Estimation of a Time Dependent OD Matrix from Traffic Counts Using Dynamic Traffic Simulation

Toshio Yoshii *
Masao Kuwahara *

* Institute of Industrial Science, University of Tokyo
7-22-1 Roppongi, Minato-ku Tokyo 106, Japan
Tel +81-3-3402-6231, Fax +81-3-3401-6286, e-mail yoshii@nishi.iis.u-tokyo.ac.jp

ABSTRACT

This study proposes a method of estimating a time dependent OD (Origin-Destination) matrix from traffic counts using dynamic traffic simulation and investigates how accurately the OD matrix can be estimated in relation to the simulation parameter values.

1. INTRODUCTION

Time-dependent OD matrix is required to realize the optimum traffic control and planning. Many dynamic traffic simulation models have been developed in order to reproduce traffic condition and evaluate policies of traffic control, such as signal control, one-way traffic control and so on. Dynamic models need a time-dependent OD as the input data, especially one composed of small OD zones. On the other hand, as it is hard to observe the dynamic OD matrix, some estimating methods from traffic counts have been proposed[1]. However, simulation can not reproduce the observed traffic counts using a OD matrix estimated by these method, because the relationship between OD volumes and traffic counts in the estimating model differs from one in the dynamic simulation. Therefore, we propose a estimating method using dynamic traffic simulation. Using OD matrix estimated by this method, traffic simulation can reproduce observed traffic counts more accurately. After development of this estimating model, we apply the model to a real network with our dynamic simulation model, SOUND[2], and examine its validity.

2. THE METHOD OF ESTIMATING A TIME-DEPENDENT OD MATRIX

We have already developed the model to estimate time-dependent OD volumes from traffic counts in a general network with route choice activities[1]. The model consists of two parts ; (a) construction of the relationship between the time dependent OD volumes and traffic counts at each link and (b) estimation of a unique time-dependent OD matrix subject to the relationship obtained in (a). In the first part, we define a three-dimensional network to relate OD matrix to traffic flow on links. We then propose a method of estimating route choice probabilities. In the second part, we employ the Entropy Maximizing method for the static OD matrix estimation and extend it to time-dependent model.

In this study, we propose a new algorithm replacing the first part with the simulating part. The algorithm consists of two parts ; (a) simulating part and (b) estimating part. In the simulating part, traffic condition is reproduced by dynamic traffic simulation model, and the relationship between OD volumes and traffic counts can be obtained. On the other hand, in the estimating part, a dynamic OD matrix can be estimated using the relationship calculated in the simulating part. These two parts are repeatedly implemented to obtain OD volumes. An outline of the algorithm is summarized as follows :

Step 0-1 : Prepare a three dimensional network.

Step 0-2 : Define driver's route choice model.

Step 0-3 : Set parameters such as traffic capacity and ones in the route choice model.

Step 0-4 : Initialize the OD volumes.

Step 1 : Implement the traffic simulation and identify which links each OD volume passes through.

Step 2 : Update time-dependent OD matrix by applying the entropy maximizing method[1] under constraints of the relationship between OD and observed link flows obtained at Step 1.

Step 3 : Replace current OD volumes by updated OD volumes.

Step 4 : If converge, finished. Otherwise, go to Step 1.

