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Forecast of Passenger and Freight Traffic Volume Based on Elasticity Coefficient Method and Grey Model

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Abstract

The increase in passenger and freight traffic in a region reflects the development of railways, highways, waterways, aviation, and pipeline. With the growth of economy, China's transportation develops rapidly. However, the passenger and freight traffic present different growth features in different regions. Therefore, a reasonable forecast model for passenger and freight traffic and the analysis of relationship between regional transportation and economy are important for transportation planning. The elasticity coefficient between the passenger traffic volume, freight traffic volume and gross domestic product (GDP) is calculated based on the data from 2001 to 2010 in different regions in China. Then, the relationship between the change of regional traffic volume and regional economic development is obtained. With the analysis of the pros and cons for different forecast models, Elasticity Coefficient Method, GM (1, 1) model, and DGM model have been used to forecast passenger and freight traffic volumes from 2011 to 2015. In order to improve the accuracy of the forecast results, the combined models based on the variance reciprocal and the optimal weighting are applied to optimize the forecasting model. Among all the forecast models, the combined model with optimal weights outperforms other models with a relative error less than 0.006% for the freight traffic volume. The accuracy of forecast models on passenger and freight traffic volume has been improved, which provides a reasonable basis for the planning and development of the transportation system.

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Key words: Coefficient of elasticity; passenger and freight traffic volume; GM (1, 1) model; DGM model; combination model

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1. Introduction

Forecasting on passenger and freight traffic volume is the basis of planning and construction of transport facilities. At the same time, it provides valuable policy-making information for the government departments which conducts market regulation and management. Forecasting traffic volume accurately plays an important role for the healthy development of transportation. Volume depends on transportation demand, which is effected by regional population, structure of economy, industrial scale and layout, mechanization level, urbanization level and social culture etc. Therefore, how to forecast volume reasonably and improve accuracy is an import issue. In this context, researchers pay much attention to different forecast approaches including qualitative forecast or quantitative forecast methods. Quantitative forecast methods include exponential smoothing, grey forecasting model, and regression analysis.

In addition, China is a country with a vast territory. Regional economy development is unbalanced. Passenger and freight traffic volume and elasticity coefficient of gross domestic product (GDP) differ greatly. Therefore, the relationship between traffic volume and economic development is difficult to analyze. Analyzing elasticity coefficient is an effective approach to determine such relationship. Meantime, the future passenger and freight volume can be obtained by analyzing elasticity coefficient correctly. This paper forecast the passenger and freight volume according to static and dynamic elasticity coefficient models. In order to improve accuracy, a grey model and a combined model are also used to predict passenger and freight volume of different regions in China.

2. Passenger and freight traffic volume forecast based on elasticity coefficient method

This paper has applied the elasticity coefficient to forecast passenger and freight volume firstly. According to GDP data of different regions from 2001 to 2010 and the data of passenger and freight traffic volume, elasticity coefficient of passenger and freight volume in different regions can be calculated. Further, elasticity coefficient has been used to forecast passenger and freight traffic volume from 2011 to 2015 in different regions.

2.1. Elasticity coefficient

The transportation elasticity coefficient is defined as a numerical measure of the relative response of volume to changes in GDP, which can be expressed as follows:

\[
\text{Transportation elasticity coefficient} = \frac{\text{Rate of change of volume}}{\text{Rate of change of GDP}}
\]

In this research, passenger and freight traffic volume and GDP in different regions are used to calculate transportation elasticity coefficient.

Elasticity coefficient can be divided into static and dynamic elasticity coefficient, depending on different methods of calculation. The calculation for static elasticity coefficient is relatively simple and used more frequently.

