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Logistics Demand Forecast in Shandong Province Based on Grey Forecast

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Abstract: This paper takes the logistics demand in Shandong Province as the research object, selects the freight turnover volume as the key indicator. After collecting and sorting out the logistics data in recent years, it analyzes and builds models by using the grey prediction model to clarify its development trend and obtain the prediction results, which show that the freight turnover volume gradually increases in the future and the logistics demand presents a growing trend. This research has important guiding significance for the logistics planning and resource allocation in Shandong Province, and is conducive to the relevant departments to reasonably arrange resources and improve logistics efficiency.

Keywords: Shandong province; logistics demand; grey forecast; cargo turnover

1. Introduction

In the context of economic globalization and the rapid logistics industry development, the accurate prediction of logistics demand has become a crucial task in supply chain management and logistics planning. In the complex and changeable market environment, accurate prediction of logistics demand can help enterprises to scientifically plan resources, improve operational efficiency, reduce costs, and then gain a competitive advantage in the fiercely competitive market. Therefore, logistics demand prediction has become a hot spot of common concern in the academic and practical fields.

Shandong Province is a strong economic province and a key logistics hub in China. Accurately predicting its logistics demand is of great significance to the economic development of the region and the good operation of the logistics industry. However, because logistics demand is affected by many factors such as economic development, population growth, and industrial structure changes, it is difficult and challenging to predict. Therefore, it is extremely critical to explore a feasible and accurate logistics demand forecasting method. Grey prediction is a prediction method based on incomplete information, which is widely used in many fields such as economic prediction and social development prediction. The main idea is to gray the existing data and construct a mathematical model to infer the future development trend. Compared with the traditional mathematical model, the grey prediction method has certain advantages in the case of less data and strong uncertainty.

Many scholars in academia have carried out different research on logistics demand forecasting. Wang Caifeng [1] established GM(1,1) model to predict the logistics demand of Tibet Autonomous Region based on the actual data of cargo turnover in Tibet Autonomous Region. Yin Yanwei, Xiang Ga, Ren Yawei [2] take Shenyang as an example, based on the grey GM(1,1) model to predict the logistics demand of the northeast

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region, and by comparing with the actual value, the feasibility of the model is verified. Wang Meng, Li Xin [3] used the GM(1, 1) model to predict the logistics demand of British agricultural products. Xia Wenhui [4] used the historical data of freight volume in Chongqing to construct GM(1,1) model to predict the freight volume and its development trend in Chongqing in the next ten years.;At the same time, Gu Jiamin [5] predicted the logistics demand of related cities based on the grey prediction method, and the accuracy of the logistics demand prediction results obtained was high. Chen [6] selected Guangxi freight volume and cargo turnover as the influencing factors of Guangxi logistics demand. Xu Zhao [7] studied the forecasting method of urban logistics demand, and took Wuxi City as a case to predict the freight volume of Wuxi City in the next few years. Based on the existing research, this paper uses the grey prediction method to predict the logistics demand of Shandong Province, and provides decision support for the logistics planning and resource allocation of Shandong Province.

2. Introduction of Grey Forecasting Model

Grey prediction model is a unique prediction method, which is based on grey system theory. In the real world, there are many systems with incomplete information and scarce data, and the grey prediction model has good applicability to such systems. Tracing its origin, it was born in the 1980 s. It is a highly innovative achievement created by Chinese scholars through in-depth research and exploration. Since its inception, with the passage of time, the grey prediction model can predict the development trend of various economic indicators in many fields, especially in the economic field, and provide a strong reference for enterprises to formulate strategic planning and the government to carry out macro-control. In the social field, it can be used for population growth trend prediction, social phenomenon change analysis, etc., to help social management and policy formulation; in the field of environment, the prediction of environmental quality changes, resource consumption trends, etc., providing key support for the implementation of environmental protection and sustainable development strategies, etc., has been widely used in prediction and decision support.

The core point of this model is that it can skillfully process and transform those incomplete data sequences by using a special gray processing method, and further construct the corresponding mathematical model on this basis. With this model, we can reasonably infer and predict the future development trend of the system based on the current data. Its inherent basic assumption profoundly reflects the characteristics of the system, that is, there is often a special gray area in the whole development process of the system. This gray area covers those unknown and incomplete information parts. Because these information are difficult to obtain directly or clearly grasp, it is necessary to conduct in-depth and detailed analysis and prediction of existing data. In this way, we can excavate and reveal the inherent laws hidden behind these data.

Compared with the traditional prediction methods, the traditional prediction methods are often more stringent in data requirements, and a large number of complete and accurate data are needed to make more accurate predictions, while the grey prediction model shows unique advantages. When faced with the dilemma of missing data, it can still work on limited existing data ; under the condition of large uncertainty, that is, when the fluctuation of data is frequent and the relationship between data is vague, the grey prediction model can make a relatively reasonable and valuable prediction for the future development of the system by virtue of its unique theory and method system, so as to stand out among many prediction methods and become a powerful tool for dealing with the prediction problem of incomplete information and uncertain system.

