Prediction model of transport sharing rates of the comprehensive transportation corridor

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Abstract:
Aiming at the problem that the prediction of transport structure doesn’t have enough accuracy, in this paper the influence factors of transport structure were determined, and the transport structure of the future characteristics year was predicted. The results show that: In this model, the average error of the freighter model and the passenger model is less than 2%; In the Logit model, the average error of the freighter model and the passenger model is more than 5%. So the error of the predictive method is smaller than that of the Logit model.

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Keywords: Traffic planning; Transport corridor; Sharing rates; Transport capacity predictive method.

1. Introduction
Our country is entering a new comprehensively constructing and developing stage of modern integrated transport, while the integrated transport structure optimization has become an important content, which is the key to build the scientific comprehensive transport system. The prediction of the integrated transport structure is an important part of the integrated transport system. It is the prerequisite of the structure optimization to accurately predict the transport structure.

There were several developmental stages of the prediction of the transport structure. Earlier studies of the transport structure were found in the United States, which depended on the purpose and ease, to make resources of different mode achieve the best fit. The study of Magnanti and Wong analyzed the relationship of the travel time of the different regions to reach the centers in the city, and gave the prediction model of the urban passenger traffic structure.

In comparison, our research on the development of transport structure were limited, most of which has focused on the inner city and the passenger transport structure.

Aiming at passenger and cargo transport, selecting behavior of different transport mode and its relationship of the influence factors are studied, and the relationship of the integrated transportation system structure and its influencing factors are analyzed, to seek a practical sharing ratio of the comprehensive transport system.

2. The model establishing
Usually, there are a variety of transportation modes, trip generation point and trip attraction point
between different modes of transport, technical performance, operating conditions and services in different ways. Thus it has different service properties in the time, cost, safety, convenience, comfort and other aspects. When people travel, they always have different desire to different modes of transport. For the different types of travellers, they have different social economic properties, and they desire to meet the different levels when they choice different modes of the transportation. Therefore, the utility function is used to measure the satisfaction of travellers. When choosing different modes of transportation, the higher the satisfaction that they get is, the greater the utility value is, and vice versa. Usually, when travelling, they always strive to choose the way by which they can satisfy the maximum desire of the traffic modes, that is, to achieve utility maximization.

According to the requirements of the travel purpose, combined with the conditions of the travellers, the status of the transportation, and the experience of others, they set their stance and attitude of making decision. Then they make the rational decision.

2.1 The model assuming

For the comprehensive transportation structure optimization is mainly for transportation decision making and planning to provide technical support, in the actual model, considering the macro decision, the following assumptions are given:

1 The study area is the closed system;
2 Ignoring the impact of regional traffic pollution and limiting by using land of the traffic planning
On the transportation structure;
3 The traffic assured demand of the total area;
4 Bicycler is rational, that is, the greater a mode of transportation of the utility value is, the greater
The possibility of selected is, and the makers always choose to have maximum utility the route to have maximum utility, namely, following the principle of utility maximization.

2.2 The model description

The model thinks the sharing ratio of a certain transport is decided by two parts: constraint selecting part and freedom selecting part.

The constraint selecting part is determined by the transport capacity and traffic volume. Stated mathematically:

\[ k_j = \sum_{i=1}^{\text{max}} \alpha_i \frac{v_i}{c_i} \]

(1)

Where \( k_j \) = reflecting the preference index of the i kind of mode of transportation for a person or a portion to the constraint selecting part;
\( \alpha_i \) = the calibration parameters, reflecting the influence of the j kind of mode of transportation;
\( v_i \) = the relative transportation volume of the j traffic modes of transportation;
\( c_i \) = the relative carrying transportation capacity of the i traffic modes of transportation.

The relative transportation volume of the j traffic modes of transportation is computed as:

\[ v_j = \frac{v_j}{v_{\text{min}}} \]

(2)

Where \( v_j \) = the absolute transportation volume of the j traffic modes of transportation;
\( v_{\text{min}} \) = the minimum value of absolute transportation volume of the j traffic modes of transportation.
There is different occupying space in different road vehicles of each kind of mode of transportation. When the transportation capacity is calculated, therefore, the equivalent conversion of all kinds of vehicle is needed, which is to all sorts of all kinds of vehicle conversion into a standard.

\[ c_e = c \sum P_i E_i \]  

(3)

Where \( c_e \) =the equivalent transportation capacity; 
\( c \) =the total transportation capacity without the conversion; 
\( P_i \) =the i kind of vehicles the percentage of the total equipment; 
\( E_i \) =the i kind of vehicles conversion coefficient.