2.1.1. Static elasticity coefficient

Currently, the method used to determine transportation static elasticity coefficient can be divided into two categories: one is to calculate the value of elasticity coefficient directly according to its definition, such as the geometric average method and arithmetic average method; the other is to use regression analysis to determine the value of elasticity coefficient. In this paper, a logarithmic linear regression method is used to determine static elasticity coefficient. Its equation can be expressed as:

\[
\ln T = A + E \ln G
\]

Where \( T \) is the traffic volume; \( A \) is coefficient; \( E \) is transportation elasticity coefficient; \( G \) is the GDP.
With the regional data of passenger traffic volume, freight traffic volume and GDP from 2001 to 2010, logarithmic linear regressions of different regions was completed and the static elasticity coefficient of passenger and freight traffic volume in different regions was obtained. The mean value of elasticity coefficient for freight volume is 0.5752, which means the freight volume and GDP is relatively inelastic. Elasticity coefficients of Beijing and Yunnan are -0.3751 and -0.0998, which reflects that the regional freight volume does not vary much with the regional economic growth. Elasticity coefficients of Anhui and Tibet are 1.2812 and 1.4111, which means that the regional economic growth has effects on the freight volume growth.

The mean value of elasticity coefficient of passenger volume is 0.6389, which means lack of elasticity. However, compared with elasticity coefficient of freight volume, the relationship between passenger volume and economic development is closer. The elasticity coefficients of passenger volume of Inner Mongolia, Heilongjiang, and Yunnan are -0.0261, -0.0799, and -0.0066. This result shows that the regional passenger volume does not increase with the development of economy. Elasticity coefficients of Beijing and Tianjin are 1.2081 and 1.4661, which means that the economic development has facilitated the increase of passenger volume.

2.1.2. Dynamic elasticity coefficient

In the model of dynamic elasticity coefficient, elasticity coefficient is calculated using the relative change rate between passenger, freight volume and time. The regression equation on passenger volume and time is fitted based on the data of from 2001 to 2010. The regression equation between GDP and time can be derived. Then, the elasticity coefficient can be calculated using differential equation. Based on the following Equation (2), the elasticity coefficient can be calculated.

$$ E_t = \frac{T_t^\prime(\Omega) \cdot \Omega(\Omega)}{T(\Omega)} $$

(2)

The regression equations on passenger, freight, GDP, and time $t$ can be obtained using quadratic curve fitting in MATLAB. Then, the derivation of the regression equations is calculated and input to Equation (2). Finally, the dynamic elasticity coefficient for each region is derived. For example, Elasticity coefficients of freight/passenger volume from 2011 to 2015 of Tianjin are showed in Table 1:

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger</td>
<td>1.5055</td>
<td>1.4459</td>
<td>1.3974</td>
<td>1.3575</td>
<td>1.3241</td>
</tr>
<tr>
<td>Freight</td>
<td>-0.4591</td>
<td>-0.6801</td>
<td>-0.985</td>
<td>-1.4343</td>
<td>-2.1629</td>
</tr>
</tbody>
</table>

Using the dynamic elasticity coefficient method, the time-varying characteristics of elasticity coefficient can be considered. This method can reflect the actual trend of transportation elasticity coefficient and the results cannot be affected by the fluctuations of the data. Because $E, T, G$ is a function of time, the elasticity coefficient in different time can be determined and the future traffic volume can be forecasted at the same time. Comparing with static elasticity coefficient based method; this method does not require that $T, G$ has a statistical relationship. Therefore, this method can be applied in a wider range.

2.2. Passenger and freight volume forecast based on static elasticity coefficient

After elasticity coefficient is determined, passenger and freight volume in the future years can be forecasted according to the models shown as follow:

$$ y_t = E_{eq} \left(1 + \frac{i}{r} \right)^t $$

(3)

$$ i = Eq $$

(4)

Where $y_t$ is value of traffic volume at time $t; y_t^\prime$ is value of traffic volume at time $t'; E$ is coefficient of elasticity; $q$ is the average growth rate of economy during the next period of time, %.
The growth rate of GDP in different region from 2011 to 2015 can be obtained from 12th Five-Year Plan. Then, the static elasticity coefficient and the regional economic growth rates are input to the Equations (3) and (4) in order to forecast the passenger and freight volume of each region from 2011 to 2015. For example, the results of Beijing are shown in Table 2:

Table 2. Forecasting results of passenger and freight volume from 2011 to 2015 in Beijing based on static elasticity coefficient

