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Development of the Origin-Destination Flow Estimation Method for Traffic Condition Prediction

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In order to predict traffic condition using traffic simulation with good accuracy, we have developed the method of estimating more accurate OD (Origin-Destination) flow by minimizing the difference between calculated and observed traffic volume. Validity of this method was checked by applying it to the prediction of traffic condition, and it was found that the accuracy of prediction was improved by this method.

Keywords: *Traffic Information System, ITS, OD Estimation, Traffic Simulation*

1. Introduction

Services of the route guidance based on traffic conditions, such as traffic congestion, accidents, and traffic restrictions, have been realized thanks to the expansion of VICS (Vehicle Information Communication Systems) in Japan. In the future developments, it is desired more advanced traffic information, such as the route of the shortest travel time and the predicted arrival time, will be provided. For a system to offer such information it needs to be able to predict the future traffic conditions and also traffic conditions at location where information is not collected. In order to realize this, traffic conditions prediction by traffic simulation is effective, since traffic simulation can predict traffic condition over a wide area taking into account the influence of accidents and traffic restrictions.

In order to predict traffic conditions using traffic simulation, input data such as the road network, signal timing, and Origin-Destination (OD) flow (i.e., an OD matrix), are required. Above all, OD flow is the most important for traffic simulation, but it is difficult to observe directly. Thus, we estimate it on the basis of the statistic data taken from questionnaires, such as "Road Traffic Census" and "Person Trip Survey" in Japan. However, estimated OD flow exhibits very large deviance from actual traffic demand because it based the information from questionnaire. Therefore, when the OD flow is used as input data, it is difficult to predict the traffic condition with high accuracy.

There have been several studies on OD estimation. Oneyama [1] proposed a method of estimating OD flow by the extended entropy maximization method. In this method, change of travel behavior is taken into consideration by Space-Time network. However, the travel time of all links are needed to determine the probability of choosing a route. In a wide area, this method is not suitable for estimating OD flow, since it is difficult to observe the travel time of all links.

In order to improve the accuracy of the traffic simulation, we have developed the method of estimating more accurate OD flow by minimizing the difference between calculated and observed traffic volume. The features of this method are as follows.

- In the process of OD estimation, change of travel time can be taken into consideration. The travel time of all links are not needed, because these are obtained by Traffic Simulation Model.
- The accuracy of estimation of traffic congestion can be improved by recognizing that there are two different traffic parameter relationships, depending

on whether traffic is in the free flow range or in the congestion range.

- By using GA (Genetic Algorithm) to search for optimal OD flow, estimation can be performed at high speed.

Validity of this method was checked by applying it to the prediction of traffic condition at Toyota-city, Aichi Pref., and it was found that the accuracy of prediction was improved by this method.

Using this method, traffic condition prediction with high accuracy can be realized by traffic simulation. By predicting traffic condition, dynamic traffic information and dynamic route guidance will be supplied to drivers.In this way, traffic congestion will be improved with dispersion of traffic demand.

