Study on the Transit Network Evaluation Method Based on the Transit Ridership Model

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Abstract

Traditional four-step travel forecasting models are usually used to predict changes in car travel patterns and to evaluate the road transportation system. The application is unsatisfactory when they are used to evaluate the transit transportation system. Based on the transit origin-destination (OD) adjustment, this paper proposes a framework on future transit network evaluations, where the transit ridership model and OD difference method are simultaneously used. The proposed method formulates the relationship between transit ridership and zonal population, employment, transit service level, and so on. In addition, the difference between transit counts and estimates for base year are considered in the development of the transit OD for future year. It is expected to perform better than conventional models in terms of transit network evolutions. The validation of the proposed method is tested in Fuzhou City Transit Development Project.

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Keywords: urban traffic; transit ridership model; origin-destination difference method; transit network evaluation

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1. Introduction

Traditional travel forecasting models consist of four distinct procedures, i.e., trip generation, trip distribution, mode choice and trip assignment. In the four-step, or the sequential forecasting procedure, the solution of one step is used as the input of the subsequent step. Thus, errors incurring in the upper steps will be inherited by the sequent steps. This usually leads to a large deviation from the true traffic flow distribution. For the base year, this deviation can be reduced by employing the method of vehicle origin-destination (OD) matrix estimation. That is to say, the vehicle OD for traffic assignment will be adjusted according to the observed link flows. The difference between prior OD and adjusted OD can be thought as the modelling error which should be treated in the future year forecasting. Therefore, the OD difference method has been proposed to adjust vehicle OD matrices in future years.

Compared with the vehicle travel pattern and road system, the public transit system is usually modelled with lower accuracy in traditional travel forecasting models. In recent years, however, the development of the public transit system attracts more and more attentions by city governments because of its environment-friendly characteristics. Therefore, more researches and applications on high-accuracy public transit models have been conducted. Transit ridership models represent a precise, quick-response alternative for forecasting transit patronage. They have already been widely used to evaluate and compare different urban public transport development schemes internationally. Transit ridership models are directly and quantitatively responsive to land use and transit service characteristics within the immediate areas of transit stops (or stations). So, they are more sensitive than state-of-practice four-step models in capturing effects of localized conditions within transit station area.

The traditional transit network evaluation method can be summarized in 3 steps: (1) develop a four-step travel forecasting model according to the base year data; (2) forecast future year input data (population, employment, etc.); (3) run the travel model for future forecasting, and evaluate the transit network. This method suffers from two major drawbacks: (1) the model errors, or the difference between observed and estimated transit flows for the base year cannot be reflected in the future forecasting; (2) errors (especially in the mode choice step) incurring in the upper steps will be inherited by the sequent steps, so errors are accumulated. This paper presents a framework to evaluate future year transit networks, where a transit ridership model at macro level is developed and the difference method is adapted for the transit OD adjustment. By combining the transit ridership model and transit OD difference method, problems with the traditional approach can be mitigated at some extent.

The method proposed in this paper has been applied in Fuzhou City Transit Development Project, and its validity and practicality has been verified.

2. Macro-Level transit ridership model

Transit ridership models are mainly applied at meso- or micro-level. The ridership of a transit line is usually described as a function of variables which characterize the features surrounding transit station areas or along transit routes. These variables usually include land use variable (population, population density, employment, employment density, etc.), social economic variables (family income, car ownership, etc.), environmental variables (parking facilities, walking corridor density, etc.) and transit level of service (frequency, ticket price, etc.).

Based on the basic ideas of transit ridership model, a macro-level transit ridership model can be developed. This is done by establish a relationship between zonal transit ridership and zonal land use, transit service variables. Assume that a traditional four-step travel forecasting model has been developed and by which prior transit OD flows are obtained. Then, adjusted transit OD flows can be obtained by using transit passenger counts. Different from meso- and micro-level transit ridership models, adjusted
transit OD flows, rather than the direct transit survey data, are used to calibrate the macro-level transit ridership models. Different forms of macro-level transit ridership model can be established. Take Fuzhou city for example, by combining different variables and constructing different function forms, year 2010 macro-level transit ridership can be described as a function of zonal population, employment, and transit vehicle arrival rate:

\[
\begin{align*}
P_{ph} &= 15.66 \times (0.5 \times V_{500} + V_{900})^{0.35} + 0.00787 \times Z_e + 0.01292 \times Z_p \\
A_{ph} &= 2.206 \times (0.3 \times V_{500} + V_{900})^{0.55} + 0.01315 \times Z_e + 0.00764 \times Z_p
\end{align*}
\]

where \(P_{ph}\) and \(A_{ph}\) are peak hour transit production and attraction, respectively; \(V_{500}\) and \(V_{900}\) are, respectively, peak hour transit vehicle arrival rate within 500 meters and 900 meters of zone centroid; \(Z_e\) and \(Z_p\) are the zonal population data and employment data.

