Vehicle OD Matrix Acquisition and Dynamic Traffic Assignment Simulation Based on License Plate Data

Jing-Sheng WANG, Dong-Chen MEI

School of Traffic Management, People’s Public Security University of China, Beijing, 102623, China

Email: wjs1970@126.com

Abstract: In order to obtain the OD (Origin and Destination) matrix conveniently and accurately, the paper deals with the license plate data for time varying OD matrix between traffic crossroads by SPSS and Excel VBA, using vehicle trajectory tracking method to verify the reliability of the OD matrix. It provides an accurate and efficient OD investigation method for traffic planning and management department. Then, the obtained OD matrix is simulated by Vissim for dynamic traffic assignment study. It introduces the principle of dynamic traffic assignment based on Vissim, and combines the actual situation with Vissim platform to model actual road network and calibrate parameters. Finally, a network example result of the dynamic traffic assignment simulation is analyzed and evaluated. The overall delay of the overall network after DTA is reduced by 20%. The application of simulation results in road network evaluation and traffic planning management is also analyzed.

1. Introduction

With the application of high-tech in the field of transportation, the information degree of traffic system is getting higher and higher, and the traffic data acquisition technology and intelligent distribution technology are developing rapidly.

Nanne studied the method of dynamic OD matrix acquisition by tracking vehicle driving path through vehicle identification technology and combined the traffic flow with time-varying characteristics. Yasuo et al., used automatic vehicle identification technology to obtain the license plate data and established the vehicle OD matrix prediction model, proposed the recent and long-term transportation strategy to provide reliable information. But these models are limited to the application of fast track and not applicable to the entire urban road network. The study of Dixon and Rilett found that the OD matrix estimation was more accurate than the OD matrix model based on the traffic flow. Wei Jing, Sun proposed to establish a universal simulation platform, using the shortest path method, neural network and in turn the vehicle steering rate method to supplement missing path and OD points, optimizing the precision of OD matrix.

Based on the license plate data of the electronic police system in Tangshan city, this paper uses SQL Server database and SPSS data analysis software to obtain the dynamic OD matrix of road network by combining Excel VBA programming. Vissim is applied to study and implement the dynamic traffic allocation model based on logit improvement, and the simulation results are analyzed and evaluated.
2. OD matrix acquisition method based on license plate data

2.1 Studied area
All intersections of Tangshan research area are equipped with the electronic police systems with functions of bayonet. There are ten roads in the studied area, 20 intersections, and the traffic structure is very sophisticated, and it has a certain representation and universal significance to the area. Its abstract road network is shown in figure 1.

![Figure 1  Regional Abstract Road Network](image)

2.2 Dynamic OD matrix acquisition
The sample data are the license plate data collected by the electric police system of Tangshan city on June 3, 2014, totaling more than 5.3 million.

**Step1**: Export data
SPSS software is used to export license plates, time, location and other data of 20 intersections of the studied area between 7:30 – 8:30, and duplicate data is deleted.

**Step2**: Get the O and D points of each vehicle
According to the license plate information, the data is clustered and sorted by time. The first occurrence of a certain vehicle in this period is O point, and the last position is D point.

| PLATE INFO | PASSTIME-FIRST | PASSTIME-LAST | CROSSLS H-FIRST | CROSSLS H-LAST | O | D |
|------------|----------------|--------------|----------------|---------------|---|---|
| B000NS     | 3-Jun-2014     | 3-Jun-2014   | 172            | 171           | 1 | 2 |
|            | 7:51:59        | 7:54:26      |                |               |   |   |
| B1114X     | 3-Jun-2014     | 3-Jun-2014   | 172            | 171           | 1 | 2 |
|            | 7:46:42        | 7:48:57      |                |               |   |   |
| B78A77     | 3-Jun-2014     | 3-Jun-2014   | 172            | 171           | 1 | 2 |
|            | 7:37:08        | 7:40:13      |                |               |   |   |
| ...        | ...            | ...          | ...            | ...           | ...| ...|
Step 3: Calculate matrix
Create a 20 * 20 matrix in Excel, and use Excel VBA to obtain the OD matrix after the original data statistics, as shown in table 2.

|     | D  | O  | 1  | 2  | 3  | 4  | 5  | …… | 20 | Total |
|-----|----|----|----|----|----|----|----|-----|----|-------|
| 1   | 0  | 89 | 122| 50 | 131| ……|    |     | 83 | 1023  |
| 2   | 26 | 0  | 92 | 15 | 86 | ……|    |     | 76 | 761   |
| 3   | 46 | 61 | 0  | 48 | 144| ……|    |     | 142| 1992  |
| …… | ……| ……| ……| ……| ……| ……| ……| …… | ……| ……  |
| 20  | 39 | 51 | 126| 30 | 373| ……|    |     | 0  | 1466  |
| Total| 554| 752| 1461| 438| 1417| ……|    |     | 1652| 14933 |