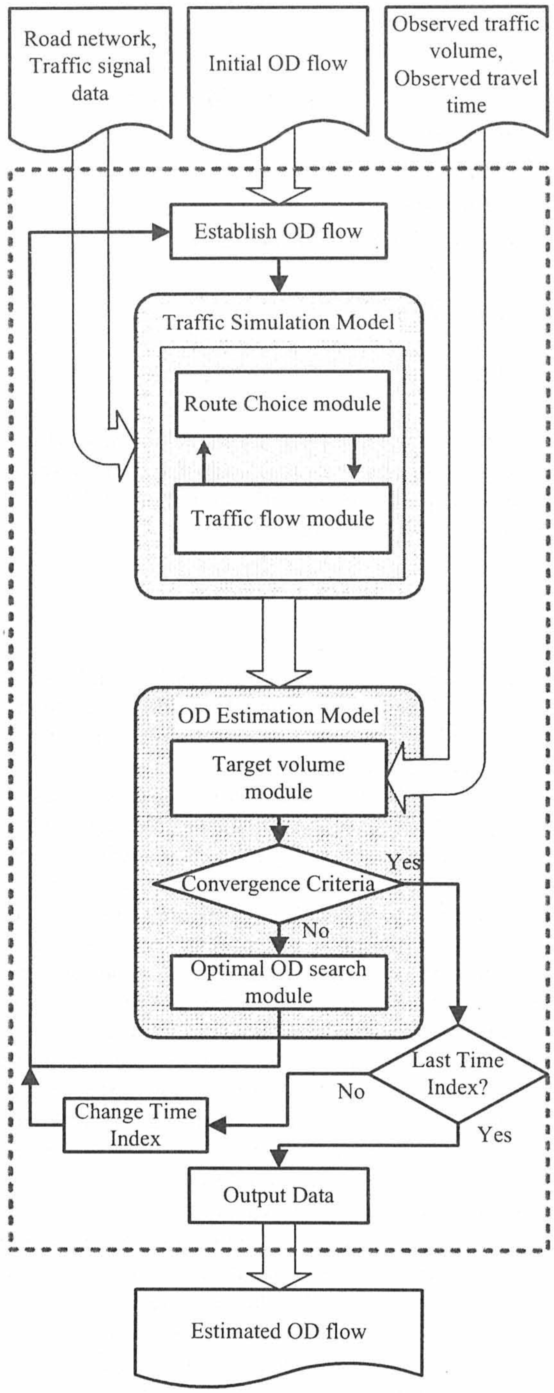

Figure 1. Structure of the algorithm of OD estimation

2. The method of OD estimation

Figure 1 shows the structure of the algorithm of OD estimation. First of all, we input node data, link data, signal data, and OD flow into the traffic simulation model, and calculate the traffic conditions, such as traffic volume and travel time over each link. We use the macroscopic traffic simulator named **NETSTREAM** (NETwork Simulator for TRaffic Efficiency And Mobility) [2]. This traffic simulator has traffic flow module and route choice module. Second, in the OD estimation model, target volume module calculates the volume to be added to calculated flow volume in each link in order to make the estimated volume equal to observed volume. Then, the optimal OD search module searches for OD flow which fulfills the target volume of each link.

Change of OD flow also changes traffic conditions. By the conventional OD estimation method, change of travel behavior with change in traffic conditions could not be taken into consideration. However in this new method, we input the searched OD flow into the traffic simulation model, and calculate traffic conditions again.

If traffic conditions thus change, the resultant change of travel behavior can be calculate by route choice module. Then, we calculate OD flow again. Thus, we calculate iteratively the traffic conditions and the change in OD flow.

2-1. Traffic simulation model

2.1.1. Traffic flow module. In **NETSTREAM**, the relationship between traffic flow Q and traffic density K is given for every link, and each vehicle is moved using this Q-K relationship. Figure 2 shows this Q-K relationship in NETSTREAM.

In this model, relationship between the speed V and density K is defined as equation (1), known as Greenshields formula.

$$V = V_f \times (1 - K/K_j) \quad (1)$$

K_j and V_f denote the jam density and free speed, respectively. And relationship between flow Q and density K is expressed in equation (2) based on equation (1) and the relation $Q=K \times V$.

$$Q = K \times V_f \times (1 - K/K_j) \quad (2)$$

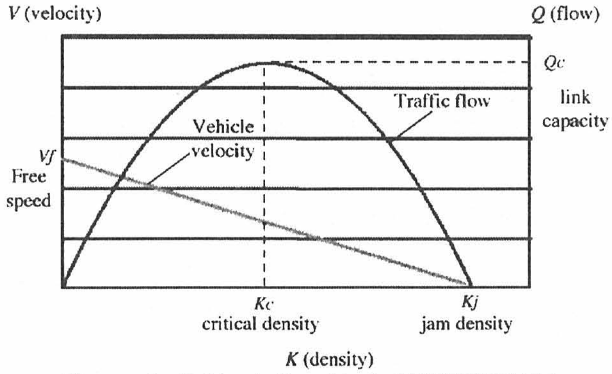

Figure 2. Q-K relationship in NETSTREAM

The relationship between the maximum traffic capacity Q_c and K_j and V_f can be expressed by equation (3) since the link capacity Q_c is realized at critical density $K_c=1/2K_j$.

$$Q_c = (K_j/2) \times (V_f/2) \quad (3)$$

Therefore, V is obtained by equation (4) with space headway $S = 1/K$.

$$V = 4Q_c/K_j \times (1 - 1/SK_j) \quad (4)$$

Thus, $L=V\times t$, the distance traveled by the vehicle in the scanning interval t is calculated by equation (5).

$$L=4Q_c/K_j \times (1 - 1/SK_j) \times t \quad (5)$$

This calculation process of vehicle movements is performed for all vehicles from downstream.

