Traffic Assignment Forecast Model
Research in ITS

WANG Wei  WANG Quan  WANG Chao

Abstract  As an important role in the development of ITS, traffic assignment forecast is always the research focus. Based on the analysis of classic traffic assignment forecast models, an improved traffic assignment forecast model, multi-ways probability and capacity constraint (MPCC) is presented. Using the new traffic assignment forecast model to forecast the traffic volume will improve the rationality and veracity of traffic assignment forecast.

Keywords  intelligent transport system; traffic forecast; multi-ways probability assignment; traffic assignment

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Introduction

The intelligent transportation system (ITS) develops rapidly along with the city sustainable development, the digital city construction and the development of transportation. One of the main functions of the ITS is to improve transportation environment and alleviate the transportation jam, the most effective method to gain the aim is to forecast the traffic volume of the local network and the important nodes exactly with GIS’ function of path analysis and correlation mathematic methods, and this will lead a better planning of the traffic network.

Traffic assignment forecast is an important phase of traffic volume forecast. It will assign the forecasted traffic to every way in the traffic sector. If the traffic volume of certain road is too big, which would bring on traffic jam, planners must consider the adoption of new roads or improving existing roads to alleviate the traffic congestion situation.

This study attempts to present an improved traffic assignment forecast model, MPCC, based on analyzing the advantages and disadvantages of classic traffic assignment forecast models, and test the validity of the improved model in practice.

1 Analysis of classic models

1.1 Shortcut traffic assignment

Shortcut traffic assignment is a static traffic assignment method. In this method, the traffic load impact in the vehicles’ travel is not considered, and the traffic impedance (travel time) is a constant. The traffic volume of every origination-destination couple will be assigned to the shortcut between the origination and destination, while the traffic volume of other roads in this sector is null. This assignment method has the advantage of simple calculation; however, uneven distribution of the traffic volume is its obvious shortcoming. Using this assignment method, the assignment traffic volume will be concentrated on the shortcut, which is obviously not realistic. However, shortcut traffic assignment is the basis of all the other

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WANG Wei, State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, 129 Luoyu Road, Wuhan 430079, China.
E-mail: jobs_king8286@163.com
traffic assignment methods.

1.2 Multi-ways probability assignment

In reality, travelers always want to choose the shortcut to the destination, which is called the shortcut factor; however, as the complexity of the traffic network, the path chosen may not necessarily be the shortcut, which is called the random factor. Although every traveler hopes to follow the shortcut, there are some whose choice is not the shortcut in fact. The shorter the path is, the greater the probability of being chosen is; the longer the path is, the smaller the probability of being chosen is. Therefore, the multi-ways probability assignment model is guided by the LOGIT model:

\[
P_i = \frac{\exp(-\theta F_i)}{\sum_{j} \exp(-\theta F_j)}
\]

where \( P_i \) is the probability of the path section \( i \); \( F_i \) is the travel time of the path section \( i \); \( \theta \) is the transport decision parameter, which is calculated by the follow principle: firstly, calculate the \( P_i \) with different \( \theta \) (from 0 to 1), then find the \( \theta \) which makes \( P_i \) the most proximate to the actual \( P_i \).

The shortcut factor and the random factor is considered in multi-ways probability assignment, therefore, the assignment result is more reasonable, but the relationship between traffic impedance and traffic load and road capacity is not considered in this method, which leads to the assignment result is imprecise in more crowded traffic network. We attempt to improve the accuracy through integrating the several elements above in one model-MPCC.

2 Multi-ways probability and capacity constraint model

2.1 Rational path aggregate

In order to make the improved model more reasonable in the application, the concept of rational path aggregate has been proposed. The rational path aggregate, which is the foundation of MPCC model, constrains the calculation scope. Rational path aggregate refers to the aggregate of paths between starts and ends of the traffic sector, defined by inner nodes ascertained by the following rules: the distance between the next inner node and the start can not be shorter than the distance between the current one and the start; at the same time, the distance between the next inner node and the end can not be longer than the distance between the current one and the end\[1\]. The multi-ways probability assignment model will be only used in the rational path aggregate to assign the forecast traffic volume, and this will greatly enhance the applicability of this model.

2.2 Model assumption

1) Traffic impedance is not a constant. It is decided by the vehicle characteristic and the current traffic situation.

2) The traffic impedance which travelers estimate is random and imprecise.

3) Every traveler chooses the path from respective rational path aggregate.

Based on the assumptions above, we can use the MPCC model to assign the traffic volume in the sector of origination-destination couples.