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger(unit: 10000-people)</td>
<td>148097</td>
<td>162411</td>
<td>178107</td>
<td>195321</td>
<td>214199</td>
</tr>
<tr>
<td>Freight(unit: 10000-ton)</td>
<td>21109</td>
<td>20476</td>
<td>19861</td>
<td>19265</td>
<td>18687</td>
</tr>
</tbody>
</table>

2.3. Passenger and freight volume forecast based on dynamic elasticity coefficient

We input the dynamic elasticity coefficient and the regional GDP growth rates into the Equations (3) and (4). The passenger and freight volume of each region from 2011 to 2015 can be obtained. For example, the results of Beijing are shown in Table 3:

Table 3. Forecasting results of passenger and freight volume from 2011 to 2015 in Beijing based on dynamic elasticity coefficient

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger(unit: 10000-people)</td>
<td>158145.5</td>
<td>183647.8</td>
<td>211774.3</td>
<td>242775.1</td>
<td>276926.9</td>
</tr>
<tr>
<td>Freight(unit: 10000-ton)</td>
<td>18304.44</td>
<td>13862.64</td>
<td>7943.022</td>
<td>-1261.27</td>
<td>-4561.34</td>
</tr>
</tbody>
</table>

3. Passenger and freight traffic volume forecast based on grey model

Regional passenger and freight traffic are affected by many factors. In order to forecast regional passenger and freight volume accurately, we must collect a great deal of information and consider all kinds of factors, which lead to the difficulty in establishing the forecast model. Even the established model cannot be used because of unavailable data. The grey system theory applies limited known data to predict the behaviour of the unknown system.

Grey prediction has caught much attention of many researchers because of its high forecast accuracy, simple principle, and convenient operation. It has been successfully applied in the passenger and freight volume forecast. The paper uses GM (1, 1) model and DGM model to forecast the regional passenger and freight volume from 2011 to 2015.

3.1. Passenger and freight volume forecast based on GM (1, 1) model

3.1.1. GM (1, 1) model

GM (1, 1) model is an important grey theory based model, which is commonly used to forecast a system with limited data. The model is generally used for short-term prediction.

Original form of the model is as follows:

\[ \dot{X}^{(1)}(k) + aX^{(1)}(k) = b \]  

(5)

Differential equation can be formulated as:

\[ \frac{dx}{dt} + ax = b \]  

(6)

Where \( a \) is the development coefficient; \( b \) is grey volume.
We solve Equation (6) and obtain Equation (7):

$$x^{(i)}(k+1) = \left[ x^{(i)}(1) - \frac{b}{a} \right] e^{-ak} + \frac{b}{a}$$

(7)

The solving process of the model GM (1, 1) is as follows:

1) Use regional passenger /freight volume as the initial data:

$$X^{(0)} = \{x^0(1), x^0(2), \ldots, x^0(n) \}$$

(8)

2) Use accumulated method to obtain a new sequence:

$$X^{(i)} = \{x^i(1), x^i(2), \ldots, x^i(n) \}$$

(9)

3) Generate nearest sequence:

$$Z^{(i)}(k) = 0.5X^i(k) + 0.5X^i(k-1)$$

(10)

4) Set $$A = (a, b)$$ using the least square method to solve $$A$$ according to Equation (11):

$$A = \left( B^T B \right)^{-1} B^T Y_n$$

(11)

Where $$Y_n = (x^0(2), x^0(3), \ldots, x^0(n))^T$$, $$B = \begin{pmatrix} -z^{(i)}(2) & -z^{(i)}(3) & \cdots & -z^{(i)}(n) \\ 1 & 1 & \cdots & 1 \end{pmatrix}^T$$;

5) Input the obtained $$a$$ into the equation to obtain the value of $$x^{(i)}(k+1)$$ and save the series to forecast.