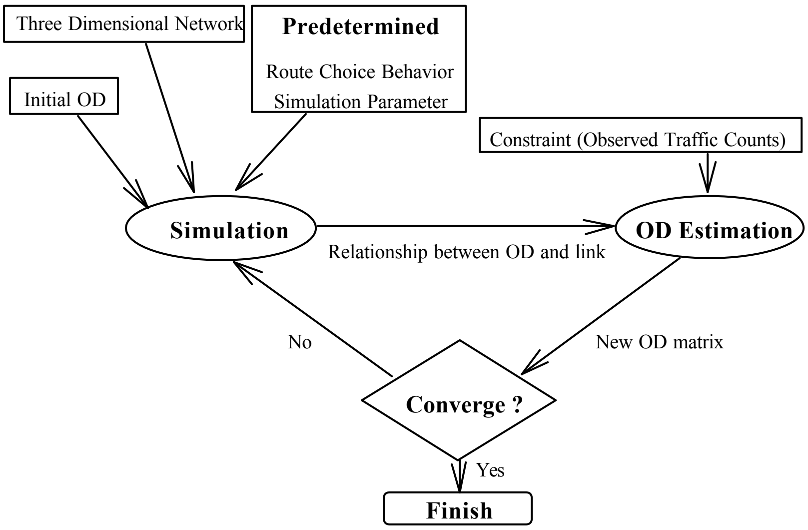

Fig.1 *The Proposed Estimation Algorithm*

2.1 Three Dimensional Network

In this model, we prepare a three dimensional network. Time axis has been divided into time intervals as shown in Fig.2 and Fig.3. For example, the trajectory, a vehicle departed from origin at a time interval h_r moves to destination along the routes(link ***a-f***), is drawn by thick line in both figures. This one shows that a vehicle pass through links ***a*** and ***b*** at time-interval h_r , links ***c***, ***d*** and ***e*** at time-interval h_r+dt and link ***f*** at time-interval h_r+2dt.

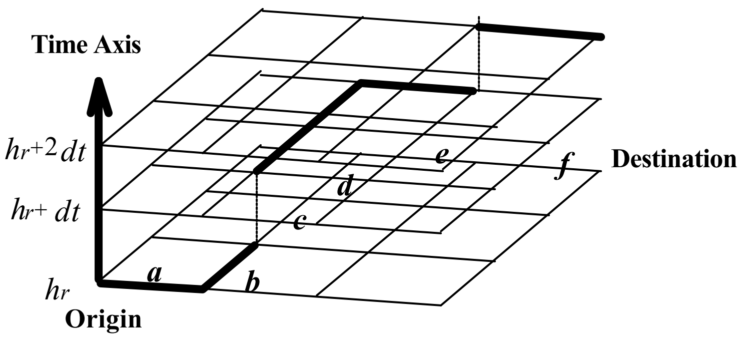

Fig.2 *A Three Dimensional Network*

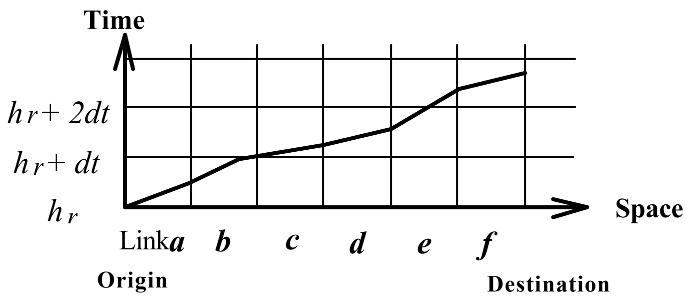

Fig.3 *A Vehicle Trajectory in a Time-Space Plane*

2.2 Driver's Route Choice Behavior

Let us assume user's route choice probability such that

$$P_{kw}(h_r) = \mathrm{Prob}\left[C_{kw}(h_r) + e_{kw}(h_r) \le C_{mw}(h_r) + e_{mw}(h_r)\right], \forall m, \qquad (1)$$

where

$P_{kw}(h_r)$:route choice probability of path k of a vehicle departing from origin r of OD pair w at time-interval h_r

$C_{kw}(h_r)$:cost of path k of a vehicle departing from origin r of OD pair w at time-interval h_r

$e_{kw}(h_r)$:an error term of $C_{kw}(h_r)$

Assuming that error term $e_{kw}(h_r)$ has the Wible distribution, we obtain the following well known Logit model with parameter q :

$$P_{kw}(h_r) = \frac{\exp(-q \cdot C_{kw}(h_r))}{\sum_m \exp(-q \cdot C_{mw}(h_r))} \qquad (2)$$

In this study, we use this type of route choice model.

2.3 Dynamic Traffic Simulation

We use a dynamic traffic simulation model, SOUND[2], which reproduces dynamic traffic condition incorporating drivers' route choice behavior. SOUND requires time-dependent OD volumes and values of parameters such as link traffic capacities, q in route choice model and others.

2.4 OD Replacement

Replace current OD volumes with calculated one in the iterative algorithm using Method of Successful Average [3]. Its formula is shown in eqn.(3).

$$Q_{rsh}^{n+1} = \frac{n \cdot Q_{rsh}^{n} + R_{rsh}}{n+1}$$

(3)

where

Q^n_{rsh} : traffic volume on n th iteration departing from origin r to destination s at time-interval h

R_{rsh} : traffic volume calculated at Step 2 departing from origin r to destination s at time-interval h

3. APPLICATION

3.1 Application Network

We apply our estimating method to the Toyota City area. The network is shown as Fig.4 There are 18 origin nodes, 31 destination nodes and 540 OD pairs. In this network, we have observed traffic counts at 21 intersections and 13 parking facilities from 6:30 a.m. to 9:30 a.m.. As traffic data have been obtained each 15 minutes, time-interval is set as 15 minutes. Every traffic direction in each observed point has been observed. Then total number of traffic observation data amounted to 1998.

