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Research Article

Research on Freight Development of Guangdong Province Based on Grey Theory Model

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Logistics and economic development complement each other. The comprehensive competitiveness of Guangdong provincial economy ranks first in China. Under the influence of COVID-19, the freight development of Guangdong Province has been affected, but there is still lack of quantitative research. It is significant to explore the trend of economic development through the freight development of Guangdong Province. Based on the grey theory model, this paper uses six freight indexes to research freight development of Guangdong Province. Under the assumption that COVID-19 did not happen, we predicted the development value of freight index of Guangdong Province from January to December in 2020 and studied the influence based on the comparison between the predicted value and actual value. The empirical study shows three impact characteristics: stage characteristics, structural characteristics, and entity transmission characteristics. COVID-19 has a negative impact on the development of total freight volume, highway freight volume, waterway freight volume, and air freight volume in Guangdong Province. The influence values were −23.001%, −29.344%, −11.296%, and −3.838%. But, the freight volumes of railway and pipeline were positively affected by 14.343% and 13.057%, respectively, due to their continuity and substitution to other transportation modes. To further explore the abate measures of COVID-19 impact on Guangdong's freight development, the grey correlation model is introduced to study the correlation factors of freight development of Guangdong Province. Through the research of the related factors, this paper puts forward some measures to promote the freight development of Guangdong Province in the postepidemic era.

1. Introduction

Guangdong Province is the South Gate of China, located in the South China Sea shipping hub position, since the Qin and Han Dynasties have become the starting point of the maritime Silk Road. The comprehensive competitiveness of Guangdong provincial economy ranks first in China. Since 1989, Guangdong's GDP has ranked first in China for 32 consecutive years, becoming the largest economic province in China. In 2020, Guangdong Province's GDP reached 11.08 trillion yuan, accounting for one-eighth of China's economy. The nine cities in the Pearl River Delta of Guangdong Province join hands with Hong Kong and Macao to build the bay area of Guangdong, Hong Kong, and Macao and become one of the four bay areas in the world side by side with New York Bay area, San Francisco Bay area, and Tokyo Bay area. The developments of economy and logistics complement each other. The rapid economic development of Guangdong Province promotes the improvement of logistics development level [1–4], which further supports the economic development of Guangdong Province.

The COVID-19 outbreak as a public health emergency has a negative impact on the economy from multiple channels. It also has a direct impact on the logistics economy. The epidemic situation affects the demand and supply of the logistics market. It affects the development of logistics enterprises through the operation of logistics and indirectly transmits to the field of logistics through the impact on domestic real economy and foreign trade. In the postepidemic period, the relevant supporting policies need a certain industry and time transmission, so COVID-19's impact on the logistics industry is characterized by multiple channels and multiple spatial and temporal superposition. Guangdong Province as an important node of the global supply chain, the total freight volume, road freight volume, railway freight volume, waterway freight volume, air freight volume, and pipeline freight volume has been affected by COVID-19.

In order to study the impact of COVID-19 on freight transportation in Guangdong Province and explore mitigation measures, this paper intends to use the grey prediction model GM (1, 1) to analyze the impact and introduce the grey correlation model to conduct a quantitative study on the correlation degree of the factors affecting the freight development of Guangdong Province. According to the correlation factors of the freight development of Guangdong Province, this paper puts forward some measures to promote the freight development of Guangdong Province in the postepidemic era.

2. Literature Review

2.1. Research Progress on Forecasting Freight Development. In recent years, logistics development prediction has become a hot issue for scholars. The methods commonly used by scholars include exponential smoothing [5–7], linear model [8], BP neural network method [5–9], multiple regression analysis [5, 9], seasonal autoregressive model [10–13], discrete wavelet technology [14], vector autoregressive method [15], and Markov chain theory [16], which are widely used in the prediction of logistics and freight development. In addition to conventional prediction methods, scholars also innovate prediction methods, such as a genetic algorithm and backpropagation (GA-BP) prediction model (optimized backpropagation neural network model using genetic algorithm), which are used to predict freight volume demand with small error [17]. Scholars use L-OD logistics demand forecasting method and construct a new model of double constraint gravity model to forecast logistics distribution, which achieves good forecasting effect. The state travel demand model (STDM) [18] is introduced to forecasting freight development, and a new hybrid multicriteria decision-making model combining Delphi, analytic network process (ANP), and quality function deployment (QFD) in fuzzy environment is applied to freight forecasting [19].

2.2. Application of GM in Forecasting Freight. Grey system theory is an effective method of studying and modeling systems consisting of small sample sizes that contain a limited amount of information and is widely used in many fields. The valuable information is extracted by processing the known information. This is further used to explore the evolution laws of the system and thus establish a prediction model. As there are many factors influencing the freight development of Guangdong Province, e.g., environmental factors of transportation and logistics, regional economic environment, government policy, and science and technology environment, it can be regarded as a grey system. Thus, it can be described using a grey model (GM). The GM (1, 1) is the most generally used grey model. GM (1, 1) used to predict the freight volume achieved satisfactory results [5, 9, 20–24].

To sum up, the grey prediction model is widely used in logistics development and freight volume prediction. Therefore, it is scientific and feasible to use the grey prediction model in the quantitative research of Guangdong freight development:

(1) The innovation of this paper is the prediction of impact value refined to month which is a more precise observation of COVID-19's impact on Guangdong's freight development.
(2) Practical significance: through quantitative and accurate research on the monthly impact value of freight development in Guangdong Province, we can grasp the situation of economic operation in Guangdong Province from the side and promote the formulation and implementation of relevant economic stimulus policies, which has certain management practical significance.

3. Research Methods

3.1. Introduction of GM (1, 1). The differential equation of grey system theory is called GM. G stands for grey, M stands for model, and GM (1, 1) is a one-order and one-variable differential equation model. The modeling process and mechanism of GM (1, 1) are as follows:

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), x(3), \ldots, x^{(0)}(n)\right\}. \quad (1)$$

(1) Record the original data sequence as a nonnegative sequence, where $X^{(0)}$ is a nonnegative sequence, $X^{(0)}(k) \geq 0, k = 1, 2, \ldots, n$.
(2) Generate a cumulative data sequence $X^{(1)}$:

$$X^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \ldots, x^{(1)}(n)\right\}, \quad (2)$$

where $x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i)$, $k = 1, 2, \ldots, n$. $Z^{(1)}$is the adjacent mean generating sequence of $X^{(1)}$:

$$Z^{(1)} = \left\{z^{(1)}(1), z^{(1)}(2), z^{(1)}(3), \ldots, z^{(1)}(n)\right\}, \quad (3)$$

where $Z^{(1)}$ $(k) = 0.5x^{(1)}(k)+$ $0.5x^{(1)}(k-1)$, $k = 1, 2, \ldots, n$.

(3) Establish GM(1,1):

$$x^{(0)}(k) + aZ^{(1)}(k) = b. \quad (4)$$

in which "a" and "b" are parameters, which are development grey number and endogenous control grey number, respectively.

