Research Article

Analysis of Factors Affecting Freight Demand Based on Input-Output Model

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Freight demand is a highly variable process over economic and industrial structure, and accurate freight demand forecasting is the basis of transportation planning. In order to clarify the influencing factors of freight volume so as to analyze and predict the change trend of freight volume accurately, this paper analyzes the impact of changes in economic, industrial structure, and complete consumption coefficients on freight demand, through constructing an input-output model for transportation value analysis and forecasting freight volume by fitting data of transportation value and freight traffic. Studies have shown that the growth in economic aggregate is the main reason for the increase in the value of transportation, and the change in the complete consumption coefficient is the main reason for the increase in freight traffic.

1. Introduction

Freight demand forecasting is the basis of transportation planning. The wrong forecast of freight demand may lead to the advanced construction of transportation and waste of resources, such as Japan in the 1980s, or cause the delayed construction and the loss of freight transportation congestion, such as Iraq in the 1970s. Therefore, freight demand forecasting has aroused the interest of the transportation sector and many scholars. This paper attempts to describe and analyze the driving factors that affect China's freight demand in order to better study the future development trend of freight.

In the past, researchers believed that there was a linear relationship between freight transportation demand and GDP [1–3]. The nature of the industry, such as the proportions of primary, secondary, and tertiary industries, has different effects on freight intensity [4]. Alises and Vassallo [5] show that the economic elasticity of freight transportation is gradually decreasing. However, Zhang et al. [6] believe that economic factors are still the main factors affecting freight volume. Wang et al. [7] believe that freight volume is affected by macroeconomics, industrial structure, and supply capacity. The research of Sun et al. [8] shows that

resource and population distribution and investment in fixed assets are the main factors influencing railway freight volume. In addition, supply chain management strategies will also affect freight volume, such as inventory management strategies [9–13] and replenishment strategies [14]. Previous studies have analyzed the influencing factors of freight volume from many aspects, but because of the lack of comparative analysis of influencing factors, the importance and relevance of influencing factors cannot be reflected.

Many research models are established, such as developing and applying transportation market shares models [15], transportation supply chain models [16], spatial accounting models [17], and multiple regression models [18]. However, such methods are found difficult to predict the growth of freight volume accurately due to the complexity of the economic system and the rapid development of the service economy.

Input-output (IO) analysis method was proposed by American economist Leontief in 1925. The input-output model can analyze and investigate the quantitative dependence relationship between the freight transportation sector and other sectors in the national economy [19, 20]. The IO model captures the nature of interindustry interaction, has relatively low data requirements, and is easy to implement

[21]. Based on the expression of intersectoral multiplier effects, the IO model allows us to describe the effects on the transport system caused by shocks in the economic system, both from a theoretical and an application point of view.

This paper considers an aggregate level of freight transportation, correlates the freight volume with the operation of the economic system, and then constructs the IO model. The model is structured on two levels: the first level forecasts the output value of the production department according to the exogenous demand and the second forecasts the tonnage of goods transported according to the relationship between the value of freight demand and freight volume in the economic system. Through the elaboration of time series of input-output tables for China, the model is validated and used to formulate forecasts for different future scenarios and then the influencing factors of freight traffic are analyzed.

This paper tries to answer the following two questions: (1) the relationship between economic development and transportation demand and (2) influencing factors of freight volume growth. The novel contribution of this paper is as follows: (1) the national freight volume was predicted by the input-output model. In order to reflect the impact of changes in industrial structure on freight volume better, this paper subdivides the industrial structure into 42 sectors, and the impact of 42 sectors on freight volume was analyzed, which is more specific than the previous division of the three industries; (2) comparative analysis of the influencing factors of freight value and freight volume was carried out through the complete decomposition model, and the influence degree of economic aggregate, industrial structure, and complete consumption coefficient on freight value and freight volume was obtained, so as to obtain the changing trend of freight volume accurately.

2. Literature Review

The literature related to this paper can be divided into three parts: (1) factors affecting freight demand, (2) input-output model, and (3) freight volume forecast.

2.1. Factors Affecting Freight Demand.

Robert et al. [22] have identified and evaluated the factors of freight demand. Their research shows that population, economic activities, fuel prices, environment, and policies are the main influencing factors, among which GDP and GDP per capita are commonly used indicators of economic activity. Fite et al. [23] conducted regression analysis on 107 indexes related to freight volume and believed that the producer commodity price index of construction materials and equipment (PCPI-CM&E) was the most relevant parameter. Agnolucci and Bonilla [24] conducted a study on the relationship between freight volume and GDP in the UK from 1956 to 2003. Their research found that the decoupling of freight volume and GDP accelerated, and the price and income elasticity also decreased to 18% and 65%. Wang et al. [25] proposed a hierarchical model. The model shows that the demand for truck freight can be estimated by truck traffic, population,

number of companies, and income. Short et al. [26] studied the relationship between Sweden's economic activities and freight volume. The study found that, in the short and medium term, changes in imports and exports led to large fluctuations in freight demand; in the long run, freight demand and GDP are coupled, and there is no sign of decoupling. Wijeweera et al. [27] studied the impact of freight prices, international trade, and business cycles on Australia's rail freight demand. Their study shows that the fluctuation of freight rates and the Australian dollar was the most important factor affecting Australian rail freight. Alises and Vassallo [28] studied the impact of economic growth, industrial structure, and road transport intensity on the demand for road freight. The results show that, overall, the growth of total road transport demand is mainly driven by economic activities. Patil and Sahu [29] used regression and time series models to estimate the freight demand of Mumbai ports. Their research concluded that GDP and crude oil production are the most important factors affecting freight. Wang et al. [30] analyzed the relationship between freight demand and economic development. They believe that China's overall economic development is decoupled from freight development, and the intensity of transportation is declining. Khan and Khan [31] analyzed the demand for rail freight in Pakistan. The study showed that GDP and freight are the two most important determinants of rail freight demand. Table 1 shows the comparison between some studies and this paper.

2.2. Input-Output Model.

There are three main types of input-output models: inter-regional model-IRIO [54, 55], multiple model-MRIO [56], and multiregional econometrics model [57, 58]. Izard et al. [59] proposed an inter-regional input-output model, which introduced a trade coefficient, which represents the proportion of product m produced and used in region j used in the production and use of product n in the region. Because the proportion of trade is difficult to estimate, Moses [60] simplified the calculation of the trade coefficient, considering only the trade flow and no longer the destination. The wrong estimation of the trade coefficient may cause a large deviation in the forecast of freight traffic, which requires multiple corrections [61]. Miller [62] gave a detailed application explanation of the input-output model and constructed a fitting model of transportation and economy. Voigtlaender [63] applied a dynamic input-output model to forecast freight demand in the United States. Rey [64] discussed the application of econometrics in the input-output table model and studied the alternative methods and models of the input-output model. Havenga and Simpson [65] used an economic input-output (I-O) model as a platform, supplemented by actual data, developed supply and demand data classified by space and sector, and converted the supply and demand of South African freight into a freight flow through a gravity model. The above literature has conducted a lot of research on the application of input-output models from the perspective of theory and practice and provided theoretical and methodological support for the research of this paper.

TABLE 1: Comparison of some research studies and this paper.