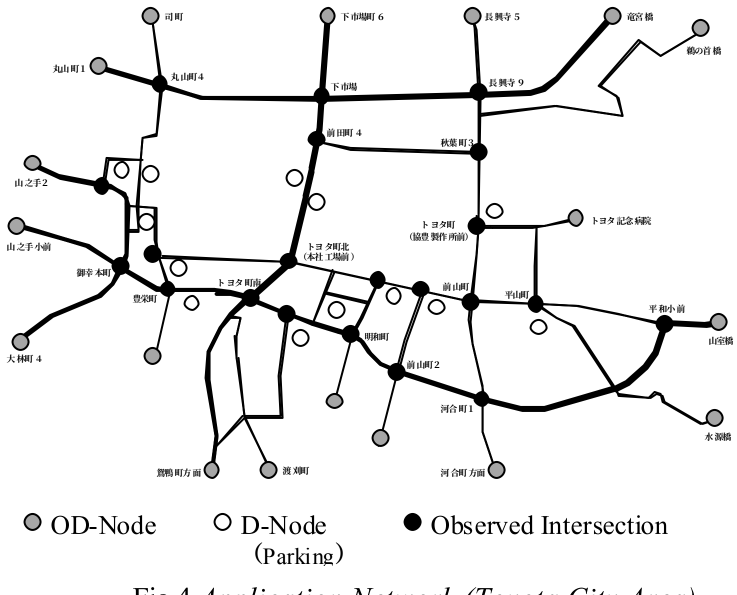

Fig.4 *Application Network (Toyota City Area)*

3.2 Initialization

We set every cell of the initial OD matrix as volume 1[veh/15min.]. Traffic capacity, one of parameters in SOUND, at each link has been determined by the geometric design and signal parameters, and parameter q in the route choice model has been set as 0.01[/sec].

3.3 Application Results

Application results are shown in figures 5 and 6.

Both figures show the difference between observed traffic counts and reproducing flows in simulation. Vertical axis shows the summation of squared errors E_{flow}^{sqd} in Fig.5 and averaged errors E_{flow}^{avg} in Fig.6 ;

$$E_{flow}^{sqd} = \sum_a \sum_h \left[v_{ah}^{sim} - v_{ah}^{obs}\right]^2$$

(4)

$$E_{flow}^{avg} = \frac{\sum_a \sum_h \left|v_{ah}^{sim} - v_{ah}^{obs}\right|}{N^{obs}}$$

(5)