3.1.2. Passenger and freight volume forecast based on GM (1, 1) model

According to the GM (1, 1) model, passenger and freight volume of different regions from 2011 to 2015 has been forecasted. For example, the forecasting results of Beijing are shown in Table 4:

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger(unit: 10000-people)</td>
<td>158145.5</td>
<td>183647.8</td>
<td>211774.3</td>
<td>242775.1</td>
<td>276926.9</td>
</tr>
<tr>
<td>Freight(unit: 10000-ton)</td>
<td>19516</td>
<td>18369</td>
<td>17288</td>
<td>16272</td>
<td>15315</td>
</tr>
</tbody>
</table>

3.2. Passenger and freight volume forecast based on DGM model

GM (1, 1) model is often used in the forecast for grey system. However, it is found that when the original data sequence has an approximate exponential growth pattern, the forecast effects of GM (1, 1) model is not good and the forecasting results are not stable. When the growth rate of traffic volume changes greatly, the forecast accuracy is low. Moreover, in the forecasting process, GM (1, 1) model depends much on the initial sequence and a small change in the initial sequence may lead to large change in the simulated sequence. To this end, the discrete DGM model is introduced in the forecast of passenger and freight volume.

3.2.1. DGM model

In the GM (1, 1) model, Equation (5) is a discrete equation, but Equation (6) is a continuous equation. In the forecast process, the parameter of Equation (5) is input to Equation (6). Putting parameter of discrete equation into continuous equation is a modelling problem of GM (1, 1). Therefore, DGM (1, 1) model is established. DGM (1, 1) gray differential equation is as follows:
\[ x^{(1)}(k+1) = \beta_1 x^{(1)}(k) + \beta_2 \]  \hspace{1cm} (12)

Where \( \beta_1, \beta_2 \) are parameters.

If \( \hat{\beta} = (\beta_1, \beta_2)^T \) is parameter column and

\[
B = \begin{bmatrix}
    x^{(1)}(1) & 1 \\
    x^{(1)}(2) & 1 \\
    \vdots & \vdots \\
    x^{(n-1)} & 1
\end{bmatrix}, \quad Y = \begin{bmatrix}
    x^{(2)} \\
    x^{(3)} \\
    \vdots \\
    x^{(n)}
\end{bmatrix}
\]

Then estimation parameter column of the least square parameter of the grey differential Equation (12) satisfies

\[
\hat{\beta} = (B^T B)^{-1} B^T Y
\]  \hspace{1cm} (13)

The estimated value of \( x^{(1)}(k+1) \) can be expressed as:

\[
x^{(1)}(k+1) = \beta_1 x^{(1)}(1) + \frac{1-\beta_1}{1-\beta_1} \beta_2
\]  \hspace{1cm} (14)

Finally, the forecasting value can be calculated using Equation (15)

\[
x^{(0)}(k+1) = \left(1 - \beta_1^{-1}\right) \beta_1 x^{(0)}(1) + \beta_1^{\text{est}} \beta_2
\]  \hspace{1cm} (15)

The solving process of the model DGM (1, 1) is as follows:

1) Use regional passenger/ freight volume as the initial data:

\[
X^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n))
\]  \hspace{1cm} (16)

2) Use accumulated method to obtain a new sequence:

\[
X^{(1)} = (x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n))
\]  \hspace{1cm} (17)

3) Calculate parameter \( \beta_1, \beta_2 \) based on \( \hat{\beta} = (B^T B)^{-1} B^T Y \)

4) Input the obtained \( \beta_1, \beta_2 \) into the Equation (14) to obtain the value of \( \bar{x}^{(0)}(k+1) \), and then save the series to forecast \( \bar{x}^{(0)}(k+1) \).

### 3.2.2. Passenger and freight volume forecast based on DGM model

According to the DGM model, passenger and freight volume of different regions from 2011 to 2015 are forecasted. For example, the forecasting results of Beijing are shown in Table 5:

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger(unit: 10000-people)</td>
<td>179636.9</td>
<td>240455.8</td>
<td>321865.9</td>
<td>430838.7</td>
<td>576706</td>
</tr>
<tr>
<td>Freight(unit: 10000-ton)</td>
<td>19387.52</td>
<td>18225.57</td>
<td>17133.27</td>
<td>16106.42</td>
<td>15141.12</td>
</tr>
</tbody>
</table>

### 4. Passenger and freight traffic volume forecast based on a combined model

In order to improve the forecast accuracy, a combined forecast model is established. The combined forecast method chooses appropriate weights for different forecast methods. The forecasting result of each model multiplies by the weight and sums up as the final forecast results.
We set $y_t$ as forecast values of a combined model at time $t$ and $\hat{y}_{it}$ as the forecast values of forecast model $i$ at time $t$. The weight for forecast model $i$ is $w_i$. The combined model can be expressed as follows:

$$y_t = \sum_{i=1}^{n} w_i \hat{y}_{it}$$

(18)

With this model, passenger and freight traffic volume can be forecasted using the reasonable weight $w_i$.