References/ Influencing factors	Transportation supply characteristics							Transport demand characteristics							Other
	Freight cost	Freight time	Reliability	Cargo damage cost	Transport distance	Transport frequency	Cargo capacity	Product size	Product types	Commodity value	Industry	Inventory cost	Delivery frequency	Interactive term	Terminal accessibility
Dewey et al. [32]	☆		☆					☆							
Holguín-Veras [33]	☆				☆			☆	☆						
Kim [34]	☆	☆	☆												
Norojono and Young [35]	☆		☆	☆	☆	☆			☆						☆
Train and Wilson [36]	☆	☆	☆												
Arunotayanun and Polak [37]		☆	☆	☆		☆	☆	☆				☆			
Patterson et al. [38]	☆		☆	☆	☆			☆							
De Jong [39]	☆	☆			☆			☆	☆		☆		☆		☆
Cavalcante and Roorda [40]							☆	☆							
Windisch et al. [41]	☆				☆			☆	☆	☆					☆
Samimi et al. [42]	☆	☆			☆			☆							
Lloret-Batlle and Combes [43]	☆			☆	☆				☆	☆					☆
Pourabdollahi et al. [44]	☆				☆				☆		☆				
Abate and de Jong [45]	☆							☆					☆		
Stinson et al. [46]	☆	☆						☆	☆						
Roman et al. [47]	☆	☆	☆			☆									
Kim et al. [48]	☆	☆	☆	☆											
Larranaga et al. [49]	☆	☆	☆												
Abate et al. [50]	☆	☆						☆	☆	☆					☆
Jensen et al. [51]	☆	☆						☆	☆						☆
Keya et al. [52]	☆	☆						☆	☆	☆			☆	☆	
Comi and Polimeni [53]	☆	☆				☆		☆							
This paper	☆	☆						☆							
	Transport economic value							Freight volume			Industrial structure		Complete consumption factor		

2.3. Forecast of Freight Traffic. Freight forecasting models can be grouped into five classes: the economic activity model, the four-step commodity model, the Origin-Destination (O-D) factoring method, the Flow Factoring Method (FFM), and the truck model. Many kinds of literature have used a variety of methods and models to predict freight volume from the national level, such as Daugherty [66], Picard and Nguyen [67], Mazzarino [68], and Regan and Garrido [69]. There are multiple measurement standards for freight traffic, and the common measurement standards are tons, ton-kilometers, and transportation costs (transportation costs or prices paid for transportation services). The accuracy of forecasting freight volume depends on the classification and aggregation of data and the estimated model [70, 71]. Among the influencing factors of freight demand, the most important influencing factors are consumer demand, production structure, and trade mode [72, 73]. Castro-Neto et al. [74] used the online support vector regression algorithm to predict the traffic flow of the road with good prediction accuracy. Chen [75] constructed a comprehensive transportation network, organically combined multiple transportation modes, and improved the accuracy of travel choice model prediction. Ahn et al. [76] combined Bayesian classifier and vector regression to predict the traffic demand of expressways and predicted and analyzed the expressway freight volume of Korea. Garrido and Mahmassani [77] developed a multinomial probit (MNP) model, which predicts freight volume based on time and space changes in transportation. Studies have shown that the model is more accurate. Pompigna and Mauro [78] used Italian economic data from 2000 to 2014 as the basis and used the macro-input-output method to analyze freight demand and forecasted Italian freight volume in 2027. The above research uses a variety of models and methods to forecast freight traffic. Generally speaking, national freight volume forecasting models are the integration of macroeconomic models.

3. Problem Description and Modelling

3.1. Model Description. The basic composition of the model is

(1) Direct consumption coefficient: the direct consumption coefficient refers to the value of the unit's total output of the jth product sector directly consumed by the ith product sector in the production process, usually recorded as a_{ij} $(i, j = 1, 2, \ldots, n)$. The formula of a_{ij} is

$$a_{ij} = \frac{x_{ij}}{X_j}, \tag{1}$$

where x_{ij} represents the input amount provided by the ith sector as an intermediate product to the jth sector and X_j represents the total investment of the jth sector.

(2) Complete consumption coefficient: the complete consumption coefficient is the number of products completely consumed by the jth sector when

producing a unit product. It is called the complete consumption coefficient of the jth sector for the first sector, usually denoted as b_{ij}. The complete consumption coefficient is the sum of direct consumption and all indirect consumption, and the calculation formula is

$$b_{ij} = a_{ij} + \sum_{k=1}^{n} a_{kj} b_{jk}. \tag{2}$$

The matrix formula is $B = A + BA$, and the formula for solving the complete consumption matrix can be obtained:

$$B = (I - A)^{-1} - I. \tag{3}$$

(3) Balance formula: the input-output table has two important balance relationships, namely, row balance and column balance. Line balance: intermediate use + final use = total output:

$$\sum_{j=1}^{n} a_{ij} x_{ij} + Y_i = X_i, \quad i = 1, 2, \ldots, n, \tag{4}$$

where Y_i represents the final use amount provided by the ith sector and X_i represents the total output of the ith sector.

Its matrix is expressed as $AX + Y = X$.

Column balance: initial investment + intermediate investment = total investment:

$$\sum_{i=1}^{n} x_{ij} + N_j = X_j, \quad j = 1, 2, \ldots, n, \tag{5}$$

where N_j represents the added value of the jth sector.

3.2. Model Assumptions. The basis of the input-output theory is Walras' general equilibrium theory, which involves the following basic assumptions.

3.2.1. Homogeneity Assumption. Assume that each industrial sector produces only one homogeneous product. That is, the product is completely replaceable in this department but irreplaceable in other departments.

3.2.2. Proportionality Assumption. The input and output of the department are directly proportional, that is, there is a linear relationship between input and output.

3.2.3. Stability Assumption. The technology, production process, and management level are relatively stable.

3.3. Division of Departments. This paper uses the input-output tables compiled by China from 2002 to 2017 as the basic data. To facilitate model processing and analysis, the 135 departments, 149 departments, and 41 departments in

different years have been uniformly adjusted to 42 departments. The specific divisions are shown in Table 2.

3.4. Decomposition of the Input-Output Model. According to the construction principle of the input-output table, the growth of transportation demand can be decomposed into three parts: increase in transportation demand caused by economic growth, industrial relevance and changes in production technology lead to the increase in transportation demand caused by changes in the complete consumption coefficient, and changes in transportation demand caused by the upgrading of industrial structure. Since the input-output table uses the value as the unit of measurement, the formula for calculating the economic value Q of transportation can be expressed as

$$Q = Z * X, \qquad (6)$$

where Z represents transportation intensity and X represents the total output.

Taking the derivative of the above formula, we can obtain

$$\partial Q = X \partial Z + Z \partial X. \qquad (7)$$

Because $Z = (Q/X) = (\sum b_j X_j / X) = \sum b_j s_j$, where b_j represents the complete consumption coefficient of each department for transportation, X_j represents the total output of each department, and s_j represents the proportion of each department's output to the total output.

The matrix of the above formula is expressed as $Z = B \times S$, where B is the complete consumption coefficient matrix and S is the structural variable.

Taking the derivative of formulas (3)–(8), we can obtain

$$\partial Z = S \partial B + B \partial S. \qquad (8)$$

Putting formulas (8) and (9) into (7), we can obtain

$$\partial Q = SX \partial B + XB \partial S + BS \partial X, \qquad (9)$$

where $SX \partial B$ represents the changes in the transportation economy caused by changes in the complete consumption coefficient, $XB \partial S$ represents the changes in the transportation economy caused by changes in the industrial structure, and $BS \partial X$ represents the changes in the transportation economy caused by changes in the total economic scale.

In the time period $[0, t]$, the change of the economic value of transportation is

$$\Delta Q = Q_t - Q_0 = B_t S_t X_t - B_0 S_0 X_0. \qquad (10)$$

Let $B_t = B_0 + \Delta B$, $S_t = S_0 + \Delta S$, and $X_t = X_0 + \Delta X$, and formula (11) can be expressed as follows:

$$\begin{aligned} \Delta Q = Q_t - Q_0 &= \Delta B S_0 X_0 + B_0 \Delta S X_0 \\ &\quad + B_0 S_0 \Delta X + B_0 \Delta S \Delta X \\ &\quad + \Delta B S_0 \Delta X + \Delta B \Delta S X_0 + \Delta B \Delta S \Delta X, \end{aligned} \qquad (11)$$

with $Q = ZX = \sum b_j s_j X$, the demand for transportation value caused by different departments can be obtained as

$$Q_j = b_j s_j X. \qquad (12)$$

Let $b_{jt} = b_{j0} + \Delta b_j$, $s_{jt} = s_{j0} + \Delta s_j$, and $X_t = X_0 + \Delta X$; then, in the period $[0, t]$, the changes in the economic value of transportation caused by different sectors are

$$\begin{aligned} \Delta Q_j = Q_{jt} - Q_{j0} &= b_{jt} s_{jt} X_t - b_{j0} s_{j0} X_0 \\ &= \Delta b_j s_{j0} X_0 + b_{j0} \Delta s_j X_0 + b_{j0} s_{j0} \Delta X \\ &\quad + b_{j0} \Delta s_j \Delta X + \Delta b_j s_{j0} \Delta X + \Delta b_j \Delta s_j X_0 + \Delta b_j \Delta s_j \Delta X. \end{aligned} \qquad (13)$$