Therefore, the relative transportation capacity of the j traffic modes of transportation is computed as:

\[ c_j = \frac{c_j}{c_{\text{min}}} \]  

(4)

Where \( c_j \) =the absolute transportation capacity of the j traffic modes of transportation; 
\( c_{\text{min}} \) =the minimum value of absolute transportation capacity of the j traffic modes of transportation.

If the index marks of the constraint selecting part are \( k_1, k_2, \ldots \), the sharing ratio of the constraint selecting part is \( k_j \left( 1 + \sum_{j=1}^{J} k_j \right) \) in the prediction of the comprehensive transportation corridor.

Assume when people are free to choose, they follow the Logit model, utility function of which should be established on generalized utility function. That does not only include the cost of travel, but also include travel time and transportation service level. It can be computed as:

\[ U_i = \sum \beta_m A_{im} + \epsilon_i \]  

(5)

Where \( U_i \) = the random utility of the I kind of mode of transportation; 
\( A_{im} \) = the m influenced attribute of the I kind of mode of transportation when they make a decision. 
\( \epsilon_i \) = the random item of the utility function of the I kind of the mode of transportation; 
\( \beta_m \) = the parameters, reflecting the importance of them attributes of the i kind of mode of transportation.

So the sharing ratio of the freedom selecting part is \( \frac{1}{\left( 1 + \sum_{j=1}^{J} k_j \right) \sum_{i=1}^{n} e^{U_i}} \).

The sum of the freedom selecting part and the constraint selecting part is a mode the probability of transportation. It can be computed as:

\[ P_j = \left( e^{U_i} + k_j \sum_{i=1}^{n} e^{U_i} \right) \left[ \left( 1 + \sum_{j=1}^{J} k_j \right) \sum_{i=1}^{n} e^{U_i} \right] \]  

(6)

Where \( n \) = the random utility of the n kind of mode of transportation; 
\( k_j \) = \( \sum_{j=1}^{n} \alpha_j \left( v_j / c_j \right) \), reflecting the preference of the I kind of transport mode for the passenger.
The key of the transportation structure prediction is to determine the coefficient of utility functions for the passengers who choose transport mode. The characteristic value of technical and economic characteristics of the various transport modes can be got by investigation. According to a various characteristic coefficient of behavior calibration of the passenger transport mode selection, the transportation structure can be predicted. The joint distribution of transportation travel probability of the joint Random selection can be computed as:

$$L = \left(\sum_{i=1}^{n} N_i\right) ! \prod_{i=1}^{n} P_i^{N_i}$$

(7)

Where $N_i$ = the volume of the I kind of the mode of transportation

The simplified maximum likelihood function is:

$$L^* = \sum N_i Ln P_i$$

(8)

3 The model calibration

The paper treats the corridor of Shanghai to Hangzhou as an example, to introduce the model calibration method. The corridor mainly includes three kinds of modes of transportation, railway, highway, and water transport, as shown in figure 1. The data for calibration mainly include the cargo and passenger data of the corridor of Shanghai to Hangzhou in 2010, which are respectively shown in table 1 and table 2.

Figure 1 The structure topology of the corridor of Shanghai to Hangzhou

Table 1 The freight data table of the corridor of Shanghai to Hangzhou

<table>
<thead>
<tr>
<th>Freight traffic Mode of transport</th>
<th>Cost (Yuan / ton)</th>
<th>Time (Hour)</th>
<th>Volume (Million tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway (i=1)</td>
<td>220</td>
<td>3.5</td>
<td>1.671</td>
</tr>
<tr>
<td>Highway (i=2)</td>
<td>550</td>
<td>1.8</td>
<td>5.944</td>
</tr>
</tbody>
</table>
Through the analysis of the mode of transportation service attributes, it is assumed that the most important factors influencing travellers’ mode choice are time and cost. Because the paper’s length is limited, these two factors are only considered. For this reason, the utility function is established as follows:

\[ U_i = \beta_1 A_{1i} + \beta_2 A_{2i} \]  

(9)

Where \( A_{1i} \) = the property of cost of the i- mode of transport in Influence decision makers choose; \( A_{2i} \) = the property of time of the i- mode of transport in Influence decision makers choose.