4.1. Determination of weight

When using the combined forecasting model, the weight is very important. The reasonable weight can improve the forecast accuracy significantly. Methods used to determine weights include the arithmetic mean method, the standard deviation method, the variance reciprocal method, the mean square reciprocal method, the AHP method, the Delphi method, and the optimal weighted method. Among them, the AHP method and Delphi method are based on subjective assessment, with errors. The arithmetic mean method is one of the simple time series forecast method, which uses the average value of the observed time series during a period of time as the next forecast value. The variance reciprocal method gives higher weights to the model with lower square error. The optimal weighted method is based on a certain optimal criterion (such as the least squares criterion, mini or max criterion). For this method, the objective function $Q$ is built and weight coefficient of combined model is obtained by minimizing $Q$ under the constraints (such as the sum of weight is 1).

In order to improve the forecast accuracy, the paper has selected the variance reciprocal method and optimal weighted method to determine the weight because these two methods have smaller error.

4.1.1. Variance reciprocal method

The variance reciprocal method gives higher weights to the model with lower square error. The calculation equation is as follows:

$$\omega_i = \frac{D_i^{-1}}{\sum_{i=1}^{n} D_i^{-1}}, \ i = 1, 2, ..., n;$$

(19)

$$\sum_{i=1}^{n} \omega_i = 1$$

(20)

In Equation (19), $D_i = \sum_{j=1}^{n} (y_j^i - y_{it})^2$

(21)

Where $D_i$ is the sum of square error of model $i$.

According to the website of China Industry Research Report, the national freight volume is 36.303 billion tons until December, 2011 and the growth rate is 13.7% compared with the same period of last year. The passenger volume reaches 35.17 billion people, with an increase of 7.6% compared with the same period of last year.

The paper applies the static elasticity coefficient model, the dynamic elasticity coefficient model, the GM (1, 1) model, and the DGM model to forecast the 2011 national freight volumes, which are 34.47682 billion tons, 34.7184746 billion tons, 35.8121 billion tons, and 35.93806855 billion tons. The relative errors are 0.0503, 0.0436, 0.0135, and 0.0101. The forecasting results with the static elastic coefficient model, dynamic elastic coefficient model, GM (1, 1) model, and DGM model are shown in Table 6.

As shown in Table 6, the relative errors vary from the models. In order to optimize the forecast results, the variance reciprocal method is used to determine weight. The forecasting results of national passenger and freight volume of 2011 are input to the Equations (19), (20), and (21). The obtained weight of static, dynamic elasticity coefficient model, GM (1, 1) model, and DGM model are shown in Table 6:
Table 6. Weights of different forecast methods for passenger and freight volume

<table>
<thead>
<tr>
<th></th>
<th>GM(1,1)</th>
<th>Static elasticity coefficient model</th>
<th>Dynamic elasticity coefficient model</th>
<th>DGM</th>
<th>Actual value of 2011 freight traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passenger</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>3712477.973</td>
<td>3465614</td>
<td>3530080.891</td>
<td>3764449.099</td>
<td>3517000</td>
</tr>
<tr>
<td>Relative error (%)</td>
<td>5.56</td>
<td>1.46</td>
<td>0.37</td>
<td>7.04</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>0.0042</td>
<td>0.0604</td>
<td>0.9328</td>
<td>0.0026</td>
<td></td>
</tr>
<tr>
<td><strong>Freight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>3581210</td>
<td>3447682</td>
<td>3471847.46</td>
<td>3593806.855</td>
<td>3630300</td>
</tr>
<tr>
<td>Relative error (%)</td>
<td>1.35</td>
<td>5.03</td>
<td>4.36</td>
<td>1.01</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>0.3358</td>
<td>0.0243</td>
<td>0.0322</td>
<td>0.6077</td>
<td></td>
</tr>
</tbody>
</table>

4.1.2. Optimal weighted method

Optimal weighted method is in accordance with the principle of “minimizing the square error of the combined model during a past period of time” to obtain weight of each forecast model.