Combining the factors that cause the economic value of transportation into similar items and decomposing them according to the complete consumption coefficient change, industrial structure change, and total output change, the change in the economic value of transportation can be expressed as

$$\begin{aligned} \Delta Q_j &= b_{jq} + s_{jq} + X_{jq}, \\ b_{jq} &= \Delta b_j s_{j0} \Delta X + \frac{1}{2} \left(\Delta b_j s_{j0} \Delta X + \Delta b_j \Delta s_j X_0 \right) + \frac{1}{3} \Delta b_j \Delta s_j \Delta X, \\ s_{jq} &= b_{j0} \Delta s_j X_0 + \frac{1}{2} \left(b_{j0} \Delta s_j \Delta X + \Delta b_j \Delta s_j X_0 \right) + \frac{1}{3} \Delta b_j \Delta s_j \Delta X, \\ X_{jq} &= b_{j0} s_{j0} \Delta X + \frac{1}{2} \left(b_{j0} \Delta s_j \Delta X + \Delta b_j \Delta s_{j0} \Delta X \right) + \frac{1}{3} \Delta b_j \Delta s_j \Delta X, \end{aligned} \qquad (14)$$

where b_{jq}, s_{jq}, and X_{jq}, respectively, represent the impact of changes in the complete consumption coefficient, changes in industrial structure, and total output on the economic value of transportation.

4. Algorithm

4.1. Total Output Forecast. The total output of a department refers to the total value of all goods and services produced by the department in a certain period. To predict the total output of a department, you can first predict the added value of each department and then use the input-output model to calculate the total output of each department.

According to the column balance principle $A_c X + N = X$ in the input-output table, the total output of the ith sector can be calculated as

$$X_i = (1 - A_c)^{-1} \text{GDP}_i, \quad i = 1, 2, \ldots, n. \qquad (15)$$

Because gray prediction is an exponential growth prediction, its prediction interval is trumpet-shaped, and the accuracy is poor in medium and long-term predictions. Therefore, to ensure the accuracy of the prediction, this paper adopts the equal-dimensional gray number recursive dynamic prediction method. The basic principle of this method [79] is that only one value is predicted at a time, and the predicted value is used to replace the first value of the original data sequence, keeping the same dimension and predicting one by one, which speeds up the convergence of the predicted value with high accuracy. From the verification

TABLE 2: 42 sectors of the three industries.

Numbering	Industry name
1	Agriculture, forestry, animal husbandry, and fishery
2	Coal mining and washing industry
3	Oil and gas extraction industry
4	Metal mining and dressing industry
5	Nonmetallic minerals and other mining and dressing industries
6	Food manufacturing and tobacco processing industry
7	Textile industry
8	Textile, clothing, shoes, hats, leather down, and its products' industry
9	Wood processing and furniture manufacturing
10	Papermaking, printing and cultural, educational, and sporting goods manufacturing
11	Petroleum processing, coking, and nuclear fuel processing industry
12	Chemical industry
13	Nonmetallic mineral products' industry
14	Metal smelting and rolling processing industry
15	Metal products' industry
16	General and special equipment manufacturing industry
17	Transportation equipment manufacturing
18	Electrical machinery and equipment manufacturing
19	Communication equipment, computer, and other electronic equipment manufacturing
20	Instrumentation and cultural office machinery manufacturing
21	Crafts and other manufacturing
22	Scrap
23	Electricity and heat production and supply industry
24	Gas production and supply industry
25	Water production and supply industry
26	Construction industry
27	Transportation and storage industry
28	Postal industry
29	Information transmission, computer service, and software industry
30	Wholesale and retail
31	Accommodation and catering industry
32	Financial industry
33	Real estate
34	Leasing and business services
35	Research and rxperimental development
36	Comprehensive technical service industry
37	Water conservancy, environment, and public facilities management industry
38	Resident services and other services
39	Education
40	Health, social security, and social welfare industries
41	Culture, sports, and entertainment industry
42	Public administration and Social Organization

Data source: National Bureau of Statistics of China.

results, the 7-dimensional prediction overemphasizes the extension of the past trend, and the prediction is too high, the 5-dimensional prediction overemphasizes the extension of the recent trend, and the prediction is lower, and the 6-dimensional prediction is more appropriate.

4.2. Complete Consumption Coefficient Prediction. The RAS method, also known as the biproportional scaling method, was proposed by Deming and Stephan [80] in 1940. The basic principle is to first assume that the input structure of the target year and the base year are the same. Under the control of the total output and intermediate use in the target year, use a set of row control vectors and a set of column control vectors to adjust the base year accordingly. Each row element and each column element of the direct consumption

coefficient matrix in the input-output table makes the total calculated direct consumption coefficient equal to each control data. The mathematical expression of the RAS method is

$$A_t = \widehat{R}A_0\widehat{S}, \tag{16}$$

where A_t is the direct consumption coefficient matrix of the target year, A_0 is the direct consumption coefficient matrix of the base year, $\widehat{R}$ is the total row multiplier matrix, and $\widehat{S}$ is the total column multiplier matrix.

The total row multiplier matrix $\widehat{R} = \widehat{r}_k\widehat{r}_{k-1}, \ldots, \widehat{r}_2\widehat{r}_1$ can reflect the degree to which intermediate products are replaced by other products. Multiply A_0 by $\widehat{R}$ left: if an intermediate product in a row in A_0 is replaced by other products, all other intermediate products in this row will be

replaced by other products to the same extent. The total column multiplier matrix $\widehat{S} = \widehat{s}_1\widehat{s}_2, \ldots, \widehat{s}_{l-1}\widehat{s}_l$ can reflect the degree of consumption of other departments by each department in the production process. Multiply A_0 by $\widehat{S}$ right: if the intermediate input of an intermediate product in a column of A_0 increases, the intermediate input of all other intermediate products in this column will increase by the same degree.

4.3. Economic Forecast. Assuming that the return to scale of the production function remains unchanged and according to the global economic growth model, it is estimated that China's total GDP as

$$\text{GDP} = \text{TFP} \times K^{\alpha} \times L^{1-\alpha}, \tag{17}$$

where TFP represents total factor productivity, K represents capital stock, L represents the total labor force, and α represents the output elasticity of capital. According to the calculation of most scholars, α is 0.55. According to the basic laws of world economic development, when an economy enters a capital surplus, the output elasticity of capital will gradually decrease, while the output elasticity of labor will slowly rise. Therefore, this paper assumes that the elasticity of capital-output will slowly decline from 0.6 in 2016 to 0.45 in 2035 and further to 0.4 in 2050.

Step 1 (predict the total labor force): the formula is

$$\ln P_t = \alpha \times \ln P_{t-1}, \tag{18}$$

where P_t is the labor participation rate in year t, P_{t-1} is the labor participation rate in the previous year in year t, and α is a constant parameter.

The labor participation rate refers to the ratio of the total employed population to the total population. Statistics from the National Bureau of Statistics of China show that, between 1995 and 2015, China's labor participation rate reached an average of about 56%, and it was quite stable. Based on this, it can be assumed that, between 2020–2050, China's labor participation rate will also remain at around 56%. The prediction results are shown in Table 3.

Step 2 (predict the capital stock): the formula is

$$K_{\text{growth}} = \frac{K_t}{K_{t-1}} - 1 = \frac{I_{t-1}}{K_{t-1}} - 6\%, \tag{19}$$

where K_{growth} is the growth rate of capital stock, I_{t-1} is the amount of capital investment in the previous year, and 6% represents the annual depreciation rate of capital. Since 2010, the growth rate of China's capital stock has been declining. The decline in capital growth may be due to the adjustment of the industrial structure. This paper predicts that, from 2021 to 2030, the average annual growth rate of capital is 7%, from 2031 to 2040, the average annual growth rate of capital is 5%, and from 2041 to 2050, the average annual growth rate of capital is 3%.

