

The Traffic Flow Prediction of Newly-Constructed Expressway Based on ETC Database

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Abstract: The traffic flow prediction of newly-constructed expressway can provide reference for highway capacity design and highway toll standard formulation, but the traffic flow prediction of newly-constructed expressway is always considered a complicated project. With the wide application of electronic toll collection system, it is possible to effectively predict the traffic flow of newly-constructed expressways. In this paper, We propose a new highway traffic flow prediction method based on ETC database. ETC database can be used to extract OD matrix of expressway network, and the dynamic traffic allocation model is applied to predict the traffic flow of newly-constructed expressway. The experimental results show that the method is feasible and effective.

Keywords: ETC database, Traffic network, Dynamic traffic assignment, Traffic volume prediction.

1. Introduction

The forecast of the traffic volume of newly-constructed expressways can not only provide reference for designing the capacity of expressways, but also provide basis for formulating the toll standard of expressways. Therefore, it has been the focus of scholars at home and abroad. However, it is a complicated process to forecast the traffic volume of newly-constructed expressways. In the past, the prediction accuracy of new expressways was not high. With the wide application of Electronic Toll Collection system in expressway network, more and more scholars predict traffic flow based on ETC database.

There were Expectation maximization algorithm[1], Multidimensional time series model[2], Neural network model[3] and so on have been used to predict traffic volume. Zhang[4] proposed that an algorithm was proposed for predicting the freeway entrance volume based on the analysis of stability pattern of freeway traffic OD data. Kim[5] proposed a dynamic OD estimation model based on abundant ETC data. Tsung[6] proposed that the ELK stack was employed to construct a platform for visualizing real-time road usage information and history in this article. Chen[7] demonstrated that the exit traffic flow prediction at Shanghai Xinqiao toll station using entry traffic flows from multiple close-related stations with Long Short-Term Memory (LSTM) model. Li presented the impact of adjusting expressway rates on the traffic flow of cars with seven seats or less. In this paper,

we proposed a dynamic traffic flow prediction of newly-constructed expressway based on ETC database, and also verified the effectiveness of the proposed method.

2. Data Preparation and Related Work

2.1. Data Source

The database in this paper includes toll station data set and gantry data set in the expressway electronic toll collection system. The system uses the ETC gantry installed on the expressway entrance and exit toll stations and the main line to record the traffic information of vehicles passing through the cross-section. We obtained the ETC data of Chongqing all-day expressway network, and the sample was collected on March 9, 2023. The data information of toll station passed data set mainly includes vehicle passed ID, entrance toll station, entry time, exit toll station, exit time and vehicle type, as shown in the table 1. The data information in the gantry data set mainly includes vehicle passed ID, gantry ID, passed gantry time, entrance toll station, entry time and vehicle type, as shown in the table 2. The types of vehicles in the data set are respectively passenger cars, freight cars and special vehicles (due to the small number of vehicles, it will not be considered in this paper). According to the number of axles, number of passengers and load mass of the vehicles, the types of passenger cars are divided into Type-I car, Type-II car, Type-III cars and Type-IV cars. Truck types are classified into Type-I truck, Type-II truck, Type-III truck, Type-IV truck, Type-V truck and Type-VI truck[9].

Table 1. Sample information of toll station passed data set

| Passed ID | Entrance station | Entry time | Exit station | Exit time | Vehicle type |
|-----------|-----------------------------------|------------|-----------------------------|-----------|--------------|
| 042***001 | Chongqing S7 Gaoxin South Station | 00:00:01 | Chongqing Sanjie Station | 00:02:57 | Type-I car |
| 030***002 | Chongqing Jijia Station | 00:00:02 | Chongqing Dazu West Station | 00:13:02 | Type-I car |
| | | | | | |
| 022***122 | Chongqing Baisha Station | 23:41:22 | Chongqing Jiangjin Station | 23:59:41 | Type-I car |

Table 2. Sample information of gantry data set

| Passed ID | Entrance station | Entry time | Passed gantry ID | Passed gantry time | Vehicle type |
|-----------|--------------------------------|------------|---------------------|--------------------|----------------|
| 020***012 | Chongqing G93 Gaoxin Station | 00:00:12 | G008550002000110010 | 00:00:12 | Type-I car |
| 010***015 | Chongqing G75 Beibei Station | 00:00:15 | G007550002000620010 | 00:00:15 | Type-I car |
| | | | | | |
| 322***500 | Chongqing C50 Jiangbei Station | 23:45:00 | S003950001000520010 | 23:59:59 | Type-III truck |