(4) Solve the parameters "a" and "b":
If $a = \left(a \;\; b\right)^T$ is a parameter column and

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(N) \end{bmatrix},$$
$$B = \begin{bmatrix} z^{(1)}(2) & 1 \\ z^{(1)}(3) & 1 \\ \vdots & \vdots \\ z^{(1)}(n) & 1 \end{bmatrix}, \quad (5)$$

then find the least square estimation coefficient sequence of differential equation $x^{(0)}(k)+az^{(1)}(k) = b$, satisfying condition $\hat{a} = (B^T B)^{-1} B^T Y$.

(5) Establish a prediction model.

Establish the whitening equation corresponding to the grey differential equation, as the following formula:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b. \quad (6)$$

As mentioned above, the time response sequence of GM (1, 1) grey differential equation $x^{(0)}(k) + az^{(1)}(k) = b$ is the following formula:

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a}, \quad k = 1, 2, 3, \ldots, n. \quad (7)$$

The predicted values generated by restoration are as follows:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), \quad k = 1, 2, 3, \ldots, n. \quad (8)$$

3.2. Grey Prediction Model (GM (1, 1)) Test

3.2.1. Modeling Rationality Test. Firstly, the modeling rationality of the original sequence $x^{(0)}$ is tested, and the grade ratio$\lambda(k)$ is used to represent

$$\lambda(k) = \frac{x^{(0)}(k+1)}{x^{(0)}(k)}, \quad (9)$$

where $k = 1, 2, 3, \ldots, n$. When all $\lambda(k) \in (e^{-(2/n+1)}, e^{(2/n+1,)})$, the GM (1,1) can be used in the $x^{(0)}$ series for satisfactory prediction modeling.

3.2.2. Grey System Model Prediction Accuracy Test

(1) Residual Error Test. After modeling with GM (1, 1), the predicted value sequence is as follows:

$$\hat{X}^{(0)}(K) = \left\{\hat{x}^{(0)}(1), \hat{x}^{(0)}(1), \ldots, \hat{x}^{(0)}(n)\right\}. \quad (10)$$

By calculating the series $X^{(0)}(K)$ and $\hat{x}^{(0)}(K)$, the following GM (1, 1) modeling rationality residual test index is obtained.

① Absolute residual is

$$\varepsilon(k) = x^{(0)}(k) - \hat{x}^{(0)}(k). \quad (11)$$

② Relative residual is

$$\Delta(k) = \left|\frac{\varepsilon(k)}{x^{(0)}(k)}\right|. \quad (12)$$

③ Average residual is

$$\overline{\Delta(k)} = \frac{1}{n}\sum_{i=1}^{n}\Delta(k). \quad (13)$$

④ Average accuracy is

$$\rho^0 = (1 - \overline{\Delta(k)}) \times 100\%. \quad (14)$$

Residual test standards are as shown in Table 1.

(2) Posterior Variance Test. Suppose $X^{(0)}$is the original sequence, $\hat{X}^{(0)}$is the simulation error sequence, and $\varepsilon^0$is the absolute residual sequence. Test standards are shown in Table 1.

① Mean value of $X^{(0)}$ is

$$\overline{x} = \frac{1}{n}\sum_{k=1}^{n}x^{(0)}(k). \quad (15)$$

② Variance of $X^{(0)}$ is

$$S_1 = \sqrt{\frac{1}{n}\sum_{k=1}^{n}\left(x^{(0)}(k) - \overline{x}\right)^2}. \quad (16)$$

③ Mean of absolute residuals is

$$\overline{\varepsilon} = \frac{1}{n}\sum_{k=1}^{n}\varepsilon(k). \quad (17)$$

④ Absolute residual variance is

$$S_2 = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(\varepsilon(k) - \overline{\varepsilon})^2}. \quad (18)$$

⑤ Ratio of variance is

$$C = \frac{S_2}{S_1}. \quad (19)$$

⑥ Probability of small error is

$$P = p\left(|\varepsilon(k) - \overline{\varepsilon}| < 0.6745S_1\right), \quad (20)$$

$$S_0 = 0.6745S_1. \quad (21)$$

3.3. Grey Correlation Degree. Correlation degree refers to the measurement of the correlation between the factors of the

TABLE 1: Grade reference table of grey system model parameters.

Accuracy class	Relative residuals ($\Delta(k)$)	Mean variance ratio (C)	Probability of small error (P)	Correlation degree (γ_{0i})
Good	0.01	0.35	0.95	0.90
Qualification	0.05	0.45	0.85	0.80
Barely qualified	0.1	0.50	0.70	0.70
Disqualification	0.2	0.65	0.70	0.60

two systems that change with time or different objects. Grey system theory puts forward the concept of grey correlation analysis for each subsystem and intends to seek the numerical relationship between each subsystem in the system through certain methods or measure the influence of each subfactor in the system on the main factor. Grey correlation analysis provides a quantitative measurement for the development and change trend of a system, which is suitable for dynamic process analysis.

The calculation steps of grey correlation degree are as follows:

(1) Establish a raw data matrix X_i for each index:

$$X_i = (x_i(1), x_i(2), \ldots, x_i(k)). \quad (22)$$

Here, $x_i(k)$ represents the original data of i factor in year k.

(2) Calculate initialization transformation of matrix X_i':

$$X_i' = \left(\frac{x_i(1)}{x_i(1)}, \frac{x_i(2)}{x_i(1)}, \ldots, \frac{x_i(k)}{x_i(1)}\right) = (x_i'(1), x_i'(2), \ldots, x_i'(k)). \quad (23)$$

(3) Calculate the difference sequence $\Delta_{0i}(k)$. The difference sequence occurs between the main factor sequence data and the measure factors:

$$\Delta_{0i}(k) = \left|x_0(k) - x_i'k\right|, \quad k = 1, 2, \ldots, n, i = 1, 2, \ldots, m,$$
$$\Delta_{0i}(k) = (\Delta_{0i}(1), \Delta_{0i}(2), \ldots, \Delta_{0i}(k)). \quad (24)$$

(4) The correlation coefficient $\xi_{0i}(k)$ and grey correlation degree γ_{0i} are calculated:

$$\xi_{0i}(k) = \frac{\min_i \min_k \Delta_{0i}(k) + \phi \max_i \max_k \Delta_{0i}(k)}{\Delta_{0i}(k) + \phi \max_i \max_k \Delta_{0i}(k)}, \quad (25)$$

where$\varphi$is the resolution coefficient, which improves the significance of the difference between the correlation coefficients, $\varphi \in (0, 1)$, and the general value is 0.5. The grey correlation degree is shown as follows:

$$\gamma_{0i} = \frac{1}{n} \sum_{k=1}^{n} \xi_{0i}(k). \quad (26)$$

In summary, the relevant parameters of the grey system model level index [20] reference table are shown in Table 1.