2.3 OD matrix test based on vehicle trajectory tracking

As shown in figure 2, the sample car has passed the intersection 126, 197, 42, 43 and 387, so it can be determined that the O point is the intersection 126, and the D point is the intersection 387. In this paper, the data based on trajectory tracking is compared with the research data, and the comparison results are shown in table 3. The error rate of 10 groups of OD data is no more than 4%, and the error rate of the 10 groups of OD data is 2.48%, indicating that the method of obtaining OD matrix obtained by this chapter is of high reliability.

| OD Pair | The actual OD | The experimental OD | Error rate |
|---------|---------------|---------------------|------------|
| (1,2)   | 89            | 88                  | 1.12%      |
3. Dynamic traffic distribution simulation based on Vissim

3.1 Dynamic traffic distribution principle based on Vissim simulation

The dynamic traffic distribution model in Vissim is based on every iterative simulation runs. The specific steps are as follows:

Step1: Obtain the travel path set between O and D. In the process of iterative simulation, a path set that can be selected by the traveler is accumulated.

Step2: Quantified travel path evaluation index. The travel path evaluation index represents the overall cost, which should be able to comprehensively reflect the distance, time, economic cost and other factors.

Step3: Choose the travel path. In this paper, a Logit algorithm based on Kirchhoff distribution is used as the path selection probability calculation model. As the number of iterations increases, the convergence status is considered when the traffic distribution flow of the network tends to stabilize.

| Path      | Travel Path Set | Selected Path | Convergence Rate |
|-----------|-----------------|---------------|------------------|
| (2,5)     | 86              | 84            | 2.33%            |
| (8,19)    | 42              | 42            | 0%               |
| ...       | ...             | ...           | ...              |
| (14,19)   | 26              | 25            | 4.00%            |
| (18,10)   | 50              | 49            | 2.00%            |
| (19,16)   | 101             | 99            | 1.98%            |
3.2 Simulation example network modeling

Step1: Parking lot and community
Parking lots can be used as the starting point and destination of transportation, and many parking lots can be built in each neighborhood. The 20 intersections of the road network are defined as 20 simulation communities.

Step2: Node
At each intersection, including the bifurcation point of the main trunk and the location where traveler need to make a path decision, all of the nodes are set to include all the possible paths.

Step3: Basic road network
According to actual situation of the road, construction of road sections, setting of signal timing and setting of right of way rules, the setting of the nodes, the calibration of the parking lot and community are completed in turn.

Step4: Traffic demand
The dynamic OD matrix is loaded into the traffic demand parameters of dynamic traffic assignment simulation by software programming method. Dynamic traffic assignment models are demonstrated in figure 4.

Figure 3  Dynamic Traffic Assignment Flow Chart Based on Vissim Simulation
3.3 Calibration of simulation model parameters
According to the measured data, the model parameters are calibrated by simulation iteration, and the final parameters are obtained when the accuracy meets the requirements. The specific parameters are demonstrated in Table 4.

| Calibration parameters | Parameter meaning   | Default value | Small cars | Bus |
|------------------------|---------------------|---------------|------------|-----|
| Travel time            | Smoothing coefficient $\alpha$ | 0.2           | 0.25       | 0.2 |
|                        | Time weight $\alpha$   | 1             | 1          | 1   |
| Total cost             | Distance weight $\beta$ | 0             | 1          | 0   |
|                        | Economic cost weight $\gamma$ | 1             | 1          | 0.5 |
| Logit model            | Sensitive coefficient $\mu$ | 1.5           | 1.8        | 1.2 |
|                        | Path utility lower limit | 0.001         | 0.001      | 0.001 |
| Kirchhoff distribution | Sensitive coefficient $k$ | 3.5           | 4.0        | 3.2 |

4. Dynamic traffic allocation simulation results analysis

4.1 Analysis of convergence process of dynamic allocation calculation
In this experiment, "15% of the path time" is selected as the basic standard of convergence, and the convergence of the whole path of the road network is used to determine the convergence of the experiment. The definition of "convergence index value" is defined as follows:

$$F_i = \frac{R_i^w - R_i'}{R_i'}$$  \(1\)

Where: $R_i^w$ is the number of unconvergent paths for the $i^{th}$ iteration; $R_i'$ is determined as the number of detours for the $i^{th}$ iteration; $R_i'$ is the total number of paths in the road network model in the $i^{th}$ iteration.
When the path distance is 2.5 times faster than the shortest path, it is judged to be a "detour", which is based on the behavior characteristics of travel in this experiment. Therefore, when the simulation model determines the convergence condition, it will ignore the part path and improve the speed of convergence.

![Figure 5  Simulation Model Convergence Process](image)

As shown in figure 5, in the first 19 times of the iteration, in order to improve the convergence speed and gradually load the traffic volume, it happened to load at 19 times to 100% traffic volume, and the fluctuation was obvious. From the 19th to the 27th, the index of convergence dropped rapidly. From 27th to 210th, it entered a period of slight fluctuation. After 210 times, it enters a plateau. Convergence is achieved after 245 iterations.