2.1. Model Establishment Process

Set the reference data column: $x^{(0)}=(x^{(0)}(1),x^{(0)}(2),x^{(0)}(3),\cdots x^{(0)}(n))$

Accumulate it once and generate:

$$x^{(1)}=(x^{(1)}(1),x^{(1)}(2),x^{(1)}(3),\cdots,x^{(1)}(n))=(x^{(1)}(1),x^{(1)}(1)+x^{(1)}(2),x^{(1)}(2)+x^{(1)}(3),\cdots,x^{(1)}(n-1)+x^{(1)}(n))$$

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

Among them.

Find the mean value sequence: $z^{(1)}=0.5x^{(1)}(k)+0.5x^{(1)}(k-1),k=2,3,4,\cdots,n$

Now: $z^{(1)}=(z^{(1)}(2),z^{(1)}(3),z^{(1)}(4),\cdots,z^{(1)}(n))$

Remember: $a=\left[a,u\right]^T, y=(x^{(0)}(2), x^{(0)}(3),\cdots,x^{(0)}(n))^T, B=\begin{bmatrix}-z^{(1)}(2) & 1\\ -z^{(1)}(3) & 1\\ \vdots & \vdots\\ -z^{(1)}(n) & 1\end{bmatrix}$,

It can be concluded from the least square method: $\hat{a}=(B^TB)^{-1}B^TY$

Finally,the grey prediction model can be obtained as: $\hat{x}^{(1)}(k)=(x^{(0)}(1)-\frac{u}{a})e^{-a(k-1)}+\frac{u}{a}$

2.2. Model Calibration

(1) Test for residuals: Let the residuals be $\varepsilon(k)$ calculate $\varepsilon(k)=\frac{x^{(0)}(k)-\hat{x}^{(0)}(k)}{x^{(0)}(k)}, k=1,2,\cdots,n$

If $\varepsilon(k)<0.2$, it can be considered to meet the general requirements; If $\varepsilon(k)<0.1$, it can be considered to meet higher requirements.

(2) The deviation value test of the ratio: First of all, by the reference data $x^{(0)}(k-1), x^{(0)}(k)$, so$\rho(k)=1-\left(\frac{1-0.5a}{1+0.5a}\right)\lambda(k)$.

The grade ratio is calculated $\lambda(k)$, and the corresponding technical deviation is obtained by using the development coefficient a. If $\rho(k)<0.3$, it can be considered to meet the general requirements; If$\rho(k)<0.1$, it can be considered to meet higher requirements.

3. Logistics Demand Forecast of Shandong Province

This paper collects the data of cargo turnover in Shandong Province from 2003 to 2022 through the National Statistical Yearbook of China Statistical Bureau, and draws a scatter plot accordingly.

From the scatter plot provided (as shown in Figure 1), we can clearly observe that during 2000−2007, the trend line formed by the data points shows a relatively stable and regular upward trend, and its growth rate remains within a relatively reasonable range. The fluctuation is small, which is in line with the logic of general economic development and gradual growth of logistics demand. However, when time entered 2008, the data points began to show a sharp upward trend, which was in stark contrast to the previous trend. This rise is not a gradual and sustainable growth, but a leap-forward and mutational growth model. Taking the data of 2007 as a reference, the growth rate of cargo turnover in 2008 is far beyond the normal growth level of previous years. In the subsequent 2009–2012 period, this abnormal growth trend has not been alleviated, but continued to intensify. The data points are high and convex on the scatter plot, forming obvious faults with the data points of the previous and subsequent years. This means that in these four years, the growth rate of cargo turnover in Shandong Province is extremely fast, far from the normal growth track.

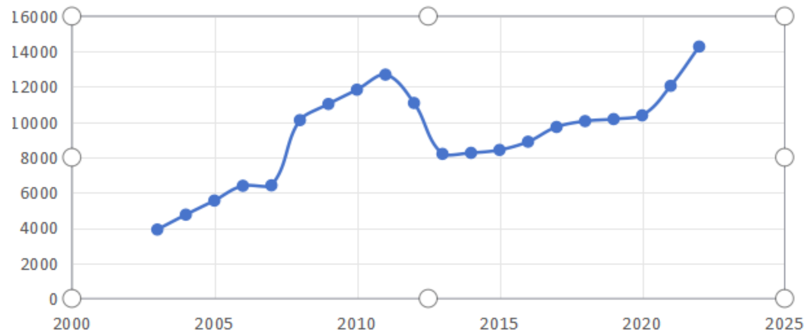

Figure 1. Scatter plot of cargo turnover in Shandong Province from 2003 to 2022.