Step 3 (forecast total factor productivity): the formula is

$$\text{TFP}_{\text{growth}} = 1.3\% + \text{CB} - \text{FP}, \tag{20}$$

where 1.3% is the potential growth rate of TFP, CB represents the growth rate of inertial growth in emerging developing countries, and FP represents factors that hinder productivity growth from failure. The formula for inertial growth rate is

$$\text{CB} = c * 2.33\% * \ln\left(\frac{\text{TFP}_{\text{USA},t-1}}{\text{TFP}_{i,t-1}}\right), \tag{21}$$

where 2.33% is a parameter of development inertia, calculated from historical data, and c is the national development speed parameter. The value is 1 for high-growth countries, 0 for declining countries, and c is between 0 and 1. Economic development itself has inertia, so this paper believes that China's economic growth inertia CB is about 0.3.

The hindering factor FB formula is

$$\text{FB} = f * 1.8\%, \tag{22}$$

where f is a hindering parameter, and its nature is opposite to c. It is 1 for declining countries and 0 for high-growth countries. Since China is an emerging developing country, the value of f should be between 0 and 0.5. Since 2006, China's total factor productivity has gradually declined. Total factor productivity is composed of human capital, R&D innovation, infrastructure, urbanization rate, and investment rate. Due to the aging of the population, the gradual improvement of infrastructure, and the decline in investment, the growth rate of TFP will continue to decline slowly in the future Trend [37]. Therefore, this paper predicts that the TFP growth rate will be 1.5% from 2021 to 2030, 1.4% from 2031 to 4040, and 1.3% from 2041 to 5050.

In summary, under the baseline scenario, China's economic development will achieve an average annual growth rate of 4.8% from 2020 to 2035 and an average annual growth rate of 3.4% from 2036 to 2050.

4.4. Industrial Structure Forecast. Use the gray system structure prediction method to predict the industrial structure in the input-output table. The calculation steps and methods are briefly described as follows.

Step 1: list the original data. Take the intermediate input data and intermediate output data of 42 industrial sectors in the 2002–2017 input-output table as the modeling sequence.

Step 2: establish a gray dynamic GM (1,1) model for the above data series. The model can reflect N related factors, and the equation of the gray state model is

$$X_1 = aX_1 + u, \tag{23}$$

where a represents the coordination coefficient between the variables.

TABLE 3: China's total population and employment forecast (2020–2050).

Year	Total population (unit: 100 million people)	Employment rate (unit: %)	Number of employees (unit: 100 million people)
2015	13.6782	56.34	7.7063
2020	14.0505	56.7	7.9666
2030	14.3203	56.91	8.1497
2040	13.8647	56.94	7.8946
2050	12.7471	56.95	7.2595

Note. The 2015 data comes from the National Bureau of Statistics of China, and the rest of the data are predicted by the author. Among them, the birth rate is assumed to be maintained at the level of 2019, and the average life expectancy is 77 years.

Step 3: according to the above GM model group, list the system state equation matrix:

$$\begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \\ \vdots \\ \dot{X}_n \end{bmatrix} = \begin{bmatrix} a_{11} & & & \\ & a_{22} & & \\ & & \ddots & \\ & & & a_{nn} \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{bmatrix}, \quad (24)$$

or it is written as

$$\dot{X} = X + U. \quad (25)$$

Predict the main indicator values of each quadrant, and calculate the structure of the intermediate input and intermediate output, respectively.

Step 4: use the Runge–Kutta method to solve the system state equation.

Step 5: perform cumulative reduction on the solution results of the equation to obtain the fitted and predicted values of each factor in the system and analyze the results. If there is a deviation, the coefficient matrix can be adjusted, simulated, and analyzed step by step to achieve a better prediction effect.

5. Model Construction and Forecasting

5.1. Forecast and Analysis of the Economic Value of Transportation. Through the analysis of total output, industrial structure, and complete consumption coefficient, combined with the basic data of the input-output table from 2002 to 2017, the economic value of transportation in 2035 and 2050 can be predicted. The forecast data is shown in Tables 4 and 5.

By 2035, the transportation value will be 696,538 trillion yuan. From 2017 to 2035, the average annual growth rate of the transportation value will be 7.25%. By 2050, the transportation value will be 1,121,637 billion yuan, and the average annual growth rate of transportation value will be 3.23%.

5.2. Regression Models. The difficulty of using the input-output model to analyze freight volume is to construct the functional relationship between value volume and freight traffic. Judging from the law of value volume and freight volume shown in the industrialization process of developed countries, the freight elasticity tends to gradually decrease,

that is, the growth rate of freight volume is lower than that of value volume. The economic significance is that the tertiary industry develops faster in the middle and late stages of industrialization, while the growth rate of the primary and secondary industries that bring more freight demand has slowed, leading to a further slowdown in freight volume growth.

Based on the 2002–2017, input-output table and the statistical data of freight volume from the National Bureau of Statistics of China analyze the functional relationship between transportation value and freight traffic. The statistical data over the years is shown in Table 6.

We started regression analysis with one explanatory variable. Firstly, analyze the correlation between freight value and freight traffic. The Pearson correlation coefficient of the two is 0.977, and the significance test probability is 0.01. The analysis shows that the correlation between the two is significant, and predictive analysis can be performed. Secondly, to predict freight traffic, it is necessary to perform a regression analysis on freight value and freight traffic. Regression analysis refers to the statistical method of quantitative analysis of the interdependence between two or more variables. According to the relationship between the independent variable and the dependent variable, it can be divided into linear regression analysis and nonlinear regression analysis. Nonlinear regression includes power function and logarithmic function.

Given the characteristics of the growth rate of freight traffic, the quadratic function, cubic function, compound function, exponential function, logistic function, and *s* function are excluded because the predicted values of these models are too high or too low. Based on the relationship between freight value and freight volume from 2002 to 2017, this paper uses the freight value as an independent variable and freight volume as a dependent variable to construct one-variable linear, power, and logarithmic functions. The fitting effect and prediction are shown in Table 7.

Although the linear regression model and power regression model have higher R^2, the logarithmic model also has good R^2. In recent decades, the freight economic elasticity of the United States, Germany, and other major developed countries has shown a trend of "∩" shape. Considering that China is about to enter the postindustrialization period and the growth law of freight volume in developed countries, the prediction effect of the logarithmic function is better. Based on the forecast of the logarithmic function (M1), China's freight volume in 2035 will be 64.485 billion tons and the freight volume in 2050 will be 72.518 billion tons. In 2017–2035, freight volume will achieve

TABLE 4: Forecast the value of each Industry's demand for transportation in 2035.

Industry number	Total output (unit: ten thousand yuan)	Complete consumption coefficient for transportation	Value of demand for transportation (unit: ten thousand yuan)	Percentage (%)
1	1694385607.67158	0.0954	161562882.649893	2.32
2	298638845.719085	0.0575	17175036.81653	0.25
3	229301196.836365	0.0395	9049175.65735843	0.13
4	129307146.775368	0.0501	6484079.06508876	0.09
5	211843472.6172	0.1060	22453457.2200924	0.32
6	3228474316.22645	0.1053	340105785.712392	4.88
7	853635246.66695	0.1376	117422343.628579	1.69
8	841006714.602347	0.1546	129998582.75392	1.87
9	609580270.115972	0.1214	74024374.9193083	1.06
10	890071738.040242	0.1254	111632630.312471	1.60
11	798728493.815842	0.1063	84897524.7620998	1.22
12	4039139792.04284	0.1386	559648454.680745	8.03
13	1880344512.12754	0.1396	262428339.838558	3.77
14	2504229609.09318	0.1066	266973521.479866	3.83
15	1065158416.30454	0.1155	123006525.792954	1.77
16	1682978234.46036	0.1205	202876346.366929	2.91
17	2429683947.14023	0.1271	308797754.667791	4.43
18	1370308888.66753	0.1164	159468719.375415	2.29
19	2612610892.33714	0.1040	271783708.552732	3.90
20	196602250.581008	0.1068	20990293.5368699	0.30
21	59787097.2414924	0.1322	7903185.38635047	0.11
22	136893612.608903	0.0673	9218409.26425335	0.13
23	1297190651.07111	0.0907	117675194.364156	1.69
24	159510145.246247	0.0904	14424819.0449973	0.21
25	54399953.1939841	0.0700	3806428.68705191	0.05
26	5957189642.43866	0.1190	709202296.350219	10.18
27	3161032372.82554	0.1779	562210630.028183	8.07
28	367581961.218591	0.2333	85768156.9498018	1.23
29	2214431048.31268	0.0716	158565802.762279	2.28
30	3292349264.93366	0.0798	262858124.788314	3.77
31	1035351065.40907	0.0949	98272095.2840489	1.41
32	4251929683.41493	0.0642	272915377.438803	3.92
33	2815285849.95493	0.0470	132374469.392868	1.90
34	3206746606.76096	0.1609	515839451.13986	7.41
35	377897718.800984	0.1301	49152590.0449114	0.71
36	1602255760.98183	0.1285	205911785.908507	2.96
37	364681798.109706	0.1080	39389822.0622763	0.57
38	774785377.775754	0.0624	48379471.9241988	0.69
39	1060080189.38893	0.0458	48525487.4586229	0.70
40	1375216767.21162	0.0961	132192061.925051	1.90
41	482313945.881959	0.1049	50578115.6117033	0.73
42	1938419823.08232	0.0977	189436875.490029	2.72