4. Construction of GM (1, 1)

4.1. Data Source and Description. The data are from the monthly open statistics of Guangdong Provincial Bureau of Statistics from 2013 to 2020. The data content includes six groups of data: total freight volume, truck freight volume, railway freight volume, waterway freight volume, air freight volume, and pipeline freight volume of Guangdong Province. For the convenience of calculation, total freight volume, railway freight volume, truck freight volume, water freight volume, air cargo volume, and pipeline freight volume are expressed. The annual freight development of Guangdong Province is counted, covering the six freight indexes. The original data to predict the development of freight of Guangdong Province in 2020 are shown in Table 2.

4.2. Rationality of GM (1, 1) Construction. The rationality of model construction was tested in advance. On the basis of the original data sequence, the stage ratio $\lambda(k)$ is calculated according to formula (10).

4.2.1. Calculation of the Grade Ratio $\lambda(k)$. The grade ratio is calculated as follows:

$$\begin{aligned}
\lambda(k)F &= (0.8486, 0.9526, 1.0130, 0.9395, 0.9341, 0.9565),\\
\lambda(k)R &= (1.0918, 1.0776, 0.9792, 1.4029, 0.9753, 0.9478),\\
\lambda(k)T &= (0.8256, 0.9319, 1.0372, 0.9450, 0.9423, 0.9595),\\
\lambda(k)W &= (0.8813, 1.0004, 0.9421, 0.8827, 0.9175, 0.9445),\\
\lambda(k)A &= (0.9167, 0.9730, 0.9250, 0.9697, 0.7466, 0.9325),\\
\lambda(k)P &= (0.9420, 1.0599, 0.9699, 0.9663, 0.8258, 1.0042).
\end{aligned} \quad (27)$$

4.2.2. Judgment of the Grade Ratio. $\lambda(k) \in (e^{-(2/n+1)}, e^{(2/n+1)})$, when $n=7$,$\lambda(k) \in (0.7788, 1.2840)$. If λ(k) in the above range, $x^{(0)}(k)$ is suitable for GM (1,1). $\lambda(k)F \in (0.8486, 1.0130)$, $\lambda(k)T \in (0.8256, 1.0372)$, $\lambda(k) \ W \in (0.8813, 1.0004)$, and $\lambda(k) \ P \in (0.8258, 1.0559)$, where $k = 2, 3, 4, 5, 6, 7$, and the grade ratios are in $(0.7788, 1.2840)$; hence,$X_F^0 X_T^0$,X_W^0, and X_P^0 can be modeled by GM (1,1). The values of grey development coefficient "-a" are 0.0429, 0.0364, 0.0752, and 0.0539, respectively, i.e., less than 0.3, which are suitable for medium- and long-term prediction.

However,
$\lambda(k)R \in (0.9478, 1.4029)$ and $\lambda(k)A \in (0.7446, 1.0442)$.
There is a grade ratio not in the region, which is not available

Table 2: Monthly data of freight indicators of Guangdong Province from 2013 to 2020 (unit: million tons) (%).

Year	Total freight volume (F)	Railway freight volume (R)		Truck freight volume (T)		Water freight volume (W)		Air cargo volume (A)		Pipeline freight volume (P)	
		Amount	Ratio	Amount	Ratio	Amount	Ratio	Amount	Ratio	Amount	Ratio
2013	3065.44	122.38	3.992	2176.43	70.999	688.51	22.460	1.32	0.043	76.81	2.506
2014	3612.49	112.09	3.103	2636.19	72.974	781.25	21.626	1.44	0.040	81.54	2.257
2015	3792.21	104.02	2.743	2828.87	74.597	780.93	20.593	1.48	0.039	76.93	2.029
2016	3743.48	106.23	2.838	2727.37	72.857	828.93	22.143	1.60	0.043	79.32	2.119
2017	3984.69	75.72	1.900	2886.19	72.432	939.04	23.566	1.65	0.041	82.09	2.060
2018	4265.78	77.64	1.820	3063.04	71.805	1023.51	23.994	2.21	0.052	99.41	2.330
2019	4459.75	81.92	1.837	3192.31	71.580	1083.71	24.300	2.37	0.053	98.99	2.220
2020	3547.51	77.67	2.189	2313.56	65.216	1036.57	29.220	2.38	0.067	117.35	3.308

Data source: according to the website data of Guangdong Provincial Bureau of Statistics.

for $X_R^{(0)}$and $X_A^{(0)}$modeled in GM (1, 1) directly. Therefore, it is necessary to do translation transformation on the data, and the translated data are $X_R^{(0)'}$ and $X_A^{(0)'}$, as follows:

$$X_R^{(0)'} = (202.38, 192.09, 184.02, 186.23, 155.72, 157.64, 161.92),$$
$$X_A^{(0)'} = (2.12, 2.24, 2.28, 2.40, 2.45, 3.01, 3.17). \tag{28}$$

The grade ratios of $X_R^{(0)'}$and $X_A^{(0)'}$are calculated:

$$\lambda'(k)R = (1.0536, 1.0439, 0.9881, 1.1959, 0.9878, 0.9736),$$
$$\lambda'^{(k)}R \in (0.9736, 1.1959), \quad K = 2, 3, 4, 5, 6, 7,$$
$$\lambda'(k)A = (0.9464, 0.9825, 0.9500, 0.9796, 0.8140, 0.9495),$$
$$\lambda'(k)A \in (0.8140, 0.9825), \quad K = 2, 3, 4, 5, 6, 7. \tag{29}$$

The grade ratios of $X_R^{0}$and X_A^{0} are in the rank of $\lambda(k)$ and $\in$ (0.7788, 1.2840). The values of grey development coefficient "$-a$" are −0.0435 and −0.0784, which are less than 0.3. So $X_R^{0}$and X_A^{0} are suitable for medium- and long-term prediction.

4.3. Construction of GM (1, 1). According to the original sequence, the accumulated sequence is generated and the differential equation is constructed. On the basis of solving the values of "a" and "b," the time response sequence is obtained, as formulas (30)–(35). The predicted values are calculated according to the time response sequence, shown in Tables 3 and 4.

$$\widehat{X}^{(1)}(k+1)_F = \left(X^{(0)}(1)_F - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} = 81237.44e^{0.0429k} - 78172.00, \tag{30}$$

$$\widehat{X}^{(1)}(k+1)_R = \left(X^{(0)\prime}(1)_R - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} = 4713.89 - 4511.51e^{-0.0435k}, \tag{31}$$

$$\widehat{X}^{(1)}(k+1)_T = \left(X^{(0)}(1)_T - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} = 71059.66e^{0.03637k} - 6888311.00, \tag{32}$$

$$\widehat{X}^{(1)}(k+1)_W = \left(X^{(0)}(1)_W - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} = 9522.20e^{0.0752k} - 8833.69, \tag{33}$$

$$\widehat{X}^{(1)}(k+1)_A = \left(X^{(0)\prime}(1)_A - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} = 25.8654e^{0.0784k} - 23.7454, \tag{34}$$

$$\widehat{X}^{(1)}(k+1)_P = \left(X^{(0)}(1)_P - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} = 1357.82e^{0.0539k} - 1281.01. \tag{35}$$

4.4. Validation of Modeling Accuracy of GM (1, 1) of Freight Volume in Guangdong Province. According to the modeling results of GM (1, 1), we will test the accuracy of the model by the residual test and posterior test.

