IOP Conference Series: Earth and Environmental Science

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To cite this article: Xuecheng Wang and Yi Zhang 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **552** 012013

IOP Conf. Series: Earth and Environmental Science **552** (2020) 012013 doi:10.1088/1755-1315/552/1/012013

The Impact of High-quality Development of China's Economy and the Change of Industrial Structure on Energy consumption in Transportation

XUECHENG WANG[1], Yi Zhang[2]*

[1]China Academy of Transportation Sciences, Beijing China,

[2]China Academy of Transportation Sciences, Beijing China,

[1]Wangxuecheng027@163.com, [2]4043665@qq.com

Abstract—This paper explores the impact of high-quality economic development orientation and changes in China's industrial structure on sustainable transportation development, including the impact of changes in transportation volume, transportation demand characteristics, and transportation energy consumption. the quantitative model of the relationship between macroeconomic factors like industrial structure changes with transportation demand and energy consumption is constructed. On this basis, traffic energy consumption is predicted under the future economic development scenarios. The research shows that the economic development model and the change of industrial structure are highly correlated with the energy consumption of transportation. The economic high-quality development scenario, following the corresponding change of transportation modes will increase the transportation energy consumption per transportation volumes, and the total amount transportation volumes and its energy consumption will decline.

1. INTRODUCTION

During the long-term rapid growth of China's economy, China's industrial structure is also undergoing a series of far-reaching changes [1]. In the past 40 years of reform and opening up, China's industrial restructuring has continued to deepen, the three industrial structures have changed, and the contribution of consumption and service industries to economic growth has increased [2,3]. This is in line with the general law of industrial structure evolution. In recent years, China's economy has also emerged with a series of new features and new trends. In particular, the Chinese government has proposed ecological civilization construction and high-quality growth of economic development orientation, which is a fundamental requirement for future development goals and development paths [4, 5, 6]. It shows that China's economy has entered a new stage of transition from high-speed growth to high-quality development [7, 8]. These changes can be reflected in the structural changes of the three industries and the structural characteristics of each industry. The changes in economic structure also bring about changes in energy consumption. On the one hand, people's living standards and the quantity and quality of material consumption have been improved. On the other hand, technological progress and industrial upgrading have improved production efficiency and energy structure efficiency [9]. These also reflect the transportation and the basic and leading industries of national economic and social development [11, 12].

The transportation industry is one of the basic departments of the national economy, and it plays a role in the entire social mechanism. In recent years, due to the rapid development of China's economy and the rapid development of the transportation industry itself, the energy consumption of the transportation industry has grown rapidly, and it has become the third largest energy-consuming industry after industrial and living consumption [14]. The factors affecting the energy consumption of the transportation industry mainly include the stage of social and economic development, transportation structure, transportation infrastructure, transportation equipment level, transportation efficiency and travel mode [15, 16]. At certain stages of social and economic development, the transportation structure is an important influence. factor. The change of transportation structure is the reflection of the change of transportation demand. The root of the change of transportation demand structure lies in the change of industrial structure [17]. Since the composition of each industrial sector and the relationship between them and the proportional relationship are different, the resulting transportation demand is different, which has an impact on the total energy consumption, energy consumption and structure of the transportation industry.

In this paper, we focused on the change of China’s transportation’ energy consumption under the perspective of China’s economy high-quality development and industrial structure change. Through the changes in the characteristics of transportation demand under economic transformation, in this paper, we reveal the development trend of energy intensity, predict its future energy consumption and energy consumption, and provide relevant policy basis for energy conservation and emission reduction.

2. INDUSTRIAL STRUCTURE AND TRANSPORTION ENERGY CONSUMPTION

2.1 Correlation Analysis of Energy Consumption and Industrial Structure in Transportation Industry

The industrial structure refers to the composition of each industry and the relationship and proportional relationship between various industries. From 1994 to 2009, the proportion of the output value of the primary industry to the gross national product fell, from 19.86% in 1994 to 10.35% in 2009, a decrease of 9.51 percentage; the proportion of tertiary industry output increased, from 1994 33.57% rose to 43.36% in 2009, an increase of 9.79 percentage; the proportion of the output value of the secondary industry was not significant, and remained at around 47%. It can be seen that the adjustment of industrial structure is mainly to accelerate the transformation and upgrading of the industry. With the development of the economy, China's industrial structure has been further optimized. In the long run, the proportional relationship between the three industries has been significantly improved, and the industrial structure is becoming rationalized and highly transformed.