2.1. Expressway Network Model

In this paper, some expressways in the southwest of the main districts of Chongqing are selected to model the expressway network. The expressways in this network include Jiuyong Expressway, Yonglu Expressway, Guanglu Expressway, Chengdu-Chongqing Ring expressway, Chongqing Ring expressway, Hebijin Expressway, Chongqing Third Ring Expressway and Rongzun Expressway. The network diagram of the expressway is shown figure 1. The paths in the network are the real paths of each expressway in the actual road network, and the nodes in the network are the real toll stations and express interchanges in the actual road network. The attributes of each path in the traffic network include toll cost and travel time. The toll cost refers to Chongqing expressway toll standard and Sichuan expressway toll standard. The travel time of the section is the average travel time calculated and counted in the ETC data set. The path attributes of the expressway network are shown in the table 3.

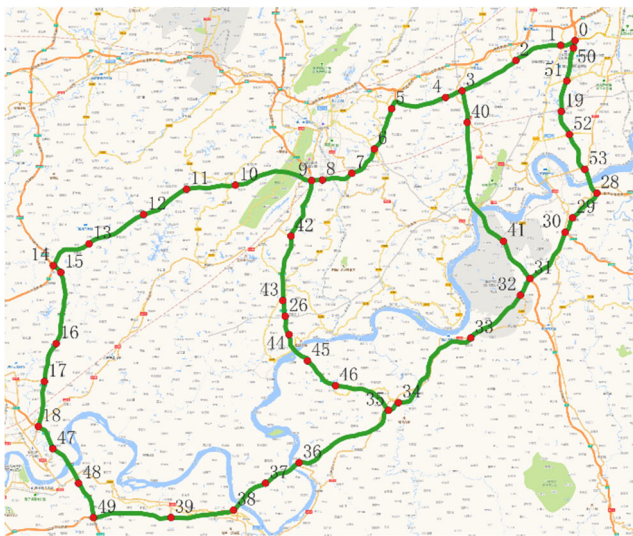


Figure 1. Expressway network

Table 3. Sample information of gantry data set

| Node A | Node B | Distance (km) | Toll (CNY) | TIME (min) |
|--------|--------|---------------|------------|------------|
| 0 | 1 | 2.2 | 1.43 | 1.32 |
| 1 | 2 | 7.1 | 4.62 | 4.26 |
| | | | | |
| 52 | 53 | 5.8 | 3.48 | 3.48 |

2.2. OD Matrix Extraction

The current OD matrix is generated based on the daily traffic data of Chongqing expressway. Most traffic communities have at least one toll station as a node in and out of the expressway network. The python program was applied to process the expressway traffic data and the gantry record data, and the matching and verification were carried out based

on the fields of "Passrd ID" and "Gantry ID" in the data. Firstly, "Entrance station" and "Exit station" in the traffic data can be directly matched to the numbers of original cell and destination cell. Secondly, in the remaining gantry record data, according to the location of "Gantry ID", outbound traffic and transit travel can be matched to the numbers of original cell and destination cell. Finally, the OD matrix is obtained for the traffic distribution of all natural models in the complete road network node.

ETC data set contains a total of 10 kinds of vehicle models. Due to different models' different degrees of influence in traffic flow, we set the conversion coefficient of 4 passenger car models as 1:1:5:1.5, and the conversion coefficient of 6 truck models as 1:1:5:2:2.5 5:3:5:4. The OD matrix units of natural models are uniformly converted from veh/d to pcu/d according to the conversion coefficients of passenger cars and trucks.