The transport capacity of the various modes of transport calculated by the formula (4), which can be seen in the following table:

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Railway (i=1)</th>
<th>Highway (i=2)</th>
<th>Water transport (i=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport capacity</td>
<td>24000</td>
<td>26000</td>
<td>8500</td>
</tr>
</tbody>
</table>

Table 4 The relative transport capacity table of the various modes of transportation

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Railway (i=1)</th>
<th>Highway (i=2)</th>
<th>Water transport (i=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The relative transport capacity</td>
<td>2.82</td>
<td>3.06</td>
<td>1.00</td>
</tr>
<tr>
<td>The relative volume of passenger transport</td>
<td>1.00</td>
<td>3.56</td>
<td>5.83</td>
</tr>
<tr>
<td>The relative volume of cargo transport</td>
<td>1.00</td>
<td>9.77</td>
<td>-</td>
</tr>
</tbody>
</table>

The calibrated cargo parameters by the Matlab as follows:
\[ \alpha_1 = 0.1829, \alpha_2 = -0.4471, \alpha_3 = 3.1811, \beta_1 = 1.2810, \beta_2 = 1.2959 \]

The calibrated passenger parameters by the Matlab as follows:
\[ \alpha_1 = 1.9914, \alpha_2 = 0.5434, \alpha_3 = -0.321, \beta_1 = 0.5702, \beta_2 = 1.3844 \]

The testing accuracy of its freight and passenger can be shown in Table 5 and Table 6. The average error of freight model is 0.15%, and the average error of freight model is 0.134%. So this model has a higher accuracy. The change in the cost of its share ratio is shown in Figure 2:
Table 5 Freight accuracy testing table

<table>
<thead>
<tr>
<th>Transport Mode of freight</th>
<th>Transport proportion</th>
<th>Transport volume (Million tons)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The calculated value</td>
<td>The actual value</td>
<td>The calculated value</td>
</tr>
<tr>
<td>Railway (i=1)</td>
<td>9.62%</td>
<td>9.63%</td>
<td>1.66955</td>
</tr>
<tr>
<td>Highway (i=2)</td>
<td>34.24%</td>
<td>34.25%</td>
<td>5.94235</td>
</tr>
<tr>
<td>Water transportation (i=3)</td>
<td>56.14%</td>
<td>56.12%</td>
<td>9.74310</td>
</tr>
</tbody>
</table>

Note: + sign indicates that the predictive value is bigger than the actual value - indicates the predicted value is smaller than the actual.

Table 6 Passenger accuracy test table

<table>
<thead>
<tr>
<th>Transport Mode of passenger</th>
<th>Transport proportion</th>
<th>Transport volume (Million person)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The calculated value</td>
<td>The actual value</td>
<td>The calculated value</td>
</tr>
<tr>
<td>Railway (i=1)</td>
<td>23.02%</td>
<td>23.07%</td>
<td>4544.61</td>
</tr>
<tr>
<td>Highway (i=2)</td>
<td>76.98%</td>
<td>76.93%</td>
<td>15197.39</td>
</tr>
</tbody>
</table>

Note: + sign indicates that the predictive value is bigger than the actual value - indicates the predicted value is smaller than the actual.

4 The model application

According to the prediction model of transport sharing rates of the comprehensive transportation corridor, the operating companies can make different pricing strategies by analyzes transport sharing rates in different situations. For instance, if the operating companies reduce the highway freight, the share rates of different transport mode changes as shown in figure 3.
Figure 3: There are bigger effects between 110 yuan to 130 yuan of the transport share rate for highway. If the price isn’t reduced to 130 yuan, there is little change in transport share rate; If the price continues to be reduced after reduced to 110 yuan, there is also little change in transport share rate; These contribute little to improve the sharing rate. So the price of highway should be between 110 to 130 yuan.

With the increase of the price of railway, the transport volume of highway mainly transfers to the water transportation. The transport proportion of the railway, however, is basically unchanged.

There are several reasons for it. On the one hand, the price of the water transport is low, the alternative of which is stronger. Therefore, there is a great influence on water transport. On the other hand, the line of railway is relatively fixed, the alternative of which is not stronger. So there is little influence on railway.

5 Conclusion

Though learning from the advanced experience, the transport capacity is introduced to study the prediction model of transport sharing rates of the comprehensive transportation corridor, the calibration method of the model is given. Eventually, we propose a practical method of transport sharing rates prediction. The established model is a model of general applicability, which can be applied to any large regional. So it laid the cornerstone for the transport structure optimization.

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References