The impact of industrial structure on the energy consumption of the transportation industry is mainly through the impact of transportation demand, which in turn affects the structure of the transportation industry. The transportation industry structure refers to the organic proportion and composition of various aspects and links within the transportation department. It mainly refers to the status of various modes of transportation in the integrated transportation system and their proportional relationship, including the volume structure and area. Structure, capacity structure and other aspects

The transportation industry is a resource-occupied and energy-consuming industry. With the growth of domestic passenger and cargo transportation, the scale of energy consumption in the transportation industry has increased year by year, and the growth rate of energy consumption is higher than the growth rate of energy consumption in the whole society. One of the fastest growing industries in China. According to statistics and accounting data, the energy consumption of transportation increased from 231 million tons in 2005 to 496 billion tons in 2018, an increase of 214%, with an average annual growth rate of 5.6%. Energy consumption accounts for an increase in the proportion of energy consumption in the country, from 9.2% in 2005 to 10.7% in 2018. As shown in Figure 1.

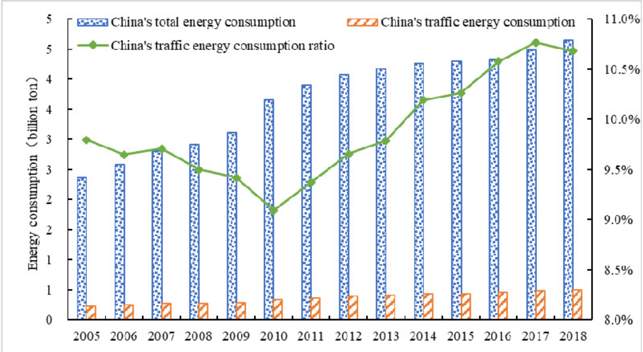

Figure.1 China's transportation industry accounts for energy consumption

Since 2005, the carbon emissions of different modes of transportation have maintained relatively rapid growth. Among them, freight transportation is the industry with the most energy consumption in the transportation sector, and the total energy consumption of freight transportation is increasing. Intercity carbon emissions have continued to increase since 2005, but the growth rate is relatively small. The carbon emissions of urban passenger transport also showed a trend of continuous increase, and the growth rate was faster. The total energy consumption gradually approached the energy consumption of intercity passenger transport. The details are shown in Figure 2.

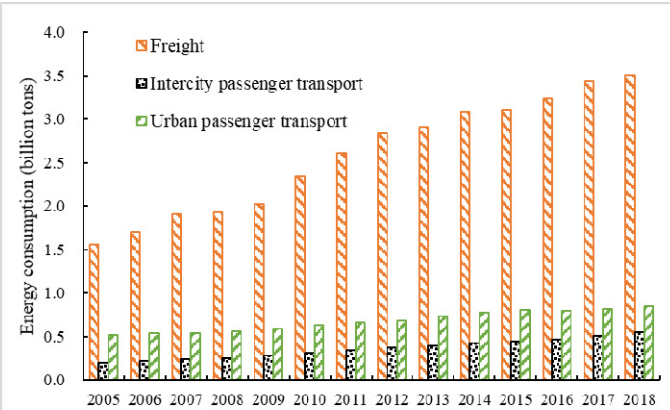

Figure.2 Energy consumption of China's transportation sector under different modes

From the point of view of cargo transportation, road transportation is the most energy consumption model, accounting for 79% in 2018. Since 2005, China's economy has experienced rapid development, and its GDP growth rate has reached 9.3%. Especially with the implementation of China's “four trillion” economic stimulus plan, the roads need materials for infrastructure such as steel and cement. The demand for transportation has increased significantly. The average annual increase in road transport turnover between 2005 and 2018 was 8.5%. At the same time, 90% of the energy consumption of road transport relied on fossil energy (IEA, 2017), resulting in a steady increase in road freight carbon emissions. With the advent of e-commerce, the demand for freight in urban distribution has increased significantly. From 2010 to 2018, the proportion of energy consumption in total freight increased from 0.1% to 0.263%. The energy consumption of waterway freight transport are relatively low compared to road freight, and the total amount shows a slow upward trend. Freight emissions from other modes are smaller. The details are shown in Figure 3.

