

Original Paper

Study on the Relatedness between Arterial Highway Freight Volume and GDP

Yuhan Li^{1*}

¹ School of Vehicle Engineering, Xi'an Aeronautical University, Xi'an, China

* Yuhan Li, School of Vehicle Engineering, Xi'an Aeronautical University, Xi'an, China

Received: August 21, 2020

Accepted: August 25, 2020

Online Published: August 27, 2020

doi:10.22158/wjssr.v7n3p92

URL: <http://dx.doi.org/10.22158/wjssr.v7n3p92>

Abstract

There is a deviation from the actual condition of freight transport and 'volume of freight transport by vehicles' counted by the current highway and waterway industry statistical statement system of China at the provincial or municipal level. This paper puts forward the concept of 'volume of freight transport in regions', uses survey data and administrative data to calculate the Grey relational degree between arterial highway freight volume and the GDP of the three industries. The quantitative analysis of the calculation results shows that the results are consistent with the actual situation, which is of certain practical significance. The variation trend of the arterial highway freight volume can reflect the economic development of the region.

Keywords

Arterial highway freight volume, Grey relational degree, GDP of the three industries

1. Introduction

According to the current highway and waterway industry statistical statement system of China, the traffic volume completed by commercial trucks that registered in some city is taken as the traffic volume of highway goods in that city, which is called "volume of freight transport by vehicles". The "volume of freight transport by vehicles" can reflect the actual condition of goods transport at the national level, but there is a deviation from the actual condition of goods transport at the provincial or municipal level, especially in the economically developed areas and less developed areas. The freight transport in the economically developed areas has certain characteristics. In addition to local trucks, there are also a considerable number of non-local trucks participating in road transport, and the transport volume completed by these non-local trucks is not included in the statistical category of the transport volume of road goods in this city. But non-local trucks share the city's freight transport

capacity, the contribution to economic development should not be underestimated.

2. Arterial Highway Freight Volume

2.1 Data Acquisition Method

Since the “volume of freight transport by vehicles” cannot directly reflect the economic situation of a certain region, we will adopt a certain method to obtain the data of truck transport in a certain place, called the “volume of freight transport in regions”.

The data studied in this paper can be divided into two parts according to their sources and acquisition methods: active survey and non-active survey. Active survey is the way to obtain the data for the study through field sampling survey, while non-active survey is the way to obtain administrative statistics through certain technical means. The highway freight transport data system is shown in Figure 1.