2.3 Calculation of path traffic impedance

Actually, travelers have different understanding to path traffic impedance, but generally, the travel cost, which is mainly made up of forecast travel time, travel length and forecast travel outlay, is considered the traffic impedance. Eq.(2) displays this relationship.

\[
C_a = \alpha T_a + \beta L_a + \gamma F_a
\]

where \( C_a \) is the traffic impedance of the path section \( a \); \( T_a \) is the forecast travel time of the path section \( a \); \( L_a \) is the travel length of the path section \( a \); \( F_a \) is the forecast travel outlay of the path section \( a \); \( \alpha \), \( \beta \), \( \gamma \) are the weight value of that three elements which impact the traffic impedance. For a certain path section, there are different \( \alpha \), \( \beta \) and \( \gamma \) value for different vehicles. We can get the weighted average of \( \alpha \), \( \beta \) and \( \gamma \) value for different vehicles. We can get the weighted average of \( \alpha \), \( \beta \) and \( \gamma \) of each path section from the statistic percent of each type of vehicle in the path section\[5\].

2.4 Chosen probability in MPCC

Actually, travelers always want to follow the best path (broad sense shortcut), but because of the impact of random factor, travelers just can choose the path
which is of the smallest traffic impedance they estimate by themselves. It is the key point of MPCC. According to the random utility theory of economics, if traffic impedance is considered as the negative utility, the chosen probability \( P^{rs} \) of origination-destination points couple \((r, s)\) should follow LOGIT model:

\[
P^{rs} = \frac{\exp(-bC^{rs})}{\sum_{j=1}^{n} \exp(-bC_j)}
\]

where \( P^{rs} \) is the chosen probability of the path section \((r, s)\); \( C^{rs} \) is the traffic impedance of the path section \((r, s)\); \( C_j \) is the traffic impedance of each path section in the forecast traffic sector; \( b \) reflects the travelers’ cognition to the traffic impedance of paths in the traffic sector, which has reverse ratio to its deviation. If \( b \to \infty \), the deviation of understanding extent of traffic impedance approaches to 0. In this case, all the travelers will follow the path which is of the smallest traffic impedance, which equals to the assignment results with Shortcut Traffic Assignment. Contrarily, if \( b \to 0 \), travelers’ understanding error approaches infinity. In this case, the paths travelers choose are scattered.

There is an objection that \( b \) is of dimension in Eq.(3). Because the deviation of \( b \) should be known before, it is difficult to determine the value of \( b \). Therefore, Eq.(3) is improved as follows:

\[
P^{rs} = \frac{\exp(-\frac{bC^{rs}}{\bar{C}_{OD}})}{\sum_{j=1}^{n} \exp(-\frac{bC_j}{\bar{C}_{OD}})} \cdot \frac{1}{n} \sum_{j=1}^{n} C_j
\]

where \( \bar{C}_{OD} \) is the average of the traffic impedance of all the assigned paths; \( b \) which is of no dimension, just has relationship to the rational path aggregate, rather than the traffic impedance. According to actual observation, the range of \( b \) which is an experience value is generally between 3.00 to 4.00. For the more crowded city internal roads, \( b \) is normally between 3.00 to 3.50\(^{[1,3]}\).

2.5 Flow of MPCC

MPCC model combines the ideas of multi-ways probability assignment and iterative capacity constraint traffic assignment.

Firstly, we can get the geometric information of the road network and OD traffic volume from related data. Then we determine the rational path aggregate with the method which is explained in Section 2.1.

Secondly, we can calculate the traffic impedance of each path section with Eq.(2), which is expatiated in Section 2.3.

Thirdly, on the foundation of the traffic impedance of each path section, we can calculate the respective forecast traffic volume of every path section with improved LOGIT model (Eq.(4)) in Section 2.4, which is the key point of MPCC.

Fourthly, through the calculation process above, we can get the chosen probability and forecast traffic volume of each path section, but it is not the end. We must recalculate the traffic impedance again in the new traffic volume situation. As is shown in Fig.1, because of the consideration of the relationship between traffic impedance and traffic load, the traffic impedance and forecast assignment traffic volume of every path will be continually amended. Using the relationship model between average speed and traffic volume, we can calculate the travel time and the traffic impedance of certain path section under different traffic volume situation. For the roads with different technical levels, the relationship models between average speeds to traffic volume are as follows\(^{[4]}\):

1) Highway : \( V = \frac{179.49}{N_{A}^{0.108}} \) \( 2 \)
2) Level 1 Roads : \( V = \frac{155.84}{N_{A}^{0.114}} \) \( 33 \)
3) Level 2 Roads : \( V = \frac{112.57}{N_{A}^{0.091}} \) \( 66 \)
4) Level 3 Roads : \( V = \frac{99.1}{N_{A}^{0.1321}} \) \( 5 \)
5) Level 4 Roads : \( V = \frac{70.5}{N_{A}^{0.1598}} \) \( 8 \)

where \( V \) is the average speed of the path section; \( N_A \) is the traffic volume of the path section.