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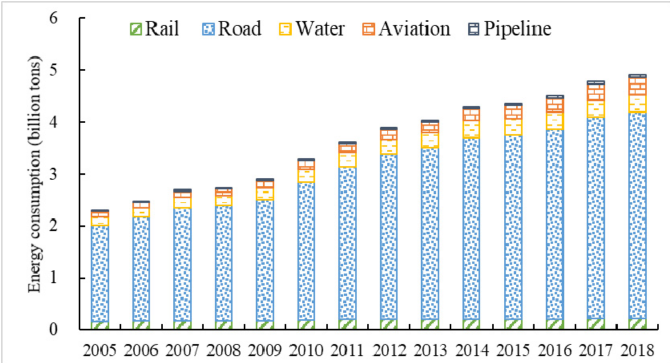

Figure.3 Energy consumption under the freight distribution model

2.2 Transport strength correlation sequence and data for economic growth

Industrial structure is closely related to freight intensity. Due to the “heavy” industrial structure in China, the transportation volume of bulk low-value-added products such as coal accounts for a large proportion, which directly leads to a high transportation intensity. The road freight turnover per unit of GDP in China is four times that of the United States. Objectively, it is an important reason for the high proportion of China's freight carbon emissions. Compared with foreign developed countries, passenger carbon emissions account for a higher proportion than freight. Therefore, the traffic demand brought by industrial structure and economic activities and the corresponding trend of traffic carbon emissions are worth studying. With the advancement of the new urbanization process, the passenger intensity is positively correlated with the social and economic development, that is, the passenger transportation intensity in the region with high economic development level is large, not only the demand for derivative is greatly increased, but also the spatial scope is expanding; but the freight intensity and economy The level of development is inversely proportional, that is, the economic development stage is still in an extensive area, the freight intensity is high; the level of economic development is high, the proportion of high value-added goods is high, and the freight intensity is lower.

According to the correlation analysis between China's GDP and passenger and freight volume data over the years, the growth of traffic volume is consistent with the growth of the economy. With the central government actively adjusting the industrial structure and vigorously developing the development orientation of service industry, modern agriculture and high-end manufacturing industry, Although the current cargo intensity is still large, it will show a downward trend year by year.

Table 1 Comparison of carbon emissions in the world

	Road freight turnover (million tons * km)	GDP (100 million US dollars)	Turnover of unit GDP road freight (ton km/dollar)
China	5795572	103557	55.9
United States	2914345	173900	16.7
Japan	210000	48500	4.3
EU	1836992	148000	12.4

From China ‘a road freight perspective, road freight continues to increase from 2005-2016. We can see that the trend of GDP is similar with the trend of road freight. However, it is worth mentioning that the total volume of road freight decreased a little bit since 2015. From figure 4 and 5, we can see that the freight intensity per GDP kept decreasing since 2005, which means that the efficient of China’s efficient of freight kept increasing.