an average annual growth rate of 1.65% and freight volume in 2035–2050 will achieve an average annual growth rate of 0.79%. For comparison, China's average annual growth rate of freight volume from 2000 to 2010 was 9.09%, and the average annual growth rate of freight volume from 2010 to 2020 was about 3.8%. Figure 1 shows the changes in the value of each industry's demand for transportation.

From the perspective of structural changes in the proportion of transportation demand by various industries, from 2017 to 2050, almost the proportions of the primary and secondary industries have declined, while the proportions of the tertiary industry have almost increased. This shows that, in the postindustrialization period, the development of the service industry was significantly faster than the development of other industries, which also led to a further slowdown in the growth of freight traffic.

From the statistics of the past years, the ranking of the value of transportation demand by each industry is shown in Figure 2.

As can be seen from the above figure, apart from the transportation industry itself, the largest demand for transportation is the construction industry, chemical industry, metal smelting, and rolling processing industry in order. From the comparison of the three industries, the second industry has the largest demand for transportation, with an average demand of 67.56%, followed by

TABLE 5: Forecast value of each Industry's demand for transportation in 2050.

Industry number	Total output (unit: ten thousand yuan)	Complete consumption coefficient for transportation	Value of demand for transportation (unit: ten thousand yuan)	Percentage (%)
1	2305058914.95858	0.1038	161562882.649893	2.32
2	225399239.252031	0.0473	17175036.81653	0.25
3	296358702.504236	0.0376	9049175.65735843	0.13
4	130754716.209892	0.0222	6484079.06508876	0.09
5	309703690.668892	0.1044	22453457.2200924	0.32
6	4993316219.24954	0.1070	340105785.712392	4.88
7	1169877601.05839	0.1415	117422343.628579	1.69
8	1168227930.42133	0.1640	129998582.75392	1.87
9	898528918.228418	0.1192	74024374.9193083	1.06
10	1296795582.07195	0.1245	111632630.312471	1.60
11	1103236675.70768	0.1197	84897524.7620998	1.22
12	6082124100.93906	0.1380	559648454.680745	8.03
13	2962043458.50494	0.1397	262428339.838558	3.77
14	3516241093.09762	0.0987	266973521.479866	3.83
15	1588705051.31154	0.1102	123006525.792954	1.77
16	2334054745.42645	0.1144	202876346.366929	2.91
17	3772776250.86454	0.1225	308797754.667791	4.43
18	1956366422.70817	0.1088	159468719.375415	2.29
19	4072416886.88244	0.0959	271783708.552732	3.90
20	273918886.849786	0.0980	20990293.5368699	0.30
21	69258710.8799772	0.1317	7903185.38635047	0.11
22	190762990	0.0681	9218409.26	0.13
23	1815383914	0.0927	117675194	1.69
24	269735335	0.0990	14424819	0.21
25	75433673.6	0.0705	3806428.69	0.05
26	9443402536	0.1151	709202296	10.18
27	5471472846	0.1713	562210630	8.07
28	811383667	0.2225	85768156.9	1.23
29	4335630503	0.0719	158565803	2.28
30	5650048503	0.0729	262858125	3.77
31	1659109449	0.0934	98272095.3	1.41
32	8406177069	0.0663	272915377	3.92
33	5398007001	0.0515	132374469	1.90
34	6425920047	0.1576	515839451	7.41
35	744685082	0.1314	49152590	0.71
36	3083798855	0.1208	205911786	2.96
37	675704995	0.1077	39389822.1	0.57
38	1377773846	0.0521	48379471.9	0.69
39	1788434989	0.0397	48525487.5	0.70
40	2444382047	0.0912	132192062	1.90
41	888041276	0.1044	50578115.6	0.73
42	3457545322	0.0978	189436875	2.72

the tertiary industry, with an average demand of 29.36%, and, finally, the primary industry, with an average demand of 3.08%.

5.3. Time Series Models.

Time series regression is another reasonable method to examine the relationship between time-ordered variables. In recent decades, the freight volume per unit GDP has been declining year by year, which is closely related to the change of industrial structure. The fitting and forecasting trend line is shown in Figure 3 (M2).

Model 2 shows good fitting effect; according to Model 2, China's freight volume will be 77.31 billion tons in 2035 and 87.81 billion tons in 2050.

The single-equation autoregressive integrated moving average (ARIMA) time series model has also achieved good forecasting results [81, 82]. The ARIMA model is a model in which forecasted values are obtained by regressing past values of the variable itself and the current value with the error terms of the past values at different lag lengths. The proposed model structure is given in

$$Y_t = C + \alpha_1 GDP_1 + \alpha_2 GDP_2 + \beta Y_{t-1} + \varepsilon, \tag{26}$$

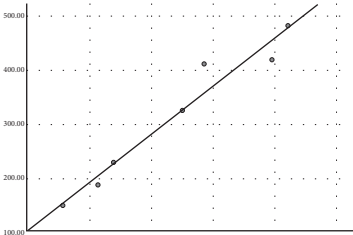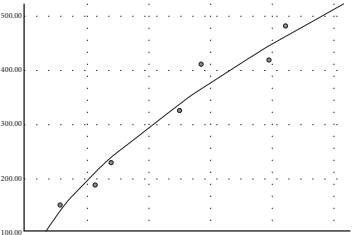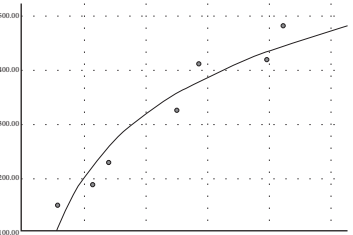where Y_t represents the freight in million tons in year t and GDP_1 represents the difference between the added value of the primary industry this year and the previous year. The remaining variables and parameters are self-explanatory. The fitting results are as follows (M3):

Table 6: 2002–2017 freight demand value and freight volume statistics.

Year	Transportation value (unit: ten thousand yuan)	Freight volume (unit: 100 million tons)
2002	284916168.9	148.34
2005	569828620.4	186.21
2007	698441069	227.58
2010	1250578926	324.18
2012	1426917180	410.04
2015	1976730089	417.59
2017	2108324779	480.49

Data source: China National Bureau of Statistics and the author's calculations.

Table 7: The fitting effect of different models and the predicted value of freight volume comparison.