v_{ah}^{sim} : reproduced traffic flow at link a at time-interval h

v_{ah}^{obs} : observed traffic flow at link a at time-interval h

N^{obs} : number of traffic obseravation data

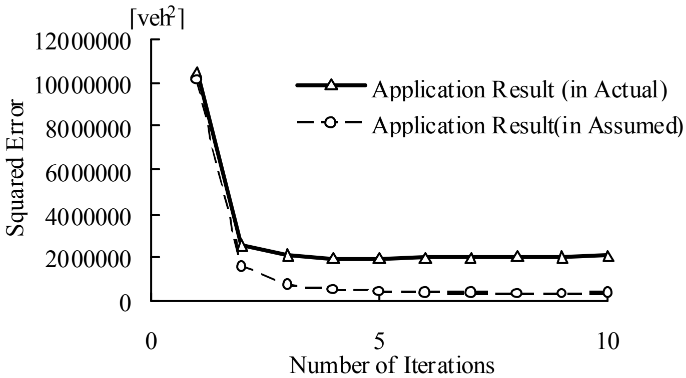

Fig.5 *Difference between Observed and Reproduced Traffic Flow (Squared Error)*

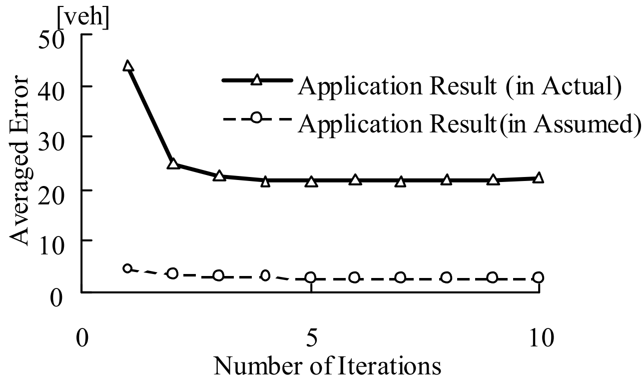

Fig.6 *Difference between Observed and Reproduced Traffic Flow (Averaged Error)*

We tested the estimation based on the actual observed link traffic counts in the Toyota city and the assumed counts. For the assumed case, the evaluation framework is shown in Fig.7. In order to prepare assumed traffic counts, we have produced link traffic counts by implementing SOUND under the assumed OD. Using the same simulation, our estimating method estimates the OD matrix. After that it has been compared to assumed one in order to evaluate the accuracy of the obtained OD matrix

Dotted lines in figures 5 and 6 show difference between observed traffic count and reproducing flows in this assumed situation comparing to one in actual situation. It has not changed after several iterations and the value of difference is smaller than one of actual case. This reason for the difference is that many kind of error items, such as the observation error, simulation accuracy and others, are included in actual case, but not in this assumed case.

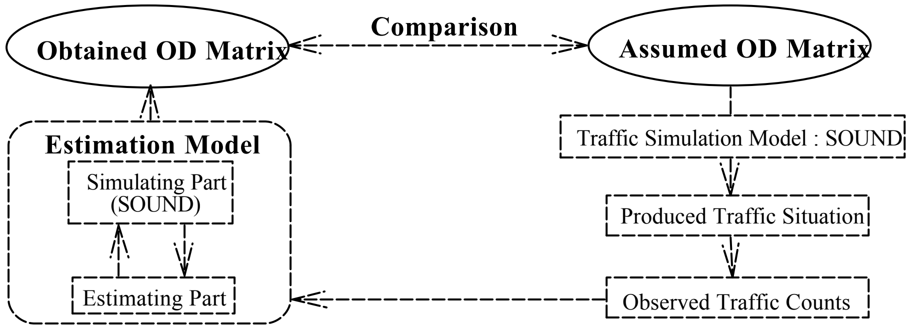

Fig. 7 *Evaluation Framework (the Assumed Case)*

4. ACCURACY OF OBTAINED OD MATRIX

4.1 The Accuracy of Estimated OD Matrix

Fig.8 shows the difference between assumed OD volumes and estimated one. Vertical axis shows the summation of square errors E_{od}^{sqd};

$$E_{od}^{sqd} = \sum_t \sum_r \sum_s \left[V_{rst}^{est} - V_{rst}^{asm}\right]^2 \tag{6}$$

V_{rst}^{est} : estimated OD volume departed at origin r to destination s at time-interval t

V_{rst}^{asm} : assumed OD volume departed at origin r to destination s at time-interval t

Fig. 9 compares assumed OD volumes and estimated ones and Fig.10 compares assumed link flows and reproduced ones. From these figures, we remark that reproduced link flows are reasonably agree with assumed ones but estimated OD volumes are not well fit to assumed ones. This results would be caused by the estimation model which tries to reproduce link flows. In order to estimate OD volumes more accurately, we should have to get more information about actual OD volumes and include it to the estimation model.