Table 3: Actual value and forecast value of the freight development index in Guangdong Province (unit: million tons).

Year	Total freight volume (F)		Railway freight volume (R)		Truck freight volume (T)	
	X_F^0	$\widehat{X}_F$	X_R^0	$\widehat{X}_R$	X_T^0	$\widehat{X}_T$
2013	3065.44	3065.44	202.38	202.38	2176.43	2176.55
2014	3612.49	3561.51	192.09	192.04	2636.19	2632.37
2015	3792.21	3717.65	184.02	183.87	2828.87	2729.88
2016	3743.48	3880.63	186.23	176.04	2727.37	2831.01
2017	3984.69	4050.76	155.72	168.55	2886.19	2935.88
2018	4265.78	4228.35	157.64	161.37	3063.04	3044.64
2019	4459.75	4413.72	161.92	154.50	3192.31	3157.43

Source: according to the calculation criteria.

4.4.1. Residual Test. The residual test is carried out to test the accuracy of GM (1, 1) in forecasting the freight volume of Guangdong Province. The predicted value of total freight volume, railway freight volume, truck freight volume, water freight volume, air cargo volume, and pipeline freight volume is compared with the original data. $\varepsilon(k)_F$, $\varepsilon(k)_R$, $\varepsilon(k)_T$, $\varepsilon(k)_W$, $\varepsilon(k)_A$, and $\varepsilon(k)_P$ and $\Delta(k)_F$, $\Delta(k)_R$, $\Delta(k)_T$, $\Delta(k)_W$, $\Delta(k)_A$, and $\Delta(k)_P$are calculated according to formulas (11)–(14), and the results are shown in Tables 5 and 6.

$$\begin{aligned}
&\Delta(k)_F \leq 0.05,\\
&\overline{\Delta(k)_F} = 0.0152 < 0.05,\\
&\quad \rho_F^0 = \left(1 - \overline{\Delta(k)_F}\right) * 100\% = 98.48\% > 90\%,\\
&\Delta(k)_R \leq 0.05,\\
&\overline{\Delta(k)_R} = 0.0297 < 0.05,\\
&\quad \rho_R^0 = \left(1 - \overline{\Delta(k)_R}\right) * 100\% = 97.03\% > 90\%,\\
&\Delta(k)_T \leq 0.05,\\
&\overline{\Delta(k)_T} = 0.0155 < 0.05,\\
&\quad \rho_T^0 = \left(1 - \overline{\Delta(k)_T}\right) * 100\% = 98.45\% > 90\%,\\
&\Delta(k)_W \leq 0.05,\\
&\overline{\Delta(k)_W} = 0.02548 < 0.05,\\
&\quad \rho_W^0 = \left(1 - \overline{\Delta(k)_W}\right) * 100\% = 97.96\% > 90\%,\\
&\Delta(k)_A \leq 0.05,\\
&\overline{\Delta(k)_A} = 0.0359 < 0.05,\\
&\quad \rho_A^0 = \left(1 - \overline{\Delta(k)_A}\right) * 100\% = 96.41\% > 90\%,\\
&\Delta(k)_P \leq 0.05,\\
&\overline{\Delta(k)_P} = 0.0441 < 0.05,\\
&\quad \rho_P^0 = \left(1 - \overline{\Delta(k)_C}\right) * 100\% = 95.59\% > 90\%.
\end{aligned} \tag{36}$$

To sum up, GM (1, 1) has a good accuracy in modeling and forecasting the freight development index of Guangdong Province and can pass the residual test.

4.4.2. Posterior Error Test. In order to further test the accuracy of GM (1,1) in forecasting the development of freight volume in Guangdong Province, a posteriori test is carried out. According to formulas (15)–(18), the original sequence's variance of X_F^0, X_R^0, X_T^0, X_W^0, X_A^0, and X_P^0 is calculated, and the results are as follows:

$$\begin{aligned}
S_{1F} &= 456.316,\\
S_{1R} &= 18.535,\\
S_{1T} &= 329.434,\\
S_{1W} &= 143.907,\\
S_{1A} &= 0.365,\\
S_{1P} &= 9.902.
\end{aligned} \tag{37}$$

Table 4: Actual value and forecast value of the freight development index in Guangdong Province (unit: million tons).

Year	Water freight volume (W)		Air cargo volume (A)		Pipeline freight volume (P)	
	X_W^0	$\widehat{X}_W$	X_A^0	$\widehat{X}_A$	X_P^0	$\widehat{X}_P$
2013	688.51	688.51	2.12	2.12	76.81	76.81
2014	781.25	744.06	2.24	2.11	81.54	75.14
2015	780.93	802.20	2.28	2.28	76.93	79.29
2016	828.93	864.88	2.40	2.47	79.32	83.68
2017	939.04	932.46	2.45	2.67	82.09	88.31
2018	1023.51	1005.32	3.01	2.89	99.41	93.20
2019	1083.71	1083.88	3.017	3.12	98.99	98.35

Source: according to the calculation criteria.

Table 5: Residual test results of GM (1,1) of freight volume in Guangdong Province.

Year	Total freight volume (F)		Railway freight volume (R)		Truck freight volume (T)	
	$\varepsilon(k)_F$	$\Delta(k)_F$	$\varepsilon(k)_R$	$\Delta(k)_R$	$\varepsilon(k)_T$	$\Delta(k)_T$
2013	0.000	0.000	0.000	0.000	0.120	0.000
2014	−50.980	0.014	−0.050	0.000	−3.820	0.001
2015	−74.560	0.020	−0.150	0.001	−98.990	0.035
2016	137.150	0.037	−10.190	0.055	103.640	0.038
2017	66.070	0.017	12.830	0.082	49.690	0.017
2018	−37.430	0.009	3.730	0.024	−18.400	0.006
2019	−46.030	0.010	−7.420	0.046	−34.880	0.011

Source: according to the calculation criteria.

Table 6: Residual test results of GM (1,1) of freight volume in Guangdong Province.

Year	Water freight volume (W)		Air cargo volume (A)		Pipeline freight volume (P)	
	$\varepsilon(k)_W$	$\Delta(k)_W$	$\varepsilon(k)_A$	$\Delta(k)_A$	$\varepsilon(k)_P$	$\Delta(k)_P$
2013	0.000	0.000	0.000	0.000	0.000	0.000
2014	−37.190	0.048	−0.130	0.058	−0.078	0.078
2015	21.270	0.027	0.000	0.000	0.031	0.031
2016	35.950	0.043	0.070	0.029	0.055	0.055
2017	−6.580	0.007	0.220	0.090	0.076	0.076
2018	−18.190	0.018	−0.120	0.040	−0.062	0.062
2019	0.170	0.000	0.103	0.034	−0.006	0.006

Source: according to the calculation criteria.