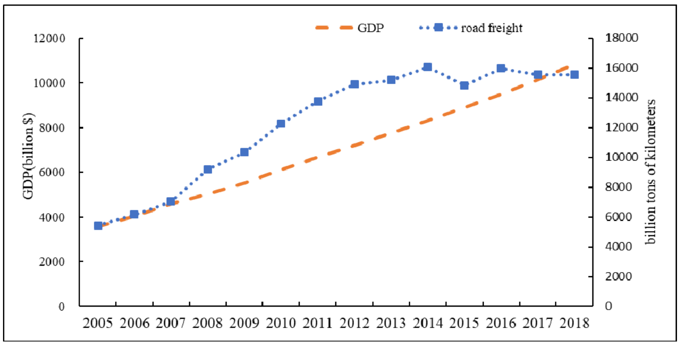

Figure4 China's road freight and GDP trend

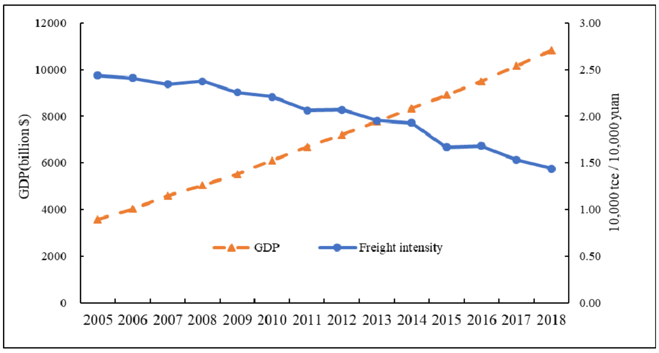

Figure5 the relationship between GDP and freight intensity

3. METHODOLOGY

3.1 Construction and calculation of assoclation models

Set the system behavior sequence to

$$X_i = \left[x_i(1), x_i(2), \ldots, x_i(n)\right] \quad i \in (0,1,2,\ldots,n) \tag{1}$$

Where, $i=0$ As the parent sequence, the rest are related sequences.

Start point zero image:

$$X_0^0 = \left[x_0^0(1), x_0^0(2), \ldots, x_0^0(n)\right] \tag{2}$$

$$X_i^0 = \left[x_i^0(1), x_i^0(2), \ldots, x_i^0(n)\right] \tag{3}$$

$$|S_0| = \left|\sum_{t=2}^{n-1} x_0^0(t) + \frac{1}{2}x_0^0(n)\right| \tag{4}$$

$$|S_i| = \left|\sum_{t=2}^{n-1} x_i^0(t) + \frac{1}{2}x_i^0(n)\right| \tag{5}$$

$$|S_i - S_0| = \left|\sum_{t=2}^{n-1}\left[x_i^0(t) - x_0^0(t)\right] + \frac{1}{2}\left[x_i^0(n) - x_0^0(n)\right]\right| \tag{6}$$

Gray absolute correlation ε_{0i}

$$\varepsilon_{0i} = \frac{1+|S_0|+|S_i|}{1+|S_0|+|S_i|+|S_i - S_0|} \tag{7}$$

The correlation degree calculation shows that the energy intensity of the transportation industry is basically consistent with the relative correlation of various industries in the national economy, indicating that the energy consumption of the transportation industry is closely related to various industries of the national economy, reflecting the ties and foundations of the transportation industry as a national economy. effect. The development of the transportation industry is in line with the development of the first, second and third industries. From the curve of the total energy consumption of the parent-station transportation industry, it is the first and second. The proportion of the structure of the industry and the comprehensive sequence of the national economy X1, X2, X3 are basically the same. The curve of the energy consumption of the transportation industry and the proportion of the first and second industry structure ratios and the correlation degree calculations show that the absolute correlation degree ri is 0.607, 0.631, 0.686, indicating that the absolute correlation degree is adjusted with the national industrial structure. Energy consumption has been highest in history and the second industry, shifting to the highest in the tertiary industry. At the same time, since the transportation industry itself also belongs to the category of the tertiary industry, its energy consumption characteristics have not fundamentally changed. This point can still be reflected in the comprehensive correlation degree.

Table.2 Grey correlation degree of energy consumption and industrial structure of transportation industry

primary industry			Secondary industry			Tertiary Industry		
ε_{01}	γ_{01}	ρ_{01}	ε_{02}	γ_{02}	ρ_{02}	ε_{03}	γ_{03}	ρ_{03}
0.500	0.607	0.554	0.500	0.631	0.566	0.500	0.686	0.593

3.2 Energy intensity

The energy intensity is equal to the ratio of energy input (energy consumption) to economic output τ :

$$\tau = \frac{E}{Y} \tag{8}$$

Where, E and Y represents energy input and economic output.