From the point of view of the distribution density of data points, the data points of 2008−2012 are more dense than other years and distributed in a higher numerical range, which indicates that the turnover of goods has achieved rapid and concentrated growth during this period. At the same time, compared with the growth trend consistency of adjacent years, the growth anomaly in 2008–2012 broke the stability of the overall data trend, making the whole data series show a growth model that is obviously uncoordinated with the previous and subsequent stages during this period.

This abnormal growth may be caused by a combination of factors. On the one hand, it may be closely related to the changes in the macroeconomic environment at that time. For example, in 2008, when the global financial crisis broke out, countries adopted economic stimulus policies, and China was no exception. Large-scale economic stimulus plans may have prompted Shandong Province to increase investment in infrastructure construction and industrial production, which led to a substantial increase in cargo turnover. On the other hand, factors such as industrial restructuring, changes in the logistics industry itself, and changes in policy orientation may also play a central role in this period, jointly triggering the abnormal growth of cargo turnover data. However, this abnormal growth trend is significantly different from the trend of other years in the scatter plot, which has a great impact on the stability and predictability of the overall data, so it needs to be eliminated. After eliminating anomalies, the required data table (see Table 1) is obtained, and the GM(1,1) model is established to predict and analyze the logistics demand trend of Shandong Province in the next five years.

Table 1. Shandong’s cargo turnover from 2003 to 2022.

Year	2003	2005	2006	2007	2013	2014	2015
Turnover of goods (billions of tons of kilometers)	3908.9	5551	6387.4	6413.4	8194.15	8253.03	8418.04
Year	2016	2018	2019	2020	2021	2022	
Turnover of goods (billions of tons of kilometers)	8884.34	10,052.2	10,166.42	10,377.4	12,049.7	14,273.49	

3.1. Establishment of Logistics Demand Model

(1) Initialize the modeling original sequence:

$$x^{(0)} = (3908.9, 4752.5, 5551, 6387.4, 6413.4, 8194.15, 8253.03, 8418.04, 8884.34, 9719.46, 10052.2, 10166.42, 10377.4, 12049.7, 14273.49)$$

(2) One cumulative generation:

$$x^{(1)} = (3908.9, 8661.4, 14212.4, 20599.8, 27013.2, 35207.35, 43460.38, 51878.42, 60762.76, 70482.22, 80534.42, 90700.84, 101078.24, 113127.94, 127401.43)$$

(3) The sliding average generates a sequence:

$$z = (6285.15, 11436.9, 17406.1, 23806.5, 31110.275, 39333.865, 47669.4, 56320.59, 65622.49, 75508.32, 85617.63, 95889.54, 107103.09, 120264.685)$$

(4) The B matrix and Y matrix are calculated, and the prediction model can be obtained as follows:

$$\hat{x}(k) = (3908.9 = 73892.9.64)e^{0.067932347(k-1)} - 73892.9064$$

3.2. Logistics Demand Model Test

According to the above calculation formula of residual error and stage ratio deviation value, the calculation results of residual error and stage ratio deviation value can be obtained (Table 2):

It can be seen from the data in the figure that the residuals meet $\varepsilon(k) < 0.2$. which means that the deviation between the predicted value of the model and the actual cargo turnover data of Shandong Province is small, and

Table 2. Calculation results of residuals and ratio deviations.

Year	2003	2004	2005	2006	2007	2013	2014	2015
residual	0.00	−0.15	−0.05	0.02	−0.05	0.12	0.07	0.02
Ratio deviation value	0.00	0.22	0.05	0.02	0.15	0.27	0.27	0.01
Year	2016	2017	2018	2019	2020	2021	2022	
Residual	0.01	0.03	0.00	−0.06	−0.11	−0.03	0.07	
Ratio deviation value	0.04	0.04	0.06	0.02	0.01	0.14	0.02	

the model has high accuracy in capturing the trend of data change. The grade ratio deviation values all meet $\rho(k) < 0.3$, which fully indicates that the mathematical relationship constructed by the model can better fit the internal change law of the cargo turnover data in Shandong Province. Based on the test results of the two indicators of residual error and grade ratio deviation value, it can be seen that the model meets the general requirements and has the ability to predict the logistics demand of Shandong Province.