The absolute residual sequence's variance of $\varepsilon(k)_F$, $\varepsilon(k)_R$, $\varepsilon(k)_T$, $\varepsilon(k)_W$, $\varepsilon(k)_A$, and $\varepsilon(k)_p$ is calculated, and the results are as follows:

$$\begin{aligned} S_{2F} &= 76.211, \\ S_{2R} &= 7.497, \\ S_{2T} &= 64.003, \\ S_{2W} &= 24.194, \\ S_{2A} &= 0.124, \\ S_{2P} &= 4.885. \end{aligned} \tag{38}$$

According to formula (19), calculate the ratio of variance of the freight index. The results are as follows:

$$\begin{aligned} C_F &= 0.167, \\ C_R &= 0.404, \\ C_T &= 0.194, \\ C_W &= 0.168, \\ C_A &= 0.365, \\ C_P &= 0.493. \end{aligned} \tag{39}$$

C_P is less than 0.5, so the posterior error test is barely qualified. C_R and C_A are greater than 0.35 and less than 0.45, respectively, and the posterior error test result is qualified. C_F, C_T, and $C_W$are less than 0.35, and hence, the posterior error test result is good.

Calculate the probability of small error according to formulas (20) and (21). The results are as follows:

$$\begin{aligned} S_{0F} &= 307.785, \\ S_{0R} &= 12.502, \\ S_{0T} &= 222.203, \\ S_{0W} &= 97.065, \\ S_{0A} &= 0.246, \\ S_{0P} &= 6.679, \\ \left|\varepsilon(k)_F - \bar{\varepsilon}_F\right| &= (0.826, 50.154, 73.734, 137.976, 66.896, 36.604, 45.204), \quad P = 1 > 0.95, \\ \left|\varepsilon(k)_R - \bar{\varepsilon}_R\right| &= (0.179, 0.129, 0.029, 10.011, 13.009, 3.909, 7.241), \quad P = 85.7 > 0.8, \\ \left|\varepsilon(k)_T - \bar{\varepsilon}_T\right| &= (0.497, 3.443, 98.613, 104.017, 50.067, 18.023, 34.503), \quad P = 1 > 0.95, \\ \left|\varepsilon(k)_W - \bar{\varepsilon}_W\right| &= (0.653, 36.537, 21.923, 36.603, 5.927, 17.537, 0.823), \quad P = 1 > 0.95 \\ \left|\varepsilon(k)_A - \bar{\varepsilon}_A\right| &= (0.020, 0.150, 0.020, 0.050, 0.200, 0.140, 0.083), \quad P = 1 > 0.95, \\ \left|\varepsilon(k)_P - \bar{\varepsilon}_P\right| &= (0.044, 6.356, 2.404, 4.404, 6.264, 6.166, 0.596), \quad P = 1 > 0.95. \end{aligned} \tag{40}$$

To sum up, the six indicators of freight development in Guangdong Province, total freight volume, railway freight volume, truck freight volume, water freight volume, air cargo volume, and pipeline freight volume, all meet the requirements of posterior error test standard $C < 0.5$, $0.8 < P$, which indicate that the accuracy of the model is qualified.

5. Impact of COVID-19 on Freight Development of Guangdong Province

The results of the rationality test of model construction, residual test, and posteriori test proved that GM (1, 1) is feasible to forecast the freight development of Guangdong Province in 2020. Due to the particularity of railway transportation and air transportation, after eliminating the influence of C value, the prediction results are shown in Table 7.

In order to reflect COVID-19's monthly impact on Guangdong Province's freight development, further explore the monthly forecast value of freight volume in Guangdong Province of 2020:

(1) Calculate the ratio of each month in different years to the freight volume of that year.

Record the freight development data of Guangdong Province from 2013 to 2019 as matrix of $A_{F7\times 12}$,

Table 7: Forecast freight volume value of Guangdong Province in 2020 (unit: million ton).

Year	Total freight volume	Railway freight volume	Truck, freight volume	Water freight volume	Air cargo volume	Pipeline freight volume
2020	4607.222	67.927	3274.392	1168.572	2.475	103.797

Source: according to the calculation criteria.

$A_{R7\times12}$, $A_{T7\times12}$, $A_{W7\times12}$, $A_{A7\times12}$, and$A_{P7\times12}$, and calculate the ratio of monthly freight volume (a_{kj}) to the total freight volume of the year ($x^{(0)}(k)$) and record it as R_{kj}, where R is ratio, k is year, and j is month:

$$R_{kj} = \frac{a_{kj}}{x^{(0)}(k)}, \quad k = 1,2,3,\ldots,7, j = 1,2,3,\ldots,12. \tag{41}$$

(2) Calculate the average freight ratio of the same month in different years:

$$\overline{R_j} = \frac{1}{7}\sum_{k=1}^{7} r_{kj}, \quad k = 1,2,3,\ldots,7, j = 1,2,3,\ldots,12. \tag{42}$$

According to formulas (35)–(41), we can calculate$\overline{R_{jF}}$, $\overline{R_{jR}}$, $\overline{R_{jT}}$, $\overline{R_{jW}}$, $\overline{R_{jA}}$, and $\overline{R_{jP}}$ from January to December, as shown in Table 8.

(3) Calculate monthly forecast value as follows:

$$\widehat{a}_{kj} = \overline{R_j}\widehat{x}^{(0)}k \quad k = 1,2,3,\ldots,9, j = 1,2,3,\ldots,12. \tag{43}$$

(4) Calculate the influence value I as follows:

$$I_{kj} = \frac{\left(a_{kj} - \widehat{a}_{ij}\right)}{\widehat{a}_{ij}} \times 100\%, \tag{44}$$

$$I_k = \frac{\left(x^{(0)}(k) - \widehat{x}^{(0)}k\right)}{\widehat{x}^{(0)}k} \times 100\%. \tag{45}$$

According to formulas (41)–(45), the monthly forecast value and impact of freight development in Guangdong Province from January to December 2020 are calculated, as shown in Tables 9 and 10 and Figure 1.

According to Tables 9 and 10 and Figure 1, reflecting the influence of COVID-19, there are three characteristics of freight transport development of Guangdong Province in 2020, which are stage characteristics, structural characteristics, and entity conduction.

5.1. Stage Characteristics. The first stage is the direct impact stage. Freight transport in Guangdong Province is stagnant during January and February. Affected by the epidemic situation, most logistics enterprises shut down except emergency logistics, and some logistics transportation channels were interrupted. The risk mainly comes from the disconnection of logistics supply and demand and the interruption of logistics channel. COVID-19 had the greatest impact on freight development in Guangdong at that time. The negative impact value of freight volume of various forms of transportation reached the peak in February. The impact value of total freight volume is −53.726%, that of truck freight volume is −65.155%, that of water freight volume is −31.232%, that of air cargo volume is −32.011%, and that of pipeline freight volume is −19.533%. However, the impact of railway is positive, and the stagnation of other transportation promotes the actual value of railway freight volume to be higher than the predicted value, and the impact value is 15.829%.