The forecast error of model $i$ at time $t$ is as follows:

$$ e_i = y_i - y_{0i}; \quad i = 1, 2, \ldots, n $$

(22)

The forecast error vector of model $i$ can be expressed as:

$$ F_i = [e_{i1}, e_{i2}, \ldots, e_{in}]^T $$

(23)

Error matrix is as follows:

$$ e = [F_1, F_2, \ldots, F_n]^T $$

(24)

Error information matrix $E_e$ is expressed as:

$$ E_e = e^T e = 
\begin{bmatrix}
E_{11} & \cdots & E_{1n} \\
\vdots & \ddots & \vdots \\
E_{n1} & \cdots & E_{nn}
\end{bmatrix} $$

(25)

Set $R_e = [1, 1, \ldots, 1]^T$ as n-dimensional vector in which all elements are 1; Set $W = [\omega_1, \omega_2, \ldots, \omega_n]$ as n-dimensional vector of the weight for forecast model $n$.

The sum square of forecast error of the combined model $S$ is:

$$ S = \sum_{t=1}^{m} e_i^2 = \sum_{t=1}^{m} \left( \sum_{i=1}^{n} \omega_i e_{ni} \right)^2 = W^T E_e W $$

(26)

According to a linear programming shown as

$$ \min \quad S = W^T E_e W $$

$$ \text{st} \quad R_n^T W = 1 $$

the optimal solution is as follows:

$$ W = \frac{E_r^{-1} R_e}{R_e^T E_r^{-1} R_e} $$

(27)

The optimum weights of each forecast model are calculated using MATLAB, the weight coefficients are shown in Table 7:

Table 7. Weights of different forecast methods using optimal weight

<table>
<thead>
<tr>
<th></th>
<th>GM(1,1)</th>
<th>Static elasticity coefficient model</th>
<th>Dynamic elasticity coefficient model</th>
<th>DGM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passenger weight</strong></td>
<td>-1.9000</td>
<td>2.7468</td>
<td>-2.0253</td>
<td>2.1785</td>
</tr>
<tr>
<td><strong>Freight weight</strong></td>
<td>0.4953</td>
<td>0.6971</td>
<td>-1.1857</td>
<td>0.9932</td>
</tr>
</tbody>
</table>
4.2. Freight volume forecast based on the combined model of 2011

4.2.1. The combined model forecast based on variance reciprocal method

According to the identified weight of the static elasticity coefficient method, dynamic elastic coefficient method, and grey model forecast method, the passenger and freight volume of 2011 is multiplied by the relevant weight. For example, the forecasting results of Beijing and China using the combined model with optimum weight are shown in Table 8:

<table>
<thead>
<tr>
<th>Region</th>
<th>GM(1,1) model</th>
<th>Static elasticity coefficient model</th>
<th>Dynamic elasticity coefficient model</th>
<th>DGM model</th>
<th>Combined model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger (unit: 10000-people)</td>
<td>Beijing</td>
<td>136730</td>
<td>148097.2</td>
<td>158145.5</td>
<td>179636.9</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>3712478</td>
<td>3465614</td>
<td>3530081</td>
<td>3764449</td>
</tr>
<tr>
<td>Freight (unit: 10000-ton)</td>
<td>Beijing</td>
<td>19516.17</td>
<td>21109</td>
<td>18304.44</td>
<td>19387.52</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>3581210</td>
<td>3447682</td>
<td>3471847</td>
<td>3593807</td>
</tr>
</tbody>
</table>

Using the combined model based on variance reciprocal method, the 2011 freight volume of China is forecast as 35.82099 billion tons and the relative error is 1.33 %. Compared with the DGM model, the relative error increases. The forecast passenger volume of 2011 in China is 35.27557 billion people and the relative error is 0.3 %. According to the results, the relative error is reduced compared with a single forecast model. Thus, the forecast accuracy is improved.