Figure 1 and 2 show the calibration results of AM peak transit generation model in Fuzhou city. The adjusted base year (or verified) transit OD flows are given, and are compared with predicted (or modelled) OD flows by the macro-level transit ridership model. Both degree of fitting (R2) between the verified and the modelled transit OD flows are higher than 0.92, which indicates a satisfactory result. This model could be improved by including more variables such as average household income, car ownership, network density, etc., so that the accuracy of the model could be increased.

![Fig.1. Calibration of AM peak transit production model in Fuzhou city (R^2=0.925)](image1)

![Fig.2. Calibration of AM peak transit attraction model in Fuzhou city (R^2=0.924)](image2)
3. Transit network quantitative evaluation method

Transit Network Evaluation Method. Transit ridership model establishes quantitative relationship between transit ridership and such variables as population, employment, transit service level, etc., which are input data of the traditional four-step travel forecasting model. As the zonal variables change in the future year, the transit ridership model can also be used to predict the transit ridership in future year. Therefore, transit ridership model can be used to evaluate a future year transit network. The traditional four-step transportation network evaluation framework and the optimized transit network evaluation framework are shown in Figs. 3 and 4.

Fig.3. Flowchart of the traditional transportation demand analysis

Fig.4. Flowchart of the transit network evaluation
Difference Method for Transit OD Flows. The optimized transit network evaluation framework simplifies the traditional transportation network evaluation framework. Some modules in traditional evaluation framework (especially mode split module) are no longer needed. This avoids the error caused by those modules. In addition, difference method of transit OD flows can be directly applied in the optimized evaluation framework, so that model error, which is the difference between observed transit flows and predicted transit OD flows in base year, can be used to adjust future year transit OD demand. Difference method of transit OD flows is described as below:

\[ Q_f = \max((Q_f + Q_b - Q_v), 0) \]

where,
- \( Q_f \) is the adjusted transit flow in future year;
- \( Q_f \) is the predicted transit flow in future year;
- \( Q_b \) is the adjusted transit flow in base year;
- \( Q_v \) is the predicted transit flow in base year.

By applying the difference method for transit OD flows, the deviations of the predicted transit OD flows from the true values are significantly reduced. Therefore, the precision of transit network evaluation is improved.

Comparison and Evaluation. The base year observed transit flows are taken as the object values, on which the outputs of the new method and the traditional method for base year are compared. The traditional method employs the four-step forecasting model to compute transit flows where population, employment and network data are input data. The new method generates transit OD flows by using transit ridership model and difference method simultaneously. These transit OD flows are then assigned onto the transit network using transit OD assignment procedure.

Take Fuzhou city for example. 85 transit flow observations are collected in 2010. Two methods are applied to forecast transit flows. The difference between the observed and the predicted values are then calculated and shown in table 1. The degree of fitting between the predicted flows and observed flows by the new method has reached 0.932, which is significant higher than the degree of fitting by the traditional method. The standard deviation also shows significant improvement.

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Number of Observation</th>
<th>Observed Flow (person/h)</th>
<th>Traditional method</th>
<th>New method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial</td>
<td>72</td>
<td>3044</td>
<td>2927</td>
<td>3043</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>13</td>
<td>1380</td>
<td>453</td>
<td>999</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
<td>2789</td>
<td>2549</td>
<td>2731</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Predicted (person /h)</th>
<th>error</th>
<th>Predicted(person /h)</th>
<th>error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial</td>
<td>-3.84%</td>
<td></td>
<td>-0.01%</td>
<td></td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>-67.15%</td>
<td></td>
<td>-27.58%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-8.61%</td>
<td></td>
<td>-2.10%</td>
<td></td>
</tr>
</tbody>
</table>

| Standard deviation | 1012.07 | 436.267 |
| degree of fitting  | 0.571   | 0.932   |

4. Transit network evaluation application

The transit network evaluation framework proposed above can be used to evaluate short-term transit network scenario, and it has been used in Fuzhou city transit development project. The input data, i.e.
year 2012 zonal population and employment, are estimated by interpolating the population and employment between the base year (year 2010) and the future year (year 2020). The 2012 transit network is founded on the optimization and adjustment of the current transit network.

The proposed method is implemented with EMME. The road network contains 379 traffic zones, 5979 nodes, and 15591 links. The 2012 transit network contains 417 transit lines (one-way).

Fig. 5. Future year AM peak transit volume distribution in Fuzhou city

Fig. 6. Future year transit network evaluation
The transit network evaluation results include the transit flow distribution (shown in Fig.5) and parameters of a solo line (shown in Fig.6). It can be seen that the line ridership, passenger-kilometer, average loading degree, maximum loading degree and cross section maximum ridership are given. These constitute the basis for the feasibility study of opening a new transit line.

5. Conclusions

To overcome the defects of traditional transit network evaluation method, this paper proposes a new transit network evaluation method. The proposed method combines the transit ridership model and OD difference method, and significantly improves transit network evaluation accuracy. The method has been applied in Fuzhou city, and its validity and practicality has been verified. It should be noted that the interaction between transit OD flows and passenger car OD flows are neglected, for the purpose of presenting the essential ideas of this paper. This will be treated in further study.

References