	Unary linear function	Power function	Logarithmic function
Fitting curve			
Fitting equation	$y = 0.0000001784 * x + 101.547$	$y = 0.001 * 0.607^x$	$y = -3176.496 + 168.607 * \mathrm{LN}(x)$
R^2	0.977	0.966	0.923
Freight volume forecast in 2035	1344.17	943.34	644.85
Freight volume forecast in 2050	2102.55	1259.68	725.18

Data source: China National Bureau of Statistics and the author's calculation, unit: 100 million tons.
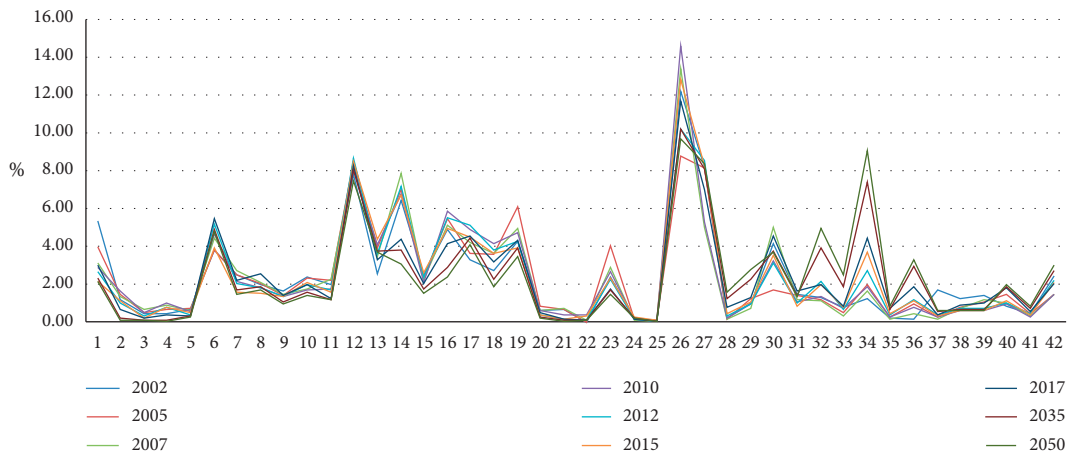
Figure 1: Statistics of changes in the value of transportation demand for various industries in China from 2002 to 2050. Data source: China National Bureau of Statistics and the author's calculation; 1–42 represent the serial numbers of each industry.
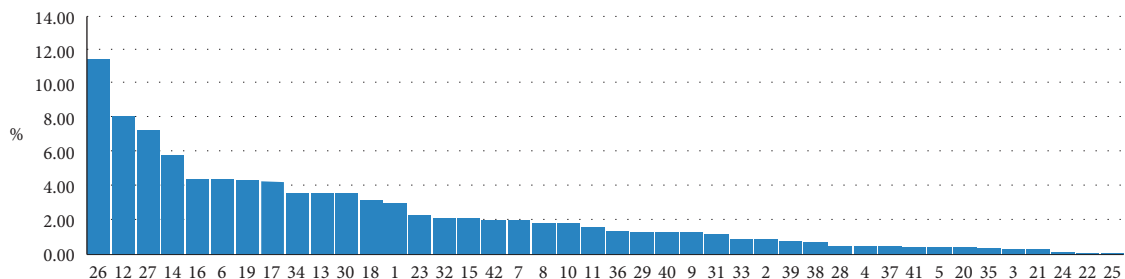

Figure 2: Statistics on the average proportion of the demand for transportation by various industries in China from 2002 to 2050. Data source: China National Bureau of Statistics and the author's calculation.
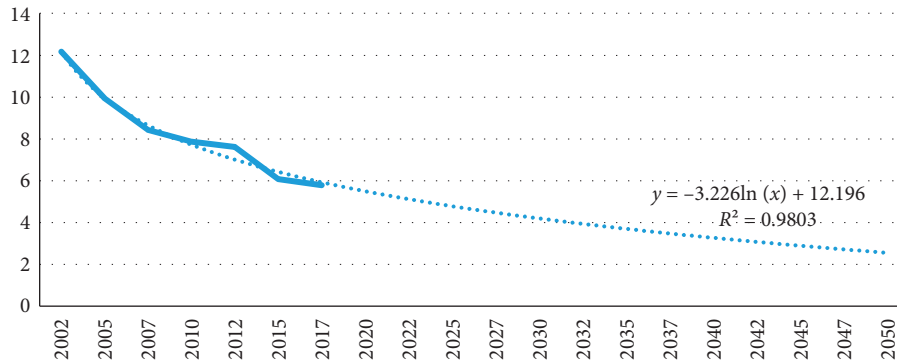
FIGURE 3: Forecast chart of freight volume per unit GDP. The solid line is the actual freight, and the dotted line is the predicted freight. The ordinate is the freight volume per GDP, and the unit is 100 million tons/trillion yuan.

$$Y_t = -10.072 + 40.874\mathrm{GDP}_1 + 9.834\mathrm{GDP}_2 + 0.976Y_{t-1}. \tag{27}$$

According to Model 3, China's freight volume will be 65.02 billion tons in 2035 and 79.18 billion tons in 2050. The errors for univariate time series models vary from about 0.06% to 7.98%, whereas the error for multivariate time series models lies between 0.13% and 7.17% at 95% confidence level. Multivariate time series model shows better prediction effect and further verifies the accuracy of the regression model.

6. Numerical Experiments and Analysis

6.1. Analysis of the Impact of Changes in the Economic Value of Transportation. The complete decomposition model is used to decompose the changes in the economic value of transportation, and the effects of changes in the complete consumption coefficient, changes in industrial structure, and changes in economic aggregates on the economic value of transportation are calculated, respectively. The results are shown in Table 8.

From 2017 to 2035, the economic value of transportation increased to 498,865 billion yuan. From the perspective of industrial structure, the secondary industry has the greatest impact on the incremental value of transportation, accounting for 53.42%, the tertiary industry also has a greater impact, accounting for 44.53%, and the primary industry has the least impact, accounting for 2.05%. From the perspective of influencing factors, the increase in total output has the greatest impact on the changes in the economic value of transportation, accounting for 80.88%, the second is the change in the complete consumption coefficient, accounting for 19.14%, and changes in the industrial structure make transportation the economic value increment decreased by 0.01%.

The increase in the economic value of transportation from 2017 to 2050 was 923,964 billion yuan. From the perspective of industrial structure, the tertiary industry has the greatest impact on the incremental value of transportation, accounting for 49.28%, the secondary industry also has a greater impact, accounting for 48.77%, and the primary industry has the least impact, accounting for 1.95%. From the perspective of

influencing factors, the increase in total output has the greatest impact on the changes in the economic value of transportation, accounting for 86.55%, the second is the change in the complete consumption coefficient, accounting for 13.9%, and changes in the industrial structure make transportation economic value increment decreased by 0.45%.

6.2. Analysis of the Impact of Changes in Economic Aggregates on Freight Volume. Because of the uncertainty of total economic growth, two scenarios of faster economic development and slower economic development are considered:

(1) Scenario of relatively rapid economic development: in this scenario, China's economy will develop faster. It will achieve an average annual growth rate of 5% from 2021–2035 and an average annual growth rate of 3.6% from 2036–2050. Some institutions and scholars are optimistic about China's development, as shown in Table 9.

(2) Scenario of slower economic development: in the context of slower economic development, China's economic development is slightly lower than the baseline scenario. The average annual growth rate of China's economic development from 2021–2035 will drop to 4.6% and the average annual growth rate will drop to 3.2% from 2036–2050.

According to the previous assumptions for the two scenarios, the logarithmic function is used for prediction, and the calculation results and the comparison with the baseline scenario are shown in Table 10.

Judging from the calculation results of the three scenarios, the difference in economic growth rate has little effect on the forecast results of freight traffic. The degree of economic growth rate affecting freight volume represents the elasticity of GDP to freight traffic. The freight elasticity of the United States has gradually decreased since 1990 and is currently about 0.1-0.2. Germany's freight elasticity has gradually decreased since 1990 and is currently around 0.2-0.3. Due to the difficulty of economic recovery in Japan, freight elasticity has been in a negative state since 1990. Judging from the experience of the United States, Germany, and other developed countries, its freight elasticity is

TABLE 8: Analysis of the impact of changes in the economic value of transportation in 2017–2035.

	Primary industry	Percentage (%)	Secondary industry	Percentage (%)	Tertiary industry	Percentage (%)
2017–2035						
b_{jq}	64204832.37	62.81	526237944.4	19.75	364246875.7	16.40
s_{jq}	74125315.71	−72.52	310055653.5	−11.63	383447076.3	17.26
X_{jq}	112134478.7	109.71	2448872953	91.89	1473686908	66.34
ΔQ	102213995.3	100	2665055244	100	2221380860	100
2017–2050						
b_{jq}	103320453.6	57.44	650215278.5	14.43	530706763.8	11.65
s_{jq}	143829310.4	−79.96	789279860.7	−17.52	891515068.6	19.58
X_{jq}	220394994.6	122.52	4645078315	103.09	3131520513	68.77
ΔQ	179886137.8	100	4506013733	100	4553742346	100

Data source. China National Bureau of Statistics and the author's calculation, unit: 10,000 yuan.