At the end, we can repeat assigning traffic volume of path sections with the method in previous step, which is the idea of iterative capacity constraint assignment, until the traffic volume of every path section is stable.
3 Calculation instance

For validating the correctness of the improved MPCC model, this paper programs with VB 6.0 to actualize the traffic volume assignment in the traffic sector between Xiangfan to Caojiafan in the Hubei Province, and compares with the actual situation. The data is obtained from Hubei Traffic Survey Data Compilation, which is edited by Hubei Highway Authority.

3.1 Calculation of traffic volume assignment of path sections

In the traffic sector between Xiangfan to Caojiafan, there are 4 reference points: Xiangfan (A), Yicheng (B), Nanzhang(C), Caojiafan(D), and 5 path sections which are contained in the rational path aggregate. The sketch is shown as Fig.2. As is illustrated in Fig.2, there are 4 chosen paths in this traffic sector: ABD, ABCD, ACD and ACBD.

1) Calculation of traffic impedance of path sections. The parameter and calculated traffic impedance of each traffic section is shown as Table 1. In the calculation process of this instance, $\alpha$, $\beta$, $\gamma$ is respectively 0.85, 0.05, 0.2.

2) Calculation of chosen probability of path sections. In this calculation instance, the whole traffic volume from Xiangfan to Caojiafan is 15341 every day. We can calculate the chosen probability of each path section with the calculated traffic impedance above, getting $b$ of 3.30, and then forecast the assignment traffic volume of each path section through making the chosen probability of each path section multiply the whole traffic volume.

| Path section | Length (km) | Average speed (km/h) | Travel time (h) | Travel outlay (yuan) | Traffic impedance |
|--------------|-------------|----------------------|----------------|----------------------|------------------|
| AB           | 40          | 79                   | 0.51           | 0                    | 2.4335           |
| AC           | 45          | 75                   | 0.60           | 2                    | 3.1600           |
| BD           | 86          | 60                   | 1.43           | 5                    | 6.5155           |
| CD           | 74          | 63                   | 1.17           | 10                   | 6.6945           |
| BC           | 14          | 70                   | 0.20           | 2                    | 1.2700           |

Firstly, we can compartmentalize the traffic sector to two parts: AC_D and AB_D, and calculate the chosen probability and assignment traffic volume of each part. The traffic impedance of AC_D is considered as the average of the traffic impedance of ACD and ACBD. By the same token, we can get the traffic impedance of AB_D. Secondly, we can realize AC_D as an inner traffic sector, and assign the traffic volume of AC_D to the paths of ACD and ACBD. By the same token, we can get the traffic volume of ABD and ABCD from the whole traffic volume of AB_D. Therefore, repeating this process, we can get the assignment traffic volume of each path section in the traffic sector between A to D. At last, calculate the average speed of each path section with Eq.(5) to Eq.(9) under this traffic volume situation, and then recalculate the traffic impedance and assignment traffic volume of each path section until the traffic volume of each path section is stable. Adopting the MPCC model, we calculate the forecast traffic volume of the four paths and the five path sections.
which is illustrated as Table 2 and Table 3.

| Path  | Forecast traffic volume |
|-------|-------------------------|
| ABD   | 532 6                   |
| ABCD  | 326 5                   |
| ACD   | 398 3                   |
| ACBD  | 276 7                   |

Table 3  Forecast traffic volume of path section using MPCC

| Path section | Forecast traffic volume |
|--------------|-------------------------|
| AB           | 859 1                   |
| BD           | 809 3                   |
| CD           | 724 8                   |
| AC           | 675 0                   |
| BC           | 603 2                   |

3.2 Analysis of results

The actual traffic volume of each path section is shown as Table 4. The traffic volume of each path section using original multi-ways probability assignment model is shown as Table 5.

The average error ratio of the assignment results from the improved MPCC model is 5.20%, while the one from the original multi-ways probability assignment model is 8.82%. Therefore, the results from the improved MPCC model are more realistic.

| Path section | Actual traffic volume |
|--------------|-----------------------|
| AB           | 844 3                 |
| BD           | 736 1                 |
| CD           | 798 0                 |
| AC           | 689 8                 |
| BC           | 621 8                 |

Table 5  Traffic volume of each path section using original multi-ways probability assignment model

| Path section | Forecast traffic volume |
|--------------|-------------------------|
| AB           | 828 4                   |
| BD           | 605 1                   |
| CD           | 919 0                   |
| AC           | 705 7                   |
| BC           | 664 9                   |

In the assignment results from the improved MPCC model, we also can see that the error ratio of AB and AC (respectively is 1.75% and 2.15%) is smaller, while the one of BD and CD (respectively is 9.94% and 9.17%) is greater. This situation reflects that the assignment results are more accurate at the first assignment, while, when the traffic volume of inner traffic sector is reassigned, the error ration will increase obviously. This is the reason why the MPCC model should be improved further.

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