China's transportation industry and energy intensity of the first, second and third industries show as follows:

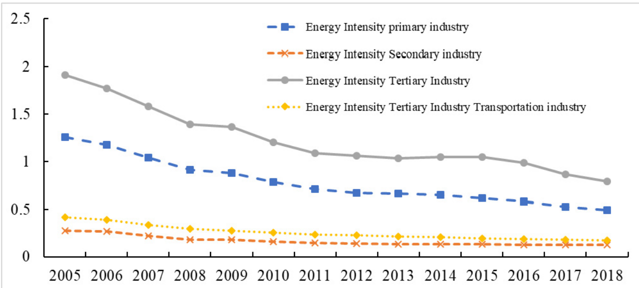

Figure6 China's transportation industry and energy intensity of three industries

Through calculations, China's transportation industry has seen a significant decline in energy intensity since 2005, with the upgrading of industries, the implementation of national energy conservation and emission reduction policies, the pace of technological advancement, and adaptation to economic restructuring. The energy intensity of the secondary industry and the primary industry also changed the fluctuation of energy intensity in 2005-2010, showing a steady downward trend. By fitting the energy intensity throughout the country over the years, it is found that the energy intensity of all provinces, municipalities and autonomous regions is exponentially decreasing, so the energy intensity is expressed by the following formula:

$$\tau_t = ke^{\lambda t} \tag{9}$$

Where, k is λ Constant, t is the rate of decline in energy intensity, Time series value. Based on the calculation data of related literatures and a large number of realistic statistical results, this paper proposes that the grey system model is used to express the development trend of the structural data series of energy intensity in various industries and provinces in China.

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4. RESULTS

Energy intensity forecast for future green transportation and related industries

Reviewing the trend of energy intensity in China's transportation from 2005 to 2018 and the first and second episodes of the national economy, the decline in energy consumption per unit of output indicates that the national economy is moving in the direction of green and low carbon. If this trend is maintained, "2009 China, The Sustainable Development Strategy Report proposes that the goal of reducing energy consumption per unit of GDP by 40-60% in 2005-2020 will be achieved. To this end, according to the characteristics of the current time series of energy intensity exponentially decreasing, it is proposed to use the gray model to predict, according to the energy intensity data of Table 3, establish the GM (1,1) model for the transportation industry energy, and get the transportation. Energy intensity time response function:

$$\hat{\tau}_J(t+1) = -29.976828 \cdot EXP(-0.060486 \cdot t) + 31.702628 \tag{10}$$

In order to reduce the verbosity of the article, the modeling theory and calculation process are omitted here. At the same time, in order to establish the reliability of the model, the test results are listed.

Energy intensity time response function for the national economy:

$$\hat{\tau}_G(t+1) = -12.942838 \cdot EXP(-0.094917 \cdot t) + 14.218838 \tag{11}$$

Time response function for energy intensity of the second industry:

$$\hat{\tau}_R(t+1) = -22.443707 \cdot EXP(-0.080638 \cdot t) + 24.369707 \tag{12}$$

Time response function for energy intensity in the primary industry:

$$\hat{\tau}_H(t+1) = -2.41232 \cdot EXP(-0.108433 \cdot t) + 2.68332 \tag{13}$$

The relative errors of the above various time response functions are generally within 5%, and the model accuracy is relatively high.

Input t=15 in function, in we can get energy intensity forecast for the transportation industry and various industries in the future is as follows：

Table.3 energy intensity forecast for the transportation industry

	Energy intensity	Rate of decline
Transportation	0.802	0.059
All sectors	0.341	0.091
Second industry	0.609	0.078
Tertiary Industry	0.061	0.102

5. CONLCUSIONS AND DISSCUSSIONS

In this paper, the previous study used GDP as an indicator to represent the level of social and economic development, and did not take into account the impact of industrial structure on transportation. Applying the grey correlation degree and the gray GM (1,1) model, the relationship between the energy intensity of the transportation industry and the first, second and third industries was established and the influencing factors were analyzed. The transportation industry is the world's largest oil consumption and fastest growing industry. The global transportation industry's CO2 emissions have increased by 136% in the past 30 years, especially in developing countries, the growth rate of transportation energy consumption and emissions has shown a rapid growth trend in the future. In the international economic development and competition, through industrial restructuring, in order to achieve energy conservation and emission reduction, while paying attention to the promotion and key impact of transportation in economic restructuring, it is very important to propose relevant technical and economic policies.