4.2.2. The combined model forecast based on optimal weighted method

According to the identified weight of the static elasticity coefficient forecast method, dynamic elastic coefficient method, and grey model forecast method, the passenger and freight volume of 2011 is multiplied by the relevant weight. The forecasting results can be obtained by summing the products. For example, the forecasting results of the combined model with optimum weight are shown in Table 9:

<table>
<thead>
<tr>
<th>Region</th>
<th>GM(1,1) model</th>
<th>Static elasticity coefficient model</th>
<th>Dynamic elasticity coefficient model</th>
<th>DGM model</th>
<th>Combined model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger (unit: 10000-people)</td>
<td>Beijing</td>
<td>136730</td>
<td>148097.2</td>
<td>158145.5</td>
<td>179636.9</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>3712478</td>
<td>3465614</td>
<td>3530081</td>
<td>3764449</td>
</tr>
<tr>
<td>Freight (unit: 10000-ton)</td>
<td>Beijing</td>
<td>19516.17</td>
<td>21109</td>
<td>18304.44</td>
<td>19387.52</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>3581210</td>
<td>3447682</td>
<td>3471847</td>
<td>3593807</td>
</tr>
</tbody>
</table>

Based on the combined model with optimum weight, the national freight volume of 2011 is forecasted as 36.29952 billion tons. The relative error is reduced to 0.01 %, which is lower than a single model. The forecasting national passenger volume of 2011 is 35.17021 billion people and the relative error is reduced to 0.006 %. Compared with the forecasting results of a single model, the forecasting accuracy has been greatly improved.

In conclusion, whether the combined model based on the variance reciprocal method or optimal weighted method is able to reduce forecast error. The combined model with optimum weight improves the accuracy of combined forecast model more effectively. However, the variance reciprocal method is simpler than the optimal weighted method. In practice, how to select these methods depends on real situation.
4.3. Passenger and freight volume forecast based on optimal weighted method from 2012 to 2015

According to the comparative analysis in the section of 4.2, the research has selected the combined model with optimum weight to forecast the passenger and freight traffic volume from 2012 to 2015. It is impossible to determine optimum weight of each model from 2012 to 2015 because passenger and freight traffic volume from 2012 to 2015 is unknown. The paper applies the obtained optimum weight of a single model based on the data of 2011 to forecast the passenger and freight volume from 2012 to 2015. The results are shown in Table 10:

Table 10. Forecasting results of freight volume from 2012 to 2015 based on the optimal weighted method