TABLE 9: Prediction of China's economic growth rate by some institutions and scholars.

Research institutions and scholars	2021–2030	2031–2040	2041–2050
Goldman Sachs	5.7	4.4	3.6
HSBC	5.5	4.4	4.1
Li Shantong, Hou Yongzhi	5.4	4.5	3.4
Li Jingwen	5.4	4.9	4.3
Xu Xianchun	5.5	4.5	3.5

Source: the long-term outlook for the BRICs and N-11 postcrisis; HSBC Global Economics Research Team; Li and Hou [83]; Li [84]; Xu [85]; unit: %.

TABLE 10: Comparison of China freight volume forecasts under three scenarios.

Scenario	Forecast for 2035	2017–2035 average annual growth rate of freight traffic (%)	Forecast for 2050	2035–2050 average annual growth rate of freight traffic (%)
Baseline scenario	644.85	1.65	725.18	0.79
Slow economic development scenario	639.7	1.60	719.36	0.79
Faster economic development scenario	649.99	1.69	739.44	0.86

Data source: author's calculation, forecast unit: 100 million tons.

between 0.1–0.3, which shows that the impact of economic aggregate growth on freight volume is gradually decreasing.

6.3. Analysis of the Impact of Industrial Structure Changes on Freight Traffic. In the late industrialization and post-industrialization period, the decline in freight volume growth was mainly caused by the upgrading of industrial structure. In this stage of industrialization, the proportion of the service industry will increase from 50% to about 70%–80%. The entire national economy is dominated by the service economy and information economy, so the growth rate of freight volume is limited.

To sort out the upgrading of China's industrial structure, its evolutionary structure over the years and the structure forecast for 2035 and 2050 are shown in Figure 4.

From the perspective of future changes in the total output structure of the industry, the primary industry has the largest decline, from 4.88% in 2017 to 2.2% in 2050, and the secondary industry has all declined to vary degrees.

Among them, the coal industry, petroleum industry, and metal mining accounted for the largest decline, with 77.9%, 45.14%, and 75.74%, respectively. The proportion of the accommodation and catering industry in the tertiary industry dropped slightly by 0.1 percentage point, and the rest increased to varying degrees. Among them, the financial industry rose the most, from 4.18% in 2017 to 8.01% in 2050.

By 2050, China's three industrial structures based on total output will account for 2.2 : 47.66 : 50.14, respectively. The structure evolution of the three industries is shown in Figure 5.

To compare the impact of industrial structure on transportation, consider the change in freight volume when only changing the industrial structure with the total economic aggregate, and the complete consumption coefficient is unchanged. Assuming that the industrial structure of 2017 is maintained in 2035 and 2050 and that the demand for freight and passenger transportation from agriculture and industry is 8 : 2 and the demand for freight and passenger
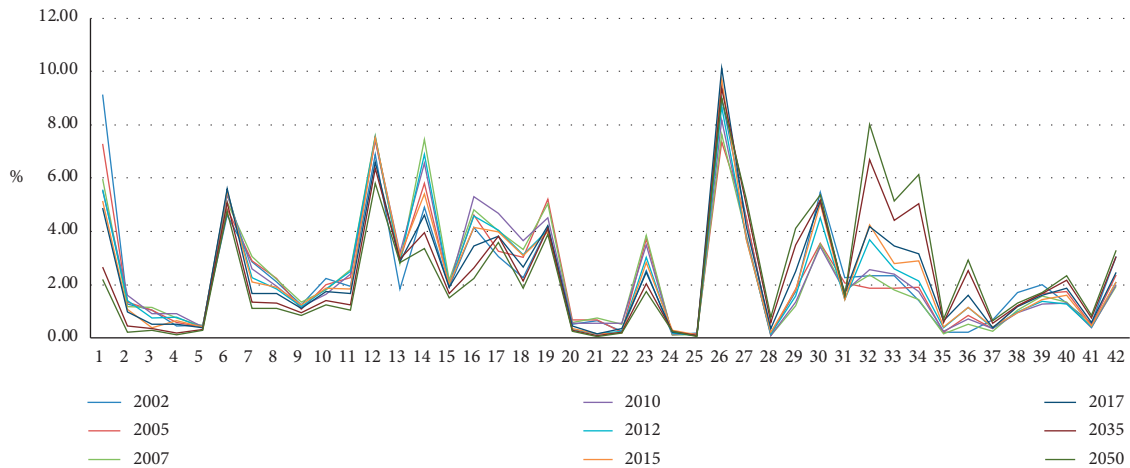
FIGURE 4: The evolution of China's industrial structure based on total output from 2002 to 2050. Data source: China National Bureau of Statistics and the author's calculation; 1–42 represent the serial numbers of each industry.
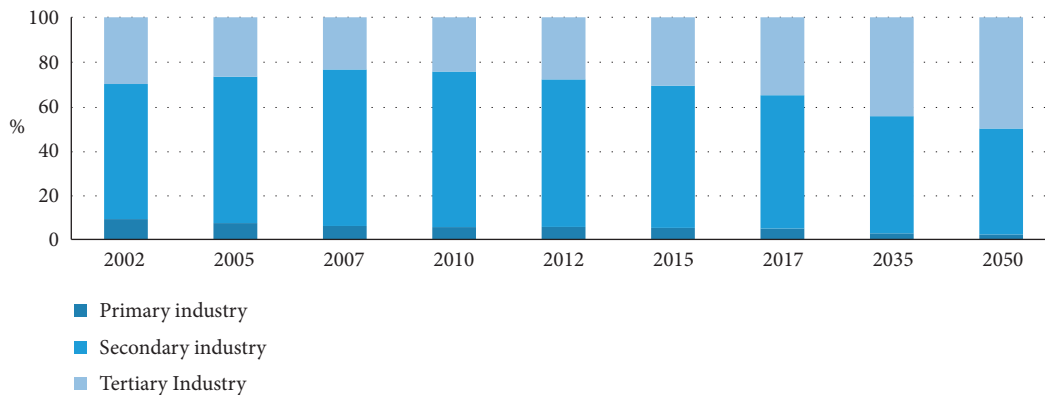

FIGURE 5: The evolution of China's three industrial structures based on total output. Data source: China National Bureau of Statistics and the author's calculation.

transportation from the service industry is 2 : 8, then the forecast value of freight volume in 2035 and 2050 is shown in Table 11.

When the industrial structure of 2017 is maintained, the predicted value of freight volume in 2035 and 2050 is 9.49% and 16.22% higher than the baseline value, respectively. This shows that the upgrading of the industrial structure has slowed down the growth rate of freight traffic. In the forecast of freight traffic, the importance of industrial structure exceeds that of economic aggregate.

6.4. Analysis of the Impact of Changes in the Complete Consumption Coefficient on Freight Traffic. The impact of technological progress on transportation is mainly reflected in three aspects: industrial upgrading has led to a decline in the proportion of traditional industrial added value such as coal, petroleum, and steel and an increase in the proportion of high-end industries such as computers, precision instruments, and equipment manufacturing. The improvement of technology makes the industry's consumption rate of coal, oil, natural gas, and other energy

sources gradually drop; the transportation capacity and service level are improved. Reflected in the input-output table, it is mainly reflected in the change of the complete consumption coefficient.

The complete consumption factor is affected by two factors. One is the direct consumption coefficient, which represents the relationship between the demand of the industry and another industry and reflects the degree of energy consumption; the second is the indirect consumption coefficient, which represents the direct and indirect demand relationship between the industry and other industries and reflects the depth and breadth of the industrial chain. Figure 6 shows the direct consumption of transportation by various industries.

From the perspective of the direct consumption coefficient, the largest direct consumption of transportation is the transportation, postal, and nonmetallic mining and processing industries. Because the direct consumption coefficient cannot reflect the industry's complete demand for transportation, it is necessary to calculate the complete consumption coefficient. The complete consumption coefficient is shown in Figure 7.

TABLE 11: Comparison of the predicted value of freight volume with the baseline predicted value when the industrial structure remains unchanged.