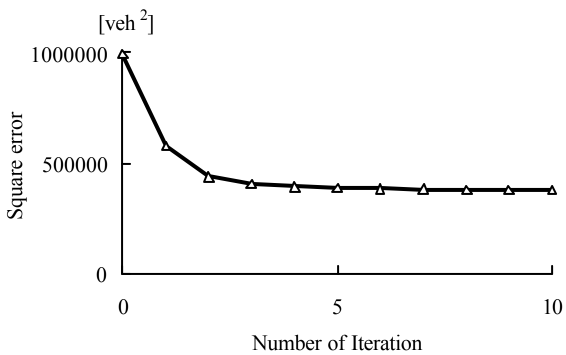

Fig.8 *Difference between Assumed OD and Estimated OD*

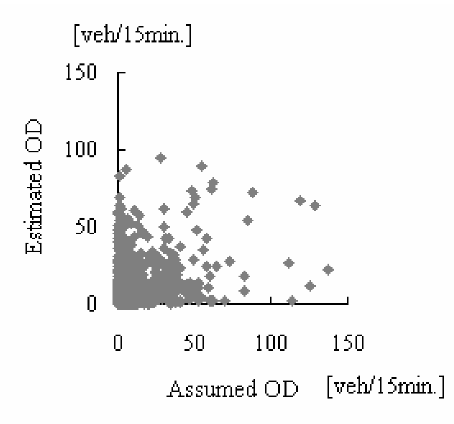

Fig.9 *Assumed OD Volumes and Estimated Ones*

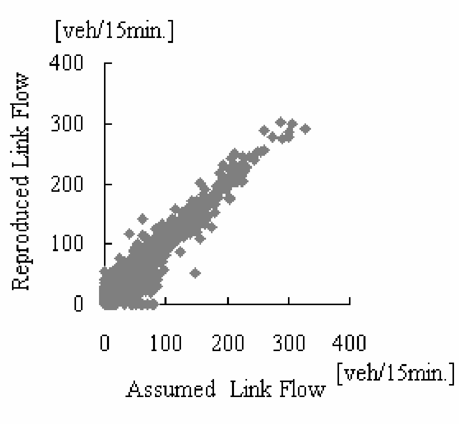

Fig.10 *Assumed Flows and Reproduced Ones*

4.2 Sensitivity of the Estimated OD Matrix to Simulation Parameters

Using this framework, we investigate how accurately the OD matrix can be estimated in relation to the accuracy of simulation parameters ; that is, traffic capacity at each link and parameter q in the route choice model. In both cases, the evaluation has been done after 10 iterations.

Traffic Capacity

We investigate to what extent the accuracy of traffic capacity at each link affects the estimated OD. The estimation model has been implemented 10 cases. In each case, less than ±1% or ±3% errors are included in traffic capacities at each link using the random sequence. The Fig.11 shows the average of final difference in 10 cases between the estimated OD and assumed one. From this figure, we confirm that more exactly simulation parameters(traffic capacity) have been set, more accurately we can obtain the estimated OD matrix.

Fig.11 *Effect of the Accuracy of Traffic Capacity*

Parameter q in Route Choice Model

For another investigation, we investigate to what extent q in Route Choice Model affects the estimated OD. The Fig.12 shows the final difference between the estimated OD and assumed one. From this figure, it would be confirmed that more exactly route choice behavior has been described, more accurately we can obtain the estimated OD matrix.

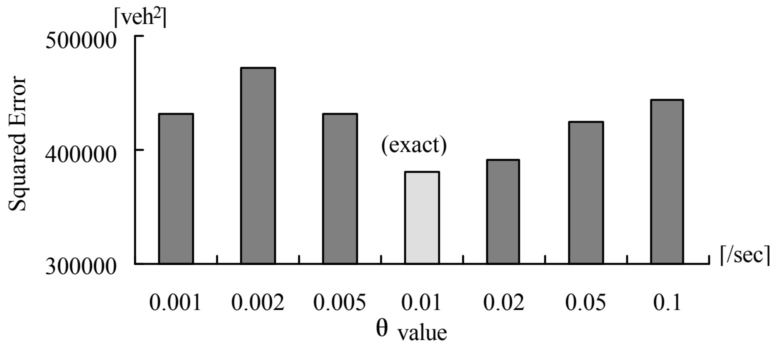

Fig.12 *Effect of the Accuracy of Route Choice Model*

5. SUMMARY AND FUTURE SCOPE

We propose a method of estimating a time dependent OD matrix from traffic counts using dynamic traffic simulation. After that, we investigate how accurately the OD matrix can be estimated in relation to the accuracy of simulation parameters. As a result, though this method can not estimate an exact OD matrix, we can understand to what extent the estimated OD matrix differs from exact one and the accuracy of the estimated OD affected by the accuracy of simulation parameters.

Some of future research topics would be :

1. We should understand how accurately OD volumes can be estimated by other alternative method.
2. We should understand to what extent traffic condition reproduced by simulation includes errors in relation to the estimated OD and each kind of simulation parameters.
3. Actual traffic data are required to validate the method.

4. Although the route choice behavior of a driver is included in simulation models, there are still enough rooms to be studied on the human factor.

REFERENCES

[1]Oneyama, H., Kuwahara, M & Yoshii, T., “Estimation of a Time Dependent OD Matrix from Traffic Counts”, The Third Annual World Congress on Intelligent Transport Systems ‘96 Orlando, CD-ROM

[2]Yoshii, T & Kuwahara, M., “Development of Traffic Network Simulation Model for Oversaturated Traffic Flow on Urban expressways”, Traffic Engineering Vol.30, No.1, pp33-41, 1995 (In Japanese)

[3]Sheffi, Y., “Urban Transportation Networks : Equilibrium Analysis with Mathematical Programming Methods”, Prentice Hall, 1985