, x_{i2}, \dots, x_{iD})$ . A particle's velocity is also a vector of  $D$  dimensions, it is denoted by  $V_i = (v_{i1}, v_{i2}, \dots, v_{iD})$ . The optimal position of the  $i$ -particle and the entire

particle group searched so far are individual extreme value  $P_{\text{Best}} = (p_{i1}, p_{i2}, \dots, p_{iD})$  and global extreme value  $G_{\text{Best}} = (g_{i1}, g_{i2}, \dots, g_{iD})$ , respectively.

The particles will update their velocity and position according to the following formula:

$$\begin{cases} v_{ij}(t+1) = wv_{ij}(t) + c_1r_1(t)[p_{ij}(t) - x_{ij}(t)] + c_2r_2(t)[g_{ij}(t) - x_{ij}(t)], \\ x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1), \end{cases} \quad (11)$$

where  $c_1$  and  $c_2$  are the learning factors,  $w$  is the inertia factor, and  $r_1(t)$  and  $r_2(t)$  are uniform random numbers in  $[0, 1]$ .  $v_{ij}(t+1)$  consists of three parts: the first part is the inertia or momentum part, which reflects the motion habit of particles and represents the tendency of particles to maintain their previous velocity; the second part is the cognitive part, which reflects the memory or recollection of the particle's own historical experience and represents that the particle tends to approach the best position in its own history; the third part is the social part, which reflects the historical experience of group cooperation and knowledge sharing among particles and represents the trend of particles approaching the best historical position of group or neighborhood.

**2.3. Algorithm Design.** The particle swarm optimization algorithm will be improved according to its characteristics. Let  $c_1 = c_2 = 2$ ,  $N = 50$ , the maximum number of iterations is  $t_{\text{max}} = 100$ , set the stop criterion to  $\text{eps} = 10^{-6}$ , according to the concept of fractional-order,  $r$  is between 0 and 1. To

avoid particles "oscillating" near the global optimal solution, let [19]

$$w = w_{\text{max}} - t \times \frac{w_{\text{max}} - w_{\text{min}}}{t_{\text{max}}}, \quad (12)$$

where  $t$  is the number of present iterations and  $w$  changes linearly between 0.1 and 0.9. The improved PSO algorithm flow chart is shown in Figure 2.

### 3. Empirical Research

In order to predict the express business volume in China, the FGM (1, 1) model is constructed. The original sequence of China's express business volume from 2015 to 2019 is  $X^{(0)} = \{206.6637, 312.8315, 400.5592, 507.1043, 635.2291\}$  (unit: 100 million, data from China Statistical Yearbook). The particle swarm optimization algorithm is iterated by MATLAB, and the results are shown in the Figure 3. It is found that as the number of iterations increases, the fractional-order eventually tends to 0.8536.

The 0.8536 order cumulative sequence is as follows:

$$\begin{aligned} X^{(0.8536)} &= \{x^{(0.8536)}(1), x^{(0.8536)}(2), x^{(0.8536)}(3), x^{(0.8536)}(4), x^{(0.8536)}(5)\} \\ &= \{206.6637, 489.2396, 831.0872, 1252.024, 1770.216\}, \end{aligned} \quad (13)$$

$\hat{a}$  and  $\hat{b}$  are obtained by the formula

$$\begin{bmatrix} \hat{a} \\ \hat{b} \end{bmatrix} = (B^T B)^{-1} B^T Y = \begin{bmatrix} -0.2033 \\ 209.8712 \end{bmatrix}, \quad (14)$$

where

$$B = \begin{bmatrix} -347.9517 & 1 \\ -660.1634 & 1 \\ -1041.556 & 1 \\ -1511.120 & 1 \end{bmatrix}, Y = \begin{bmatrix} 282.5759 \\ 341.8476 \\ 420.9370 \\ 518.1915 \end{bmatrix}. \quad (15)$$

Then the time series function is as follows:

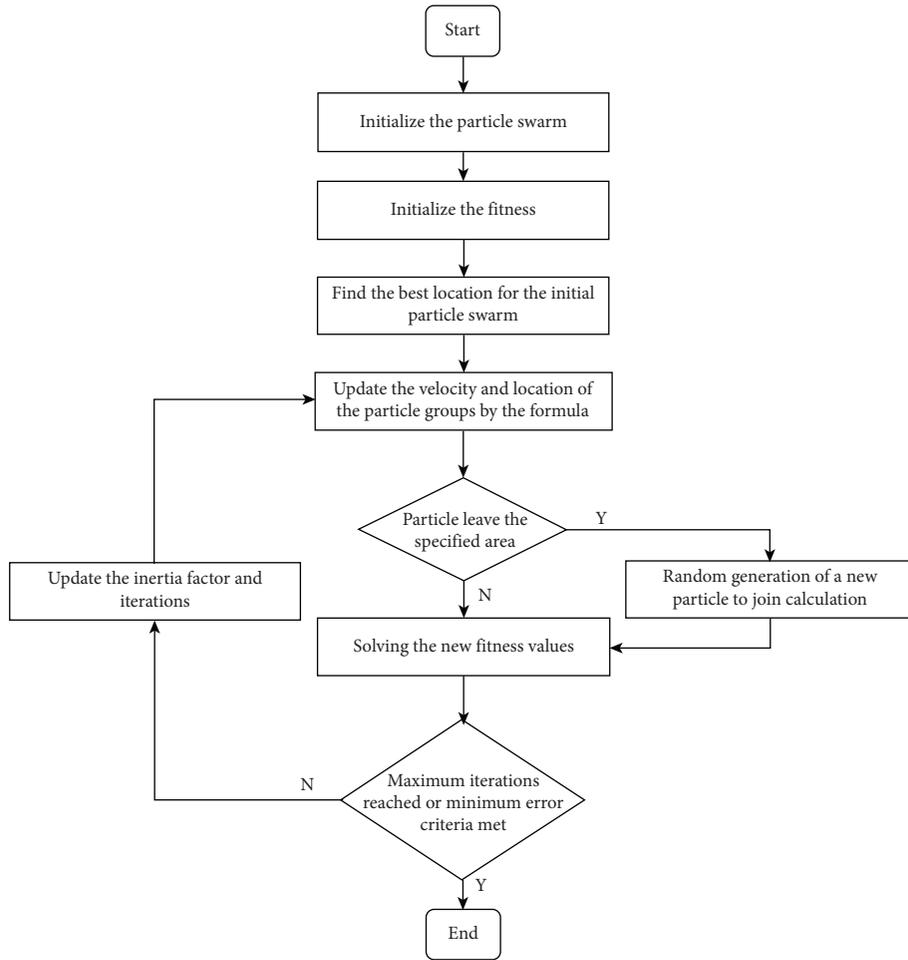


FIGURE 2: PSO flow chart.

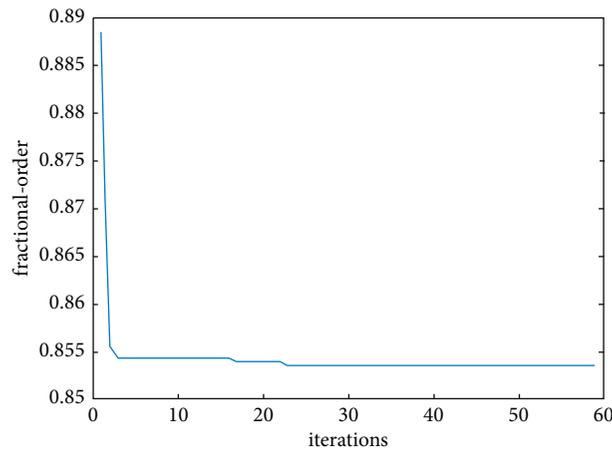


FIGURE 3: Fractional-order convergence process.

TABLE 1: The MAPE of GM (1, 1) model and FGM (1, 1) model (100 million pieces).

Year	Actual value	GM (1, 1)	FGM (1, 1) ( $r = 0.8536$ )
2015	206.6637	206.6637	206.6637
2016	312.8315	314.2032	309.5893
2017	400.5592	396.6401	400.5590
2018	507.1042	500.7057	505.4784
2019	635.2291	632.0748	630.7863
MAPE		0.64%	0.41%

TABLE 2: The prediction values of China’s express business volume from 2020-2023 (100 million pieces).

Year	2020	2021	2022	2023
Prediction value	782.3501	966.7292	1191.693	1466.627
Growth rate (%)	24.03	23.57	23.27	23.07

$$\hat{x}^{(0.8536)}(k + 1) = \left[ 206.6637 - \frac{209.8712}{-0.2033} \right] e^{0.2033k} + \frac{209.8712}{-0.2033}. \quad \text{So} \quad (16)$$

$$\begin{aligned} \hat{X}^{(0.8536)} &= \{ \hat{x}^{(0.8536)}(1), \hat{x}^{(0.8536)}(2), \dots, \hat{x}^{(0.8536)}(9) \} \\ &= \{ 206.6637, 485.9975, 828.3195, 1247.833, 1761.945, 2391.986, 3164.089, 4110.318, 5269.904 \}. \end{aligned} \quad (17)$$

Accordingly, the reduction sequence is as follows:

$$\begin{aligned} \hat{X}^{(1)} &= \{ \hat{x}^{(0.8536)(0.1464)}(1), \hat{x}^{(0.8536)(0.1464)}(2), \dots, \hat{x}^{(0.8536)(0.1464)}(9) \} \\ &= \{ 206.6637, 516.2530, 916.8120, 1422.2904, 2053.0766, 2835.4267, 3802.1560, 4993.8488, 6460.4762 \}. \end{aligned} \quad (18)$$

The predicted values are as follows:

$$\begin{aligned} \hat{X}^{(0)} &= \{ \hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \dots, \hat{x}^{(0)}(9) \} \\ &= \{ 206.6637, 309.5893, 400.5590, 505.4784, 630.7863, 782.3501, 966.7292, 1191.693, 1466.627 \}. \end{aligned} \quad (19)$$

The MAPE values of the GM (1, 1) model and FGM (1, 1) model are given in Table 1. According to Table 1, it can be found that both MAPE values of the FGM (1, 1) model and the GM (1, 1) model are small, which indicates that the simulation results are accurate. Meanwhile, the MAPE value of the FGM (1, 1) model is less than the GM (1, 1) model’s, which verifies the superiority of the FGM (1, 1) model.

The prediction values of China’s express business volume from 2020-2023 based on FGM (1, 1) model are shown in Table 2.

#### 4. Conclusions

Compared with the traditional GM (1, 1) model, the FGM (1, 1) model can reduce the MAPE and better predict the data. In addition, it can be seen that China’s express business

volume is increasing year by year, and it will exceed 100 billion pieces in 2022. At the same time, although the growth rate is declining year by year, it is still maintained at more than 23% shortly, which indicates that there is still a lot of room for development in the express delivery industry. In the future work, other prediction models can be introduced to predict China’s express business volume [20]. At the same time, the continuous growth of China’s express business volume requires the continuous improvement of the logistics system, such as the site location of the logistics center, the optimization of distribution path, and so on.

#### Data Availability

No data were used to support this study.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Acknowledgments

This work was partially supported by China Postdoctoral Science Foundation (No. 2017M611785) and Jiangsu Planned Projects for Postdoctoral Research Funds (No. 1601091C).

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