	Forecast for 2035		Forecast for 2050	
	Baseline forecast	Predicted value when the industrial structure is unchanged	Baseline forecast	Predicted value when the industrial structure is unchanged
Primary industry	25.85	47.3	25.57	56.75
Secondary industry	510.88	574.58	553.92	686.03
Tertiary industry	107.85	83.83	145.69	99.99
Total freight volume	644.58	705.72	725.18	842.77

Data source: China's National Bureau of Statistics and the author's calculation, freight volume unit: 100 million tons.
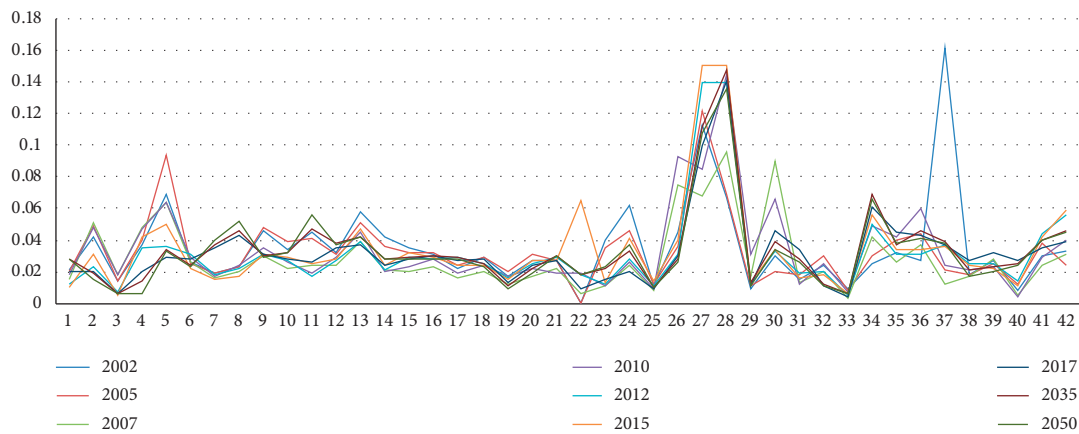

FIGURE 6: Statistics of direct consumption coefficients over the years and forecast values in 2035 and 2050. Data source: China's National Bureau of Statistics and the author's calculation; 1–42 are the industry numbers.
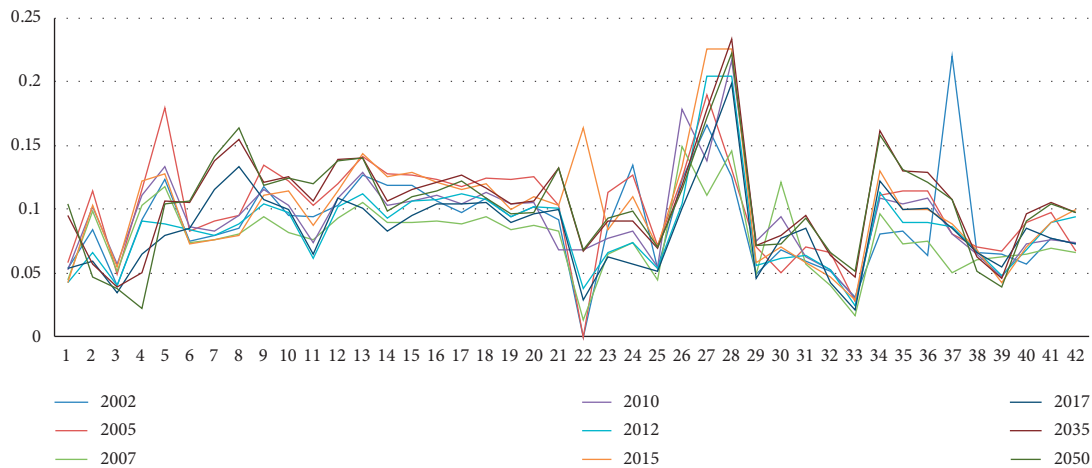

FIGURE 7: Statistics of complete consumption coefficient over the years and forecast values in 2035 and 2050. Data source: China's National Bureau of Statistics and the author's calculation; 1–42 are the industry numbers.

From the perspective of the full consumption coefficient, the postal, transportation, and construction industries have the greatest demand for transportation. From the perspective of the changes in the complete consumption coefficient and the direct consumption coefficient, except for petroleum, coking products, and nuclear fuel processing industries, the coefficient of variation of the complete consumption coefficient of other industries exceeds that of the direct consumption coefficient. This indicates that the industry chain will further deepen from now on, which also leads to a further increase in the complete consumption coefficient.

Assuming that the full consumption coefficient of 2017 is maintained in 2035 and 2050, the forecast value of freight volume in 2035 and 2050 is shown in Table 12.

When the complete consumption coefficient remains unchanged, the predicted value of freight volume in 2035

TABLE 12: Comparison of the predicted value of freight volume with the baseline predicted value when the complete consumption coefficient remains unchanged.

	Forecast for 2035		Forecast for 2050	
	Baseline forecast	Predicted value when the complete consumption coefficient does not change	Baseline forecast	Predicted value when the complete consumption coefficient does not change
Primary industry	25.85	18.14	25.57	13.3
Secondary industry	510.88	317.02	553.92	459.76
Tertiary industry	107.85	45.25	145.69	116.55
Total freight volume	644.58	380.41	725.18	589.6

Data source: China's National Bureau of Statistics and the author's calculation.

and 2050 will decrease by 40.98% and 18.7%, respectively. This shows that the change in the complete consumption coefficient is the main reason for the change in freight traffic.

7. Conclusion

This paper constructs a freight value and freight volume analysis model based on the input-output method and predicts the development trend of China's freight volume and uses a complete decomposition model to analyze the factors affecting freight value and freight volume. The study reached the following conclusions:

(1) The growth rate of China's freight volume will gradually decline, with an average annual growth rate of 1.65% from 2017 to 2035 and an average annual growth rate of 0.79% from 2035 to 2050. Research shows that China freight volume in 2035 is 64.458 billion tons and 72.518 billion tons in 2050.

(2) From the perspective of industrial structure, the tertiary industry has the greatest impact on the incremental value of transportation, accounting for 49.28%, the secondary industry also has a greater impact, accounting for 48.77%, and the primary industry has the least impact, accounting for 1.95%. From the perspective of influencing factors, the increase in total output has the greatest impact on the changes in the economic value of transportation, accounting for 86.55%, the second is the change in the complete consumption coefficient, accounting for 13.9%, and changes in the industrial structure make transportation economic value decreased by 0.45%.

(3) When the industrial structure of 2017 is maintained, the predicted value of freight volume in 2035 and 2050 is 9.49% and 16.22% higher than the baseline value, respectively. This shows that the upgrading of the industrial structure has slowed down the growth rate of freight traffic. When the complete consumption coefficient remains unchanged, the predicted freight volume in 2035 and 2050 will decrease by 40.98% and 18.7%, respectively. This shows that the change in the complete consumption coefficient is the main reason for the change in freight traffic. The change in

economic aggregate has a limited impact on freight traffic, and the upgrading of industrial structure will cause a decline in freight traffic. The increase in the full consumption coefficient indicates that the integration between industries is improving, which means that the accuracy of freight forecasting through industry division will decrease.

As this paper is compared with the previous models, the main differences of this paper are as follows: (1) this paper further subdivides the industry, dividing the industry sector into 42 sectors, which is more refined than the previous three industry divisions and can better reflect the relationship between different industries and freight demand; (2) in the past, factor analysis often used methods such as multiple regression and cluster analysis, which could not reflect the importance and relevance of factors. This paper uses a complete decomposition model to analyze the influencing factors of freight volume, which can effectively analyze the relationship between the influencing factors; (3) this paper combines gray forecasting and input-output analysis, which can analyze the factors of future freight demand changes, which is more practical and referential than the previous analysis of the current status of influencing factors.

Due to the lack of freight data of related industries, this paper predicts the freight volume from the overall freight value and industry GDP, and the accuracy of the forecast needs to be tested. Future research can further analyze the influence relationship between different industries based on this model, use feature analysis to further optimize the industrial structure, and use this model in conjunction with the OD tables for transportation planning research. Further statistics on the freight volume data of related industries and the use of the fusion of multiple models to make predictions can improve the accuracy of freight volume forecasts, which is the direction of future research.

Data Availability

The data used to support the findings of this study are included in the paper.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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