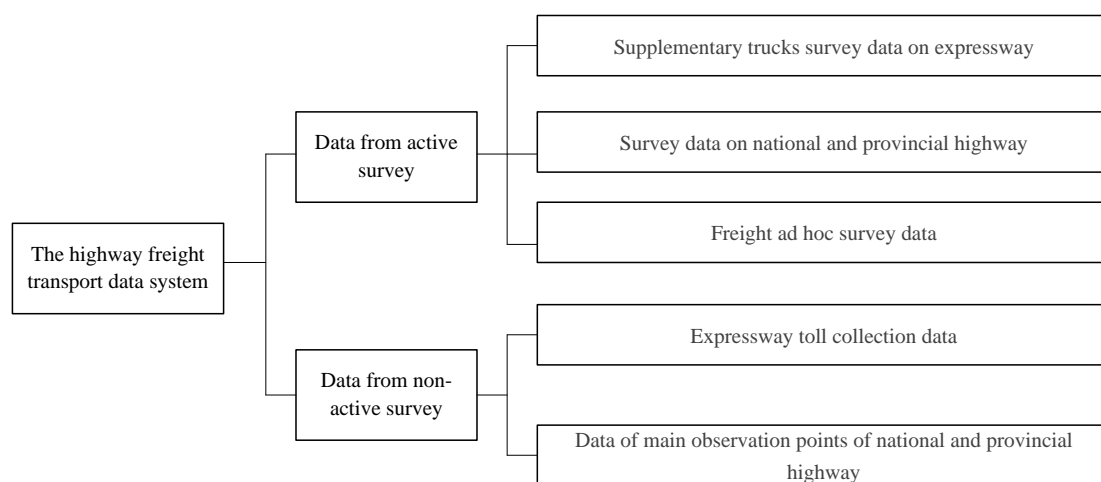


Figure 1. The Highway Freight Transport Data System

2.2 Data Calculation Method

Arterial highway freight volume refers to the volume of freight completed by trucks from all over the country on arterial Highway. It includes both trucks whose license plate is registered in the region and those registered in the outer region. Considering the freight turnover can fully reflect the information of freight volume and driving volume of freight transport, this paper uses the freight turnover as arterial highway freight volume for analysis and calculation. Arterial Highway freight turnover consists of expressway freight turnover and freight turnover of national and provincial highway. The calculation method is described below.

2.2.1 Volume of Freight Transport of Expressway

Expressway toll collection data is a full-caliber statistics, using expressway toll collection data for analysis can be counted all the freight traffic data of all the trucks passing through the expressway of a

certain area, the data accuracy error is small, easy to grasp the actual situation of the development of freight transport.

Expressway freight turnover is the sum of the product of the tonnage of goods and the distance they are transported by all trucks on the expressway network. The calculation is as follows.

$$V_E = \sum_{i=1}^n M_i * L_{Ei} * d \quad (2.1)$$

M_i -Average daily freight volume density of section i

L_{Ei} -Mileage of section i on the expressway

d -Number of days all the year round

n -Number Expressway sections

2.2.2 Volume of Freight Transport of National and Provincial Highway

According to the national and provincial highway survey and the toll collection data of expressways, the tonnage of goods of each vehicle type can be obtained, and the freight turnover of national and provincial highways can be calculated by the tonnage of goods of trucks and the data of main observation points of national and provincial highway.

The calculation method of driving volume on national highways is as follows.

$$X_N = (\sum_{i=1}^n T_{Ni} \cdot L_{Ni}) / a \quad (2.2)$$

$$a = L_{No} / L_{Nt}$$

T_{Ni} -Numbers of vehicles on section i of national highway

L_{Ni} -Mileage of the section i on national highway

n -The number of sections observed on national highway

L_{No} -Observation mileage of ordinary national highway

L_{Nt} -Total mileage of ordinary national highway

The calculation method of driving volume on provincial highways is as follows.

$$X_P = (\sum_{i=1}^m T_{Pi} \cdot L_{Pi}) / b \quad (2.3)$$

$$b = L_{Po} / L_{Pt}$$

T_{Pi} -Numbers of vehicles on section i of provincial highway

L_{Pi} -Mileage of the section i on provincial highway

m -The number of sections observed on provincial highway

L_{Po} -Observation mileage of ordinary provincial highway

L_{Pt} -Total mileage of ordinary provincial highway

Through equations (2.2) and (2.3), the driving volume of national and provincial highway can be obtained respectively. Then, the tonnage of goods of each vehicle type obtained from the survey can be

putted into equations (2.4) and (2.5). After calculation, the annual freight turnover of national highway and provincial highway can be obtained.

$$V_N = d \cdot \sum X_N \cdot f_a \quad (2.4)$$

$$V_P = d \cdot \sum X_P \cdot f_a \quad (2.5)$$

d ——Number of days all the year round

Finally, the arterial highway freight volume can be obtained from equation (2.6).

$$V_A = V_H + V_N + V_P \quad (2.6)$$

3. Calculation Method of Relatedness

Grey Relational Analysis is a common method for analyzing multi-factor dynamic correlation. Compared with regression analysis, variance analysis and other methods, grey relational Analysis has fewer constraints and can analyze the development trend. It has no excessive requirements on sample size and low requirements on data regularity. This paper will analyze the correlation between the arterial highway freight volume and the GDP through this method.

3.1 B-type Grey Relational Grade

B-type Grey Relational Grade examined the similarity and proximity between the relational factors. The similarity means that the closer the geometric shapes are, the closer the development trend is. Proximity refers to the fact that the functional curves of Relational factors are not completely similar, but there is little difference in each moment. This phenomenon indicates that relational factors are closely related to each other, on the contrary, they are not very closely related.