<table>
<thead>
<tr>
<th></th>
<th>Passenger (unit: 10000-people)</th>
<th>Freight (unit: 10000-ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>241482.6</td>
<td>272236.4</td>
</tr>
<tr>
<td>Tianjin</td>
<td>45461.39</td>
<td>56570.82</td>
</tr>
<tr>
<td>Hebei</td>
<td>90204.61</td>
<td>93605.04</td>
</tr>
<tr>
<td>Shanxi</td>
<td>54328.23</td>
<td>65001.44</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>52505.27</td>
<td>85951.75</td>
</tr>
<tr>
<td>Liaoning</td>
<td>103821.9</td>
<td>103200.7</td>
</tr>
<tr>
<td>Jilin</td>
<td>64575.42</td>
<td>62341.21</td>
</tr>
<tr>
<td>Heilongjiang</td>
<td>77060.77</td>
<td>96970.41</td>
</tr>
<tr>
<td>Shanghai</td>
<td>11515.54</td>
<td>12267.83</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>239911.1</td>
<td>245551.3</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>234898.8</td>
<td>237596.2</td>
</tr>
<tr>
<td>Anhui</td>
<td>165908.3</td>
<td>168166.9</td>
</tr>
<tr>
<td>Fujian</td>
<td>80596.59</td>
<td>82097.73</td>
</tr>
<tr>
<td>Jiangxi</td>
<td>68325.2</td>
<td>62080.84</td>
</tr>
<tr>
<td>Shandong</td>
<td>269810.8</td>
<td>277266.6</td>
</tr>
<tr>
<td>Henan</td>
<td>154841.1</td>
<td>146077.8</td>
</tr>
<tr>
<td>Hubei</td>
<td>102574.6</td>
<td>100931.5</td>
</tr>
<tr>
<td>Hunan</td>
<td>159066.3</td>
<td>159532.7</td>
</tr>
<tr>
<td>Guangdong</td>
<td>541624.1</td>
<td>579803.9</td>
</tr>
<tr>
<td>Guangxi</td>
<td>76237.75</td>
<td>75634.97</td>
</tr>
<tr>
<td>Hainan</td>
<td>52382.41</td>
<td>56555.7</td>
</tr>
<tr>
<td>Chongqing</td>
<td>107635.7</td>
<td>93993.7</td>
</tr>
<tr>
<td>Sichuan</td>
<td>268878.3</td>
<td>282224.4</td>
</tr>
<tr>
<td>Guizhou</td>
<td>74366.43</td>
<td>78250.58</td>
</tr>
<tr>
<td>Yunnan</td>
<td>44885.79</td>
<td>48874.06</td>
</tr>
<tr>
<td>Tibet</td>
<td>35301.07</td>
<td>52833.35</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>100878</td>
<td>104096.9</td>
</tr>
<tr>
<td>Gansu</td>
<td>62195.91</td>
<td>66016.43</td>
</tr>
<tr>
<td>Qinghai</td>
<td>11545.56</td>
<td>11665.68</td>
</tr>
</tbody>
</table>
Table 10 indicates that the national freight volume growth rate remains at no more than 15% and different regions show different growth rates. Most regions maintain an average annual growth rate higher than 10%, such as Beijing, Inner Mongolia, Shanxi, Heilongjiang, and Zhejiang. However, average annual growth rate of Tibet, Ningxia and other western provinces are higher than 20%. With the rapid development of the western region and continuous improvement of the transportation system in western region, freight volume will increase more significantly.

In addition, the passenger volume also increases with an average annual growth rate at no more than 5%. In most regions, passenger volume growth rates are at the same level and increase not significantly. However, the growth rate is higher in Beijing, Tianjin, Inner Mongolia, Xinjiang and Tibet. The large population and rapid economic growth of Beijing and Tianjin are the main reasons why the passenger traffic volume increases. The passenger volume growth rates of Tibet and Xinjiang are much higher than the national average value. The reason for this is that the rapid economic and transportation development of western regions in recent years. Especially the construction of Qinghai-Tibet line results in rapid growth of the passenger volume.

Furthermore, the adjacent regions or the regions with similar economic conditions present the similar characteristics, such as the Beijing-Tianjin-Tangshan economic circle. The elasticity coefficient of passenger and freight volume in Beijing and Tianjin is close. Besides, the freight volume elasticity coefficients of Henan and Hebei, which are adjacent regions, are close. In Qinghai, Ningxia, and Xinjiang, which are adjacent regions, the relationship between passenger/freight volume and economic development are similar.

5. Conclusions

The method for passenger and freight volume forecast has focused on quantitative and qualitative forecast. In this paper, we use elasticity coefficient, GM (1, 1), DGM model and combined model to forecast passenger and freight volume. Some conclusions can be obtained as follows:

1) The elasticity coefficient of passenger and freight volume are calculated and analysed based on the regional passengers and freight volume from 2001 to 2010, and GDP data. The different relationships and characteristics between the economic development and volume growth of different regions can be found.

2) The passenger and freight volume of different regions in China from 2011 to 2015 are forecasted based on static and dynamic elasticity coefficient model.

3) Grey model can eliminate the fluctuation of the freight/passenger volume sequence effectively. The passenger and freight traffic volume from 2011 to 2015 in each region in China is forecasted based on the GM (1, 1 and DGM model.

4) In comparison with the actual passenger and freight volume in 2011, the accuracy of the established forecast model was tested. The combined model with optimal weights outperforms other precision models with a relative error of the freight traffic volume less than 0.006%.

Although the forecast accuracy of passenger and freight volume is improved in this research, which provides a reasonable basis for the planning and development of the transportation system, we still need to refine the relationship between economic development and the increase of passenger and freight volume in the future.
Acknowledgements

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References