The second stage is the stage of entity conduction. The impact value of each subindex of Guangdong freight volume from March to May is reduced. This stage mainly focuses on the period from March to May 2020. The main impact of this stage is the uneven structure of the type and quantity of freight demand business in Guangdong Province and the short-term mismatch between supply and demand. The development of Guangdong's port freight industry has changed from explosive logistics demand in the early stage of the full resumption of manufacturing and circulation industries to the gradual emergence of real economic difficulties and the decline of logistics demand with the spread of the global epidemic.

The third stage is the policy digestion stage. This stage is mainly after May 2020; the state has issued relevant policies to support the recovery and development of the real economy and logistics industry, such as providing freeway and other measures to promote further recovery of freight. The role of policy has a certain lag and conductivity. The development of freight transportation in Guangdong Province is affected by the favorable policies and the recovery of logistics demand of the upstream manufacturing industry, which can be shown in turn in the postepidemic period. COVID-19's impact on freight development in Guangdong showed a gradual reduction. The risk points in this period mainly focus on the recovery of logistics industry, the scale of logistics investment, and the choice of new development mode.

5.2. Structural Characteristics. The impact of the epidemic on the development of freight transportation in Guangdong Province has structural characteristics. In the same period, the impact of the epidemic on the internal subbusiness sectors of freight transportation in Guangdong Province is different. The overall impact value of the epidemic on freight transportation was −23.001%, and the most affected mode was truck transportation (−29.344%), followed by waterway transportation (−11.296%) and air transportation

Table 8: Average ratio of monthly freight (unit: %).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$\overline{R_{jF}}$	7.378	6.364	7.560	8.032	8.251	8.357	8.529	8.571	8.794	9.095	9.304	9.766
$\overline{R_{jR}}$	8.379	6.965	8.429	8.073	8.596	8.089	8.367	8.299	8.358	8.510	8.709	9.225
$\overline{R_{jT}}$	7.117	6.221	7.484	7.989	8.229	8.341	8.594	8.634	8.837	9.220	9.369	9.965
$\overline{R_{jW}}$	7.986	6.598	7.576	8.109	8.282	8.458	8.389	8.375	8.722	8.862	9.271	9.372
$\overline{R_{jA}}$	7.715	6.537	7.762	8.051	8.340	8.311	8.470	8.470	8.678	8.922	9.163	9.582
$\overline{R_{jP}}$	8.055	7.280	8.157	8.236	8.262	8.312	8.359	8.765	8.609	8.567	8.677	8.720

Source: according to the calculation criteria.

Table 9: COVID-19's impact of freight development in Guangdong Province (unit, million ton; %).

Month	Total freight volume			Railway freight volume			Truck freight volume		
	Actual value	Predictive value	Impact degree	Actual value	Predictive value	Impact degree	Actual value	Predictive value	Impact degree
Jan	250.750	339.903	−26.229	5.540	5.692	−2.668	158.130	233.029	−32.142
Feb	135.680	293.208	−53.726	5.480	4.731	15.829	70.980	203.705	−65.155
Mar	223.620	348.316	−35.800	6.270	5.725	9.511	132.740	245.071	−45.836
Apr	267.320	370.044	−27.760	5.980	5.484	9.048	170.170	261.582	−34.946
May	298.390	380.134	−21.504	6.910	5.839	18.336	191.570	269.464	−28.907
Jun	308.350	385.032	−19.916	6.780	5.495	23.387	204.060	273.113	−25.284
Jul	314.180	392.930	−20.042	7.260	5.683	27.744	211.690	281.402	−24.773
Aug	329.530	394.878	−16.549	6.650	5.637	17.964	215.540	282.716	−23.761
Sep	332.890	405.139	−17.833	6.960	5.678	22.586	220.050	289.356	−23.952
Oct	349.210	419.023	−16.661	6.360	5.780	10.029	237.200	301.893	−21.429
Nov	364.490	428.661	−14.970	6.990	5.916	18.163	245.020	306.762	−20.127
Dec	373.100	449.955	−17.081	6.490	6.266	3.568	256.410	326.298	−21.418
Total impact	4607.222	3547.510	−23.001	77.67	67.927	14.343	2313.560	3274.392	−29.344

Source: according to the calculation criteria.

Table 10: COVID-19's impact of freight development in Guangdong Province (unit: million ton; %).

Month	Water freight volume			Air cargo volume			Pipeline freight volume		
	Actual value	Predictive value	Impact degree	Actual value	Predictive value	Impact degree	Actual value	Predictive value	Impact degree
Jan	78.540	93.318	−15.836	0.190	0.191	−0.493	8.340	8.361	−0.248
Feb	53.020	77.100	−31.232	0.110	0.162	−32.011	6.080	7.556	−19.533
Mar	76.200	88.529	−13.926	0.180	0.192	−6.308	8.230	8.467	−2.798
Apr	82.360	94.757	−13.083	0.180	0.199	−9.662	8.640	8.549	1.065
May	91.330	96.785	−5.636	0.200	0.206	−3.105	8.390	8.575	−2.161
Jun	87.890	98.840	−11.079	0.210	0.206	2.087	9.410	8.628	9.068
Jul	86.630	98.033	−11.632	0.200	0.210	−4.591	8.410	8.677	−3.075
Aug	95.000	97.869	−2.932	0.200	0.210	−4.593	12.140	9.098	33.432
Sep	94.440	101.925	−7.344	0.240	0.215	11.745	11.200	8.936	25.332
Oct	93.680	103.560	−9.540	0.220	0.221	−0.367	11.750	8.893	32.131
Nov	99.080	108.343	−8.550	0.220	0.227	−2.994	13.180	9.007	46.332
Dec	98.400	109.513	−10.148	0.230	0.237	−3.017	11.580	9.051	27.948
Total impact	1036.570	1168.572	−11.296	2.380	2.475	−3.838	117.350	103.797	13.057

Source: according to the calculation criteria.

(−3.838%). At the beginning of the outbreak, the railway operation remained sustainable. Due to the suspension of road transport enterprises, a large number of goods were transferred to railway transportation. Pipeline transportation can be carried out without people. The epidemic has little impact on its production and operation. Therefore, the impact of COVID-19 on the railway transportation and pipeline transportation is positive. The influence values were 14.343 and 13.057, respectively. In summary, the development structure of freight transport in Guangdong has been characterized by structural development under the influence of COVID-19.