5.1 Calculatte the energy intensity of transportation industry by unit output value

The transportation industry plays a leading, basic and supportive role in the national economy. The secondary industry is the main source of freight turnover, while the tertiary industry is the main source of passenger turnover and freight turnover. Generate the source. The energy intensity of the transportation industry is usually calculated by the energy consumption per unit of turnover, but the transportation industry is the highest in terms of energy intensity per unit of output value. The energy intensity of the transportation industry in 2018 is 0.177, which is higher than the 0.49 (10,000 tons of standard coal / 10,000 yuan) of the first of 0.134 units of the industry (10,000 tons of standard coal / 10,000 yuan) the secondary industry. This is closely related to the transportation industry's output as the passenger and cargo turnover rather than the material characteristics.

5.2 Industrial upgrading and structural adjustment have made the energy intensity of the transportation industy highly correlated with the tertiary industy

The research shows that the energy consumption of the transportation industry is highly correlated with the secondary and tertiary industries, especially in recent years, the correlation with the tertiary industry is significantly stronger than other industries. This has not been consistent with the long-standing understanding that the transportation industry and the secondary industry have the highest correlation. Traditionally, the second industry, which is represented by industry, will cause greater demand for freight, but with the industry. With the adjustment of structure and the progress of industrialization and science and technology, the transportation demand will gradually change, the transportation goods will gradually shift to many high value-added products, and the share of original bulk commodities and other resource materials will gradually decrease, and the quality price ratio will be gradually reduced. Gradually reduce; at the same time, the development of e-commerce and modern logistics will also reduce the transportation turnover to a certain extent, which makes it possible for the energy intensity of the transportation industry to decrease exponentially with economic development.

5.3 The transportation industry will support energy consumption reduction

At the same time, according to the recommendations of the International Committee on Climate Change (2006), when calculating energy consumption, it is divided into fixed sources and mobile sources. The energy consumption from the transportation industry are basically mobile sources, that is, the occurrence and attraction of transportation turnover. The tertiary industry has exerted a large gravitational effect on the transportation turnover, that is, the main direction of energy consumption in the transportation industry has been the tertiary industry is offset. With the adjustment of China's industrial structure, this shift will gradually accelerate. Driven by the industrial structure effect and the effect of scientific and technological progress, the energy intensity of the transportation industry will decrease along the natural law, and the system operation of this sequence, the gray model can be described more effectively.

In conclusion, according to the literature, the 2020-2030 energy consumption intensity data predicted by the DDEPM model shows that China's energy consumption per unit of GDP will fall to 0.0123 (unit: 10,000 t/100 million) in 2030, compared to 2005. 58.6%. In 2030, China's GDP grew by 484.5% compared with 2005. In the same period, the growth rate of carbon emissions was 142.0%, and the growth rate of GDP was much larger than the growth rate of carbon emissions. The rapid growth of GDP made the potential for energy intensity decline huge. Based on the current price, the energy intensity data based on the current price is based on the actual consideration of trend forecasting. The data has not been converted into the constant price of the base year. Considering the adaptability and balance in the economic system, it seems that the current price can better reflect the future operation of the system. Then, we apply the energy intensity time response function to calculate the future’s trend. For example, the energy intensity decline of the transportation industry by 2030 is 53.5%, which is similar to the above data. Of course, energy intensity cannot be generalized. There are also problems in the development of energy structure. With the continuous application of new energy in the transportation industry, the potential of the transportation industry to reduce energy consumption and reduce emissions is still huge. Therefore, through the calculation and analysis in the text, it can be said that the transportation industry can implement the national industrial policy, promote technological progress, industrial upgrading, and adapt to structural adjustment. As one of the three important departments of national economic energy, it can fully realize the Copenhagen World in 2009. At the climate change conference, the Chinese government's goal of reducing energy intensity by 2020 will be 40 to 45% lower than that of 2005.

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