The B-type grey relational grade of discrete functions can be expressed as follows.

$$\gamma(X_0, X_i) = \frac{1}{1 + \frac{1}{n} d_{0i}^{(0)} + \frac{1}{n-1} d_{0i}^{(1)} + \frac{1}{n-2} d_{0i}^{(2)}} \quad (3.1)$$

$$d_{0i}^{(0)} = \sum_{k=1}^n d_{0i}^{(0)}(k) = \sum_{k=1}^n |x_0(k) - x_i(k)|$$

$$d_{0i}^{(1)} = \sum_{k=1}^{n-1} d_{0i}^{(1)}(k) = \sum_{k=1}^{n-1} |x_0(k+1) - x_i(k+1) - x_0(k) + x_i(k)|$$

$$d_{0i}^{(2)} = \sum_{k=2}^{n-1} d_{0i}^{(2)}(k) = \frac{1}{2} \sum_{k=1}^n [|x_0(k+1) - x_i(k+1)] - 2[x_0(k) - x_i(k)] + [x_0(k-1) - x_i(k-1)]|$$

$d_{0i}^{(0)}, d_{0i}^{(1)}, d_{0i}^{(2)}$ are discrete functions, First-order slope difference, Second-order slope difference between $x_0(k)$ and $x_i(k)$.

3.2 Grey Absolute Correlation Degree

The principle of grey absolute correlation degree is to calculate the correlation degree according to the approximate degree between the changing trend of the time series curve of the factors. For the discrete

data column, the closeness of two curves is determined by the proximity of curves' slopes in corresponding time periods of two time series. If the slope of two curves is the same or the difference is small in each period, the correlation coefficient is high; otherwise, it is low.

$X_0 \{x_0^{(0)}(k), k = 1, 2, \dots, n\}$ is reference sequence. $X_i \{x_i^{(0)}(k), k = 1, 2, \dots, n\}$ is compare sequence. The

original data is initialized as $Y_0 \{y_0^{(0)}(k), k = 1, 2, \dots, n\}$ and $Y_i \{y_i^{(0)}(k), k = 1, 2, \dots, n\}$.

The slope of the curve at each point in time is obtained through IAGO.

$$\begin{aligned}\alpha^{(1)}(y_0^{(0)}(k+1)) &= y_0^{(0)}(k+1) - y_0^{(0)}(k) \\ \alpha^{(1)}(y_i^{(0)}(k+1)) &= y_i^{(0)}(k+1) - y_i^{(0)}(k), k = 1, 2, \dots, n-1\end{aligned}$$

Then the correlation coefficient of each time point is

$$\varepsilon(k+1) = \frac{1}{1 + |\alpha^{(1)}(y_0^{(0)}(k+1)) - \alpha^{(1)}(y_i^{(0)}(k+1))|}, \quad k = 1, 2, \dots, n-1 \quad (3.2)$$

Grey absolute correlation degree is

$$r = \frac{1}{n-1} \sum_{k=2}^n \varepsilon(k) \quad (3.3)$$

If $r > 0.6$ and close to 1, the two factors are considered to be strongly correlated. If $r < 0.5$ and close to 0, the correlation between the two is considered weak.

3.3 Gray trend relational degree

X_0 is reference sequence and X_i is compare sequence. After initializing original data, the grey trend correlation degree of the two sequences is constructed as follows.

$$\begin{aligned}r_{0i} &= \frac{1}{n-1} \sum_{k=2}^n \varepsilon_{0i}(k) \\ \varepsilon_{0i}(k) &= \frac{1}{1 + d|\Delta x_{0i}(k)| + \lambda|\Delta x_{00}(k) - \Delta x_{ii}(k)|} \\ \Delta x_{0i}(k) &= x_0(k) - x_i(k) \\ \Delta x_{00}(k) &= x_0(k) - x_0(k-1) \\ \Delta x_{ii}(k) &= x_i(k) - x_i(k-1)\end{aligned} \quad (3.4)$$

As a general rule, $d = 0.5, \lambda = 1$.