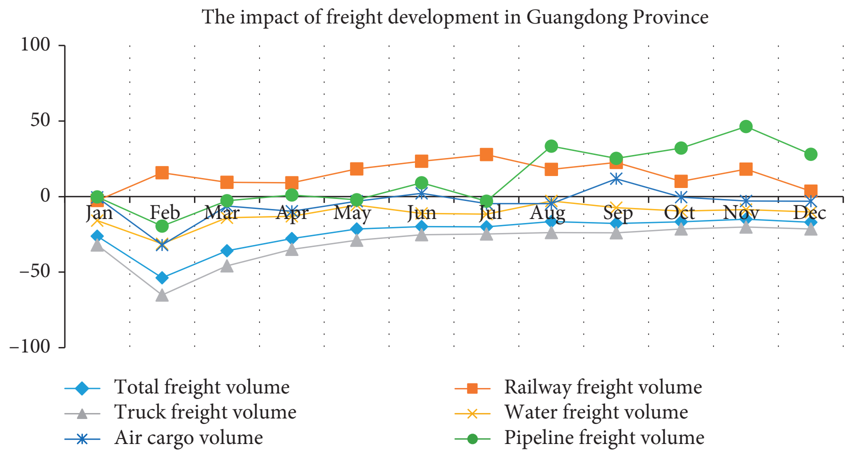

FIGURE 1: The impact of freight development in Guangdong Province.

5.3. Characteristics of Solid Conduction. Freight industry is a derivative industry. The demand of freight industry is mainly affected by the secondary industry and commodity circulation industry and is mainly affected by manufacturing industry, import and export trade, domestic trade, and manufacturing industry. As an auxiliary industry of the national economy, freight industry is an important support for the development of industrial economy. The crisis of the freight industry will be transmitted in reverse, resulting in damage to the real economy. During the epidemic period, due to traffic control, road restrictions, blocked logistics channels, staff unable to rework and resume production on time, and unsatisfied conditions for resumption of production, some freight enterprises were unable to provide normal freight service, which affected the resumption of some industrial enterprises and could not guarantee the logistics of raw materials and finished products.

6. Research on the Related Factors of Freight Development in Guangdong Province

The grey prediction model GM (1, 1) can scientifically measure the impact of COVID-19 on the development of freight transport in Guangdong. From the perspective of system theory, the development of freight transportation in Guangdong Province is the output of logistics system and the product of adapting to the economic environment and regional development of Guangdong Province. Therefore, in order to explore the countermeasures of the development of freight transportation in Guangdong Province in the post-epidemic period, we should also analyze the environmental factors. To sum up, this paper will use the grey correlation model to study the related factors of freight development in Guangdong Province.

6.1. Construction of the Index System. Scholars in the study of freight development factors divide them mainly into the regional economic factors, logistics environmental factors, and industrial factors for quantitative index selection; this paper, considering the scientificity, rationality, comprehensiveness, and comparability of the index construction, divides the related factors of the freight development of Guangdong Province into economic factors, transportation factors, science and technology factors, and policy factors, as shown in Table 11.

6.2. Calculation of Grey Correlation Degree of Influencing Factors. Based on the freight development of Guangdong Province from 2011 to 2019, total freight volume, railway freight volume, truck freight volume, water freight volume, air cargo volume, and pipeline freight volume are the main factor sequence data of the system. The historical data of $X_{11} - X_{46}$ index factors are regarded as subfactor series data, and the grey correlation resolution coefficient is 0.5 based on experience. The data involved are from the public data of the Guangdong Statistical Yearbook in 2013–2019. The grey correlation degree of influencing factors of freight development in Guangdong Province is calculated as given in formulas (24)–(26) and $\text{AVG}\gamma_{0i} = \text{avg}(\gamma_{0iF} + \gamma_{0iR} + \gamma_{0iT} + \gamma_{0iW} + \gamma_{0iA} + \gamma_{0iP})$, and the calculation results are shown in Tables 12–14.

The closer the value to 1, the higher the correlation between the self-factor sequence data and the main factor sequence data. According to the calculation results of correlation degree of Tables 12–14, $\text{AVG}\,R_{042} > \text{AVG}\,R_{044} > \text{AVG}\,R_{014} > \text{AVG}\,R_{041} = \text{AVG}\,R_{046} > \text{AVG}\,R_{023} > \text{AVG}\,R_{011} > \text{AVG}\,R_{045} > \text{AVG}\,R_{015} > \text{AVG}\,R_{024} > \text{AVG}\,R_{021} > \text{AVG}\,R_{031} > \text{AVG}\,R_{043} > \text{AVG}\,R_{043} > \text{AVG}\,R_{016} > \text{AVG}\,R_{017} > \text{AVG}\,R_{012} = \text{AVG}\,R_{022} > \text{AVG}\,R_{032} > \text{AVG}\,R_{013} > \text{AVG}\,R_{025}$; there are 15 factors with $\text{AVG}\,R_{0i}$; there are 15 factors with $\text{AVG}\,R_{0i}$ greater than or equal to 0.8, indicating that the vast majority of factors are highly related to the development of freight transportation in Guangdong Province, including operating mileage of railway, tonnage of trucks, disposable income, deposit balance of financial institutions, number of employees in transportation, warehousing and postal industry, transport aircraft, R&D personnel, GDP, mileage of oil pipeline, total retail sales of consumer goods, financial expenditure on education, Internet broadband access users, general budget revenue, tonnage of cargo ships, and total

Table 11: Index system of influencing factors of freight development in Guangdong Province.

First level indicators	Second level indicators	Variable	Characteristic
Regional economy factors	Gross domestic product	X_{11}	Positive correlation
	Proportion of added value of secondary industry	X_{12}	Positive correlation
	Total investment in fixed assets	X_{13}	Positive correlation
	Per capita disposable personal income	X_{14}	Positive correlation
	Total retail sales of social consumption	X_{15}	Positive correlation
	Total imports and exports	X_{16}	Positive correlation
	Balance of domestic and foreign currency deposits of financial institutions	X_{17}	Positive correlation
Science and technology factors	Number of Internet broadband access users	X_{21}	Positive correlation
	Internal expenditure of R&D funds	X_{22}	Positive correlation
	Number of employees of R&D	X_{23}	Positive correlation
	Education expenditure	X_{24}	Positive correlation
	Expenditure on science and technology	X_{25}	Positive correlation
Government policy factors	Revenue	X_{31}	Positive correlation
	Transportation expenditure	X_{32}	Positive correlation
Transportation environment factors	Number of employees in transportation, storage, and post industry	X_{41}	Positive correlation
	Length of railroad lines in service	X_{42}	Positive correlation
	Net tonnage of carrying vessel	X_{43}	Positive correlation
	Tonnage of truck	X_{44}	Positive correlation
	Oil pipeline mileage	X_{45}	Positive correlation
	Transport plane	X_{46}	Positive correlation

Table 12: Grey correlation results of freight development in Guangdong Province (1).

Variable	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
γ_{0iF}	0.896	0.762	0.807	0.925	0.900	0.774	0.818
γ_{0iR}	0.747	0.916	0.689	0.806	0.737	0.903	0.708
γ_{0iT}	0.894	0.747	0.816	0.904	0.897	0.758	0.829
γ_{0iW}	0.930	0.752	0.798	0.903	0.917	0.761	0.824
γ_{0iW}	0.921	0.726	0.798	0.871	0.884	0.733	0.848
γ_{0iA}	0.838	0.866	0.740	0.924	0.823	0.879	0.773
AVGγ_{0i}	0.871	0.795	0.775	0.889	0.860	0.801	0.800

Source: according to the calculation criteria.