4. Prediction Results and Explanation

According to the model, the forecast results of logistics demand in Shandong Province from 2023 to 2027 can be obtained. In 2023, the logistics demand of Shandong Province is expected to be 14,155.921 billion tons km, which reflects the scale of cargo transportation turnover in Shandong Province in that year. By 2024, logistics demand will grow to 15,150.982 billion tons of kilometers, compared to 2023 has a certain degree of improvement, showing the logistics industry in this year may appear expansion trend. In 2025, the predicted logistics demand will further rise to 16, 215.989 billion tons and kilometers, which means that the logistics industry in Shandong Province will show a sustained growth trend in these three years, which may be related to local economic development, industrial restructuring and business activity. The forecast value of logistics demand in 2026 is 17,355.857 billion tons km, which continues to maintain the growth momentum compared with the previous year, indicating that the logistics market still has a strong driving force for development during this period. More enterprises may participate in the logistics business, or existing enterprises have expanded their own logistics business scale. By 2027, it is predicted that the logistics demand of Shandong Province will reach 1,857,585 billion tons of kilometers, reaching the highest value in the five-year forecast period, which is fully demonstrated.

According to the existing data and forecast data, the logistics demand curve of Shandong Province in recent decades can be drawn (as shown in Table 3).

Table 3. Logistics demand forecast of Shandong Province from 2023 to 2027.

Year	2023	2024	2025	2026	2027
Turnover of goods (billions of tons of kilometers)	14,155.921	15,150.982	16,215.989	17,355.857	18,575.850

The orange curve in the figure is the predicted value curve, and the blue is the actual value curve. According to the scatter plot, it can be seen that there is little difference between the predicted value and the actual value, which can also prove that the prediction model meets the requirements, and the prediction results have certain feasibility (as shown in Figure 2).

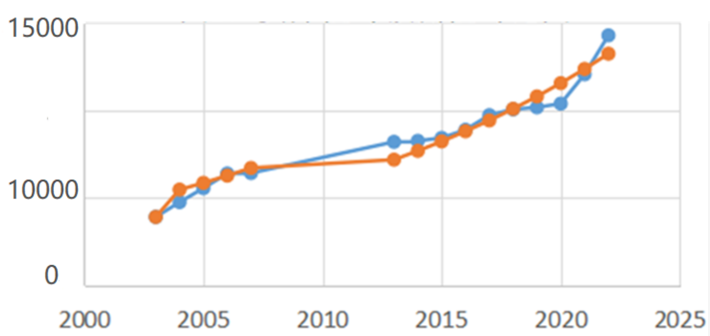

Figure 2. Scatter plot of actual value and predicted value comparison.

5. Policy Proposal

The forecast of logistics demand in Shandong Province based on grey prediction can enable us to predict and recognize the future development of logistics demand. Based on these prediction conclusions, the following policy recommendations can be made to help the development of the logistics industry in Shandong Province and optimize the allocation of resources.

(1) Strengthening the construction of logistics infrastructure: In view of the forecast that the logistics demand in Shandong Province is gradually rising, the government needs to increase investment in logistics infrastructure, covering roads, railways, ports and storage facilities. By improving the efficiency and efficiency of logistics infrastructure, it can meet the growing logistics demand and enhance the convenience and reliability of logistics transportation.

(2) Promote the use of logistics information and technology: With the increasing demand for logistics, logistics information and technology applications will become the core elements to enhance logistics efficiency and reduce costs. The government can guide logistics enterprises to strengthen the construction of information system and improve the collection, transmission and management level of logistics information. Moreover, encourage logistics enterprises to adopt cutting-edge logistics technologies such as Internet of Things, big data analysis, and artificial intelligence to optimize logistics operation processes and improve cargo tracking and distribution efficiency.

(3) Optimize the cultivation and management of logistics talents: The demand for high-quality talents in the logistics industry is increasing day by day. The government should enhance the cooperation with universities and vocational education institutions, and cultivate and introduce logistics professionals. In addition, we will strengthen the training and skills upgrading of logistics practitioners and enhance their operational management and supply chain coordination capabilities. In addition, build a complete logistics talent management system, attract and retain high-quality logistics talents, and provide strong support for the sustainable development of the logistics industry.

(4) Promote the collaborative development of the logistics industry: The growth of logistics demand does not depend on the unilateral efforts of a single enterprise or institution, but on the collaborative operation of the entire logistics industry chain. The government can focus on promoting the construction of logistics industrial parks and promoting cooperation and coordinated development among logistics enterprises. At the same time, it urges logistics enterprises to build close cooperation with suppliers, customers, transportation enterprises and other relevant parties, create an efficient supply chain network, and improve the overall logistics efficiency.

(5) Strengthen policy support and supervision measures: In order to promote the steady development of the logistics industry, it is necessary for the government to formulate relevant policy support and supervision measures. For example, build a sound logistics market access mechanism to encourage and support the development of private logistics enterprises; strengthen the supervision of logistics service quality and improve the service level of logistics industry; promote the green development of the logistics industry, and advocate the implementation of low-carbon logistics and energy conservation and emission reduction actions.

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Conflicts of Interest

The author declares no conflict of interest.

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