4. Instance Analysis

We will adopt the above methods, taking Ningbo as an example, calculate the correlation degree between the arterial highway freight volume of Ningbo and the value-added of the three industries through the grey correlation analysis method. Subject to price fluctuations, nominal GDP does not directly reflect the actual level of economic growth. The factors of price fluctuations need to be taken

into account in the correlation analysis. Therefore, we adopts the GDP index of Ningbo that published by The Bureau of Statistics of Ningbo as the compare sequence for correlation analysis, which can eliminate the influence of price fluctuations on the final result.

The index is based on the GDP of 1978 as the base of 100, and the index is obtained by eliminating the factors of price changes of each year. The growth rate of GDP index can directly reflect the actual growth rate of GDP. The arterial highway freight volume and GDP indexes of Ningbo from 2012 to 2016 are shown in Table 1.

Table 1. The Arterial Highway Freight Volume and GDP Indexes of Ningbo from 2012 to 2016

Year	2012	2013	2014	2015	2016
Freight turnover(Million ton-km)	20758	23539	26203	27965	33875
primary industry	464.07	457.14	466.09	474.09	480.36
secondary industry	14786.29	15983.86	17274.45	18943.19	20515.06
Tertiary industries	10763.65	11727.63	12587.32	13380.12	14194.38

The arterial highway freight volume of Ningbo is taken as the reference sequence X_0 in grey correlation analysis. The GDP index of the three industries is taken as the compare sequence. $X_i, (i = 1, 2, 3)$. The B-type grey relational grade, grey absolute correlation degree and gray trend relational degree are used to calculate the grey correlation degree respectively. The results can be used to quantitatively analyze the correlation between the arterial highway freight volume and each industry. It is necessary to nondimensionalize the original data because the dimension of the original data is different. The dimensionless treatment with the initial value transformation can make the growth trend more obvious and the result more persuasive. The results of dimensionless treatment are shown in Table 2.

Table 2. The Results of Dimensionless Treatment

Year	2012	2013	2014	2015	2016
X0	1	1.134	1.262	1.347	1.632
X1	1	0.985	1.004	1.022	1.035
X2	1	1.081	1.168	1.281	1.387
X3	1	1.090	1.169	1.243	1.319

After dimensionless processing of the original data, the three kind of grey correlation degrees of arterial highway freight volume and GDP of the three industries in Ningbo are calculated, and the correlation degrees of the arterial highway freight volume and GDP of the primary industry, the secondary industry and the tertiary industry are calculated as R_{01} , R_{02} and R_{03} respectively.

Table 3. The Calculation Results of Grey Relational Degree

	B-type grey relational grade	grey absolute correlation degree	gray trend relational degree
R ₀₁	0.684	0.874	0.769
R ₀₂	0.823	0.933	0.889
R ₀₃	0.814	0.932	0.881

According to the calculation results, the arterial highway freight volume has a strong correlation with the GDP of the three industries. Obviously, the ranking result of correlation degree calculated by three grey relational models are same.

The results of quantitative analysis show that the correlation degree between the arterial highway freight volume and the development of the secondary industry is the highest, and the correlation degree with the tertiary industry is slightly lower than that of the secondary industry, but the correlation degree with each industry is not much different, and the correlation degree with the primary industry is weaker than that of the secondary and tertiary industries.

5. Discussion

In this paper, the calculation results of the correlation degree between *arterial highway freight volume* and GDP of the three industries are consistent with the actual situation. This calculation method can be extended to other provinces and cities to facilitate the timely obtaining of the status of freight transport in this region and provide support for regional economic development.

References

- Cao, M.-X. (n.d.). *Research on Grey Incidence Analysis Model and Its Application*. Nanjing: Nanjing University of Aeronautics and Astronautics.
- Mckinnon, A. C. (2007). Decoupling of Road Freight Transport and Economic Growth Trends in the UK: An Exploratory Analysis. *Transport Reviews*, 27(1).
<https://doi.org/10.1080/01441640600825952>
- Sampling survey scheme of highway and waterway transportation volume*. (n.d.). Beijing: Ministry of Transport of the People's Republic of China.