Table 13: Grey correlation results of freight development in Guangdong Province (2).

Variable	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{31}	X_{32}
γ_{0iF}	0.850	0.823	0.890	0.870	0.586	0.848	0.816
γ_{0iR}	0.749	0.706	0.779	0.744	0.599	0.712	0.806
γ_{0iT}	0.848	0.819	0.882	0.867	0.590	0.859	0.824
γ_{0iW}	0.885	0.825	0.933	0.899	0.576	0.858	0.770
γ_{0iW}	0.917	0.831	0.912	0.913	0.558	0.877	0.743
γ_{0iA}	0.831	0.764	0.881	0.824	0.579	0.781	0.785
AVGγ_{0i}	0.847	0.795	0.880	0.853	0.582	0.823	0.791

Source: according to the calculation criteria.

import and export, which are most closely related to the development of freight transportation in Guangdong Province, ranking in the top 15 with the correlation degree greater than 0.8. The relevance degree of the added value of the secondary industry in the proportion of GDP is greater than 0.7, and its closeness with the freight development of Guangdong Province cannot be ignored. The relevance degree of science and technology financial

Table 14: Grey correlation results of freight development in Guangdong Province (3).

Variable	X_{41}	X_{42}	X_{43}	X_{44}	X_{45}	X_{46}
γ_{0iF}	0.916	0.947	0.808	0.915	0.908	0.902
γ_{0iR}	0.807	0.785	0.878	0.790	0.790	0.777
γ_{0iT}	0.894	0.923	0.789	0.901	0.903	0.887
γ_{0iW}	0.897	0.919	0.803	0.930	0.894	0.935
γ_{0iW}	0.864	0.876	0.767	0.906	0.829	0.942
γ_{0iA}	0.950	0.922	0.870	0.911	0.885	0.883
AVGγ_{0i}	0.888	0.895	0.819	0.892	0.868	0.888

Source: according to the calculation criteria.

expenditure is only 0.582, and its relevance with the freight development of Guangdong Province can be ignored.

6.3. Analysis of Grey Correlation Results. By using the grey correlation analysis method, we can objectively and reasonably reflect the influence degree of relevant influencing factors on the freight development of Guangdong Province and provide a quantifiable research perspective for the analysis of the relationship between regional economic factors, scientific and technological environment factors, government policy factors, transportation environment factors, and the freight development of Guangdong Province:

(1) The regional economic environment plays an important role in the freight development Guangdong Province.

The average value of the six factors of regional economy (AVG R_{01i}) is 0.827, and the value of four factors is greater than 0.8, which reflects that the economic environment is closely related to the freight development of Guangdong Province. The regional economic environment represents the demand of the freight market in the port market and reflects the impact of the economic environment on the demand of the port freight market; it also reflects the industrial transmission effect of the logistics industry affected by the real economy.

(2) The development of freight transportation in Guangdong Province should pay attention to the environmental factors of science and technology.

The value of science and technology environment factor (AVG R_{02i}) is 0.791. There is a certain degree of correlation between R&D personnel and the level of regional science and technology in Guangdong Province and the development of freight transportation in Guangdong Province, which means that the promotion and development of information technology have greatly promoted the development of freight transportation in Guangdong Province. R&D practitioners reflect the information technology talents, education expenditure reflects the strength of regional talent cultivation, and the amount of Internet broadband access reflects the basic environment of science and technology. The above three factors are greater than 0.8, which shows that the development of freight transportation in Guangdong Province is constrained by the basic conditions of the development of information technology and the cultivation of information talents. However, the government's financial expenditure on science and technology has no direct correlation with the freight development of Guangdong Province, and its correlation coefficient is only 0.582.

(3) Government policy factors guide freight development in Guangdong Province.

The value of government policy factor (AVG R_{03i}) is 0.807. The government's financial capacity and the intensity of transportation expenditure are closely related to the development of freight transportation in Guangdong Province. The amount of government's financial revenue and the intensity of transportation expenditure are helpful to improve the conditions of transportation infrastructure in Guangdong Province.

(4) The transportation environment factors directly affect the development of freight in Guangdong Province.

The value of environmental factors of transportation (AVG R_{04i}) is 0.875. The development of freight transportation in Guangdong Province is closely related to environmental factors of transportation. The correlation degree between the environmental factors of transportation and the freight development of Guangdong Province is greater than 0.8. The operating mileage of railway and oil pipeline reflects the overall infrastructure of freight industry. The number of employees in transportation, warehousing, and postal industry reflects the human resource factors of logistics industry. The number of trucks, ships, and aircraft reflects the basic equipment conditions of logistics. The above indicators are closely related to the freight development of Guangdong Province.

7. Conclusions and Suggestions

This paper makes a quantitative study on the development trend of freight transport in Guangdong from the perspective of freight volume. However, the research needs to be further expanded to fully reflect the overall situation of freight development in Guangdong Province, such as the study of freight market price factors and the change of supply-demand relationship. The empirical study shows the COVID-19 has a certain impact on the freight development of Guangdong, which has the following characteristics: stage characteristics, structural characteristics, and physical transmission characteristics; the total freight volume of Guangdong is affected by −23.001%, and the truck transportation is affected by −29.344%, with −11.296% for water transportation and −3.838% for air transportation. Due to the continuity of transportation and the substitution for other transportation modes, the freight volume of railway and pipeline transportation is affected by 14.343% and 13.057%, respectively.

To further explore the abate measures of COVID-19 impact on Guangdong's freight development, the grey correlation model is introduced to study the correlation factors of freight development of Guangdong Province. This paper selects four factors including regional economic environment, science and technology environment, government policy, and transportation and logistics environment, covering 20 subfactors. Through the research, it is found that the average correlation degree of the four factors is greater than 0.7 and the order of correlation degrees is as follows: transportation and logistics environment factors, government policy factors, and science and technology environment factors.

Through the research on the related factors of freight development of Guangdong Province, this paper puts forward the following measures to promote the freight development in Guangdong Province in the postepidemic era: first, pay attention to improving the freight infrastructure equipment in Guangdong Province, improve the efficiency of infrastructure equipment operation, and improve the connection ability of transportation modes, such as sea rail combined transportation, sea air combined transportation, and sea land combined transportation. Second, the government continues to invest in transportation infrastructure and introduces relevant measures, such as reducing and exempting tolls, operating taxes, and so on. Third, strengthen the linkage between freight development and economy, pay attention to the trend of economic development, and timely adjust the strategy of freight development and operation. Fourth, pay attention to strengthening the construction and application of information technology and intelligent technology in freight operation and improve the intelligent and digital degree of freight operation process.

Data Availability

The data used to support the findings of the study and related data are available from all the authors upon request.

Conflicts of Interest

The authors declare there are no conflicts of interest regarding the publication of this paper.

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