4.2 Dynamic traffic allocation simulation results analysis
In this paper, OD pair data, node evaluation data and vehicle-road network evaluation data are analyzed. The model has a total of 400 OD pairs and 20 OD pairs produced by the 3rd community. In table 5, "Travel time" represents the average travel time of all transportation between the OD pair, the "Relative delay" represents the ratio of delay to travel time, and "travel distance" represents the average distance of all travel paths in the OD set.

| OD Pair Results                      | Travel Time/s | Delay/s | Relative delay | Distance traveled /m |
|--------------------------------------|--------------|--------|---------------|----------------------|
| 3: JianHua-JianShe -1: XiangYun-WeiGuo | 515          | 92     | 0.18          | 2692                 |
| 3: XiangYun-WeiGuo -2: XiangYun-Huainan | 413          | 53     | 0.13          | 2272                 |
| 3: JianHua-JianShe -3: JianHua-JianShe | 0            | 0      | 0             | 0                    |
| ……                                   | ……           | ……    | ……            | ……                   |
| 3: JianHua-JianShe -20: BeiXin-LongZe | 1080         | 420    | 0.39          | 4402                 |

As shown in table 6, node traffic status and service level reflect the traffic condition of the whole road network. In addition, emissions and fuel consumption data have reference value to traffic planning and traffic management departments.
Table 6  Evaluation Results of 20 Intersections

| Node                      | Queue /m | Vehicles | Delay /s | Stops | Emissions CO/g | Emissions NOx/g | Emissions VOC/g | Fuel Consumption / gallon |
|---------------------------|----------|----------|----------|-------|----------------|-----------------|-----------------|--------------------------|
| 1: XiangYun-WeiGuo        | 17.95    | 1993     | 51.14    | 0.90  | 3776           | 735             | 875             | 54.02                    |
| 2: XiangYun–HuaYan        | 20.91    | 2548     | 33.13    | 0.95  | 3352           | 652             | 777             | 47.95                    |
| 3: JianHua-JianShe        | 48.96    | 5246     | 85.61    | 1.21  | 14778          | 2875            | 3425            | 211.42                   |
| ...                       | ...      | ...      | ...      | ...   | ...            | ...             | ...             | ...                      |
| 20: BeiXin-LongZe         | 30.15    | 3323     | 71.32    | 1.02  | 7856           | 1529            | 1821            | 112.39                   |

Table 7 shows the evaluation data of the whole road network, including the average speed, the delay time, the number of stops, and the number of vehicles arrived etc..

Table 7  Evaluation Results of Vehicle-Road Network

| Simulation Run | TIMEINT (s) | DELAYAVG (s/veh) | Stops | SPEEDAVG (km/h) | DELAYSTOPAVG (s/veh) | Vehicles arrived |
|----------------|-------------|------------------|-------|-----------------|-----------------------|------------------|
| 1              | 0-3600      | 82.93            | 1.83  | 20.09           | 70.31                 | 1243             |
| 2              | 0-3600      | 90.85            | 1.91  | 19.93           | 74.97                 | 1869             |
| 3              | 0-3600      | 93.46            | 1.93  | 19.87           | 75.54                 | 2499             |
| ...            | ...         | ...              | ...   | ...             | ...                   | ...              |
| 200            | 0-3600      | 239.59           | 5.30  | 15.13           | 174.52                | 11400            |
| 210            | 0-3600      | 241.56           | 5.28  | 15.09           | 176.91                | 11388            |
| 220            | 0-3600      | 238.88           | 5.16  | 15.15           | 174.68                | 11425            |
| 230            | 0-3600      | 238.75           | 5.23  | 15.15           | 174.34                | 11334            |
| 240            | 0-3600      | 239.30           | 4.84  | 15.14           | 177.01                | 11373            |
| 245            | 0-3600      | 239.89           | 5.02  | 15.13           | 176.44                | 11398            |

4.3 Dynamic traffic allocation simulation results evaluation

The traffic evaluation software Vistro is used to evaluate the saturation, delay and service level of the simulation network. In this paper, the delay is selected as the key indicator for analysis, as shown in figure 6. After the dynamic allocation, the improvement effect of the intersection 16 is most obvious, and the delay of the 20 intersections decreased by 19.17% on average. The results show that the dynamic distribution model plays an important role as “peak clipping and valley filling” in the road network traffic flow.

Figure 6  Comparison of Delays Before and After Dynamic Distribution of Network Nodes
4.4 Analysis of application of dynamic traffic distribution

(1) Application of road network evaluation

The results of the evaluation of OD, node and road network can be used to verify the rationality of traffic management and planning scheme, and can also be used to implement the advanced ITS industry system.

(2) Application of intersection management and planning

Most of the current intersection management practices are focused on single point govern and lack of systemic. This paper provides a new method for the systematic management of intersection from the perspective of the cohesion between "micro" and "macroscopic" transportation system.

5. Conclusions

In this paper, the method of using SPSS and Excel VBA for license plate data mining is constructed, and dynamic OD can be obtained, and the precision is higher than 95%. A division method of traffic plot based on travel time was put forward, the dynamic OD is used as input for dynamic traffic assignment simulation, and the result shows that the overall network delay is reduced by nearly 20%. The application value of the paper is analyzed from two aspects: traffic evaluation and intersection management.

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