3. Dynamic Traffic Assignment

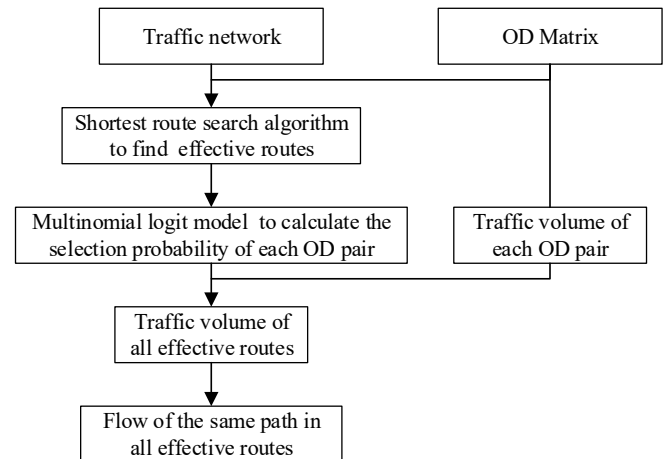


Figure 2. Algorithm flow chart of Dynamic Traffic Assignment model

The route search algorithm is applied to search the effective path between any two traffic districts in the traffic network, and the cost and travel time of the effective path are calculated by superposition. The travel impedance function with time value is used to calculate the travel impedance of each effective path. Aiming at different effective routes of the same pair of OD, multiple logit path selection model is used to calculate the travel selection probability of each effective path between the same pair of OD cells. The traffic volume of each vehicle type of the OD pair is multiplied by the path selection probability to obtain the traffic volume of each path. The traffic volume of all paths is converted into the traffic volume of each section in the traffic network by the decentralized reduction method, that is, the traffic volume of the section in the network is calculated.

4. Experiment and Result

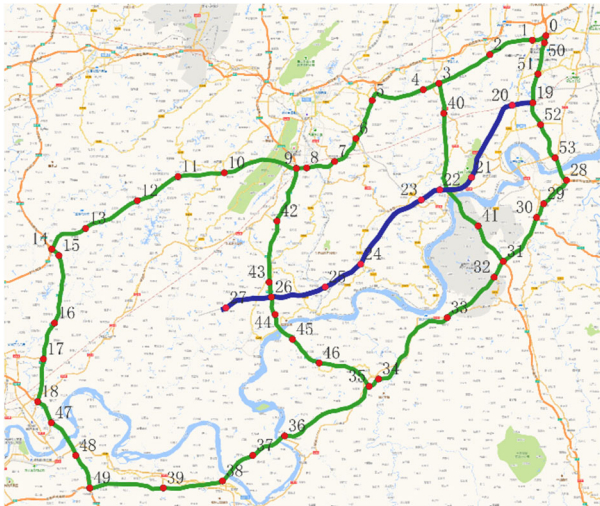


Figure 3. Newly-constructed expressway transportation network

In order to alleviate traffic congestion on the parallel highways, it is planned that a newly-constructed expressway (shown in the blue line in the Figure 3) will be built into the network to share the traffic flow on the parallel expressways. It is very important to forecast the flow of newly-constructed expressway. The flow prediction of newly-constructed

expressway can provide reference for expressway capacity design, and can also be used to formulate expressway toll standard policy, forecast and calculate the toll income of the highway in the future, and provide basis for the investment loan of new expressway. In this paper, dynamic traffic assignment based on ETC data set is proposed to predict the traffic flow of newly-constructed expressways.

According to the OD extraction method in Section 2.3, 366 OD pairs are obtained in the newly-built expressway network in the figure 3. Due to the large number of OD pairs, the following table lists part of the traffic flow of some OD pairs.

Table 4. Some OD pairs of traffic network flow

| Original node | Destination node | Flow (pcu/d) |
|---------------|------------------|--------------|
| 0 | 2 | 515 |
| 0 | 6 | 1070 |
| 0 | 8 | 1566 |
| | | |
| 52 | 47 | 1108 |
| 52 | 48 | 43432 |

We take the OD matrix of the new expressway network as the data source and apply the dynamic traffic assignment model to get the traffic volume of the new expressway, as shown in the following table 5.

Table 5. Some OD pairs of traffic flow

| Start of path | End of path | Flow (pcu/d) |
|---------------|-------------|--------------|
| 19 | 20 | 5022 |
| 20 | 19 | 5201 |
| 20 | 21 | 3974 |
| 21 | 20 | 3958 |
| 21 | 22 | 3974 |
| 22 | 21 | 3958 |
| 22 | 23 | 2181 |
| 23 | 22 | 2026 |
| 23 | 24 | 2181 |
| 24 | 23 | 2026 |
| 24 | 25 | 2181 |
| 25 | 24 | 2026 |
| 25 | 26 | 2063 |
| 26 | 25 | 1647 |

5. Conclusion

In this paper, expressway ETC data set is used to predict the traffic volume of newly-built expressways in the expressway network. Based on toll station data and gate frame data in ETC database, we obtain OD matrix in expressway network, and consider the real toll standard and pass travel time in the actual road network to establish expressway traffic network. Finally, we introduce a dynamic traffic distribution model to predict the traffic flow of newly-constructed expressways. The experimental results show that the dynamic traffic assignment model is effective in predicting the flow of newly-constructed expressways

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