2.1.2. Route choice module. Each vehicle trip is generated from the origin to destination, and on departure time which are given by OD flow. For all Origin-Destination pairs, two or more routes are created beforehand, and for each vehicle is chosen a route using the probability of choosing a route given by route choice module. The route choice module determines the probability according to the LOGIT model based on travel time along each link.

When the number of efficient routes is n and sets travel time of the *k-th* route is t_k, the probability of choosing *k-th* route P_k is described as equation (6).

$$P_k = \frac{\exp(-\gamma\, t_k)}{\sum_{i=1}^{n} \exp(-\gamma\, t_i)} \quad (6)$$

Here, γ expresses the sensitivity of the probability of choosing a route to the change of travel time.

Moreover, the traffic simulation model records the information such as Origin-Destination, time of generated trips, and the probability of choosing a route of the passed vehicles of each link, and reports the information to the OD estimation model on-line.

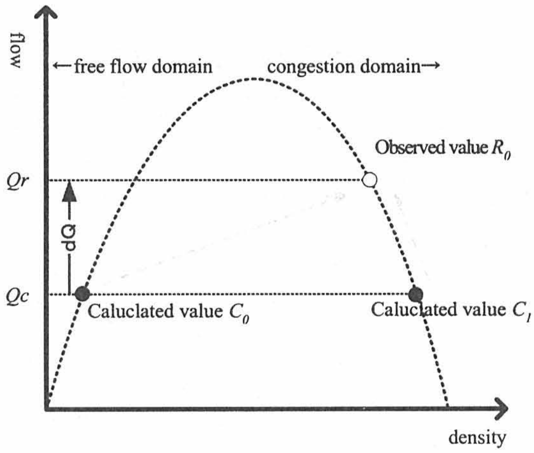

Figure 3. The relationship of density and flow with calculated and Observed value

2-2. OD estimation model

2.2.1. Target volume module. When the observed traffic volume and the calculated traffic volume by the traffic simulation module are compared and there is variance, we calculate the target volume to minimize the difference.

Figure 3 shows the relationship of density and flow with calculated and observed value. In Figure 3, dQ which is the difference of volume between calculated value C_0 and observed value R_0 is obtained by equation (7),

$$dQ = Q_r - Q_c \quad (7)$$

and the difference of volume between calculated value C_1 and Observed value R_0 is obtained by the same equation.

Here, if the number of vehicles into the link increases, the traffic volume will also increase in free flow range, on the other hand, the traffic volume will not increase in congestion range. Therefore, in the case of the calculated value C_0, if the volume of dQ is added to the link, the calculated value is not equal to R_0. Moreover, in the case of the calculated value C_1 is that of already congested traffic, and if the volume of dQ is added to the link, traffic congestion will become intense and the traffic volume will not increase.

As mentioned above, by this method, the target volume is determined by calculated value and observed value by a method differing depend upon whether traffic is in free flow range or congestion range.

Table 1 shows the target volume by the combination of free flow range or congestion range.

Table 1. The target volume

		Calculated value	
		Free flow	Congestion
Observed value	Free flow	dQ	$-\alpha$
	Congestion	α	β

Since the characteristic of the *Q-K* relationship is unique in each link, α and β differ for every link. However, in order to determine these values accurately, it is necessary to know the detailed *Q-K* relationship, and, for that reason, long-term observation data is required. When the observation of *Q-K* relationship is difficult, α and β are given by the equation (8) depicting the average *Q-K* relationship. C denotes positive value.

$$\alpha = |dQ| \quad (|dQ| > C)$$
$$\alpha = C \quad (|dQ| \leq C)$$
$$\beta = -dQ \qquad (8)$$

2.2.2. Optimal OD Search module. In this module, we search for the optimal OD volume which satisfies the target volume of each link.

For example, in the case of the traffic simulation of middle scale city, the number of OD pairs in a time period is about 10000 pairs, and there are three increments of change in volume in one OD pair (-1, 0, +1) in the minimum case. In this case, the number of combinations is $3^{10000} = 1.6 \times 10^{4771}$, and it is almost impossible to search for optimal OD flow out of all combinations. Therefore, in order to improve the estimation accuracy and speed, a technique which can search efficiently is required.

In this module, GA (Genetic Algorithm) was used to search for the optimal OD volume in a short time efficiently. GA is widely used, when searching for a good solution in various optimization problems. In this method, the gene of GA was made the change in volume of each OD flow.

The relationship between dV_i which change in volume of the OD pair i, and dQ_L which denote change in volume of link L can be described as equation (9).

$$dQ_L = \sum_{i=0}^{w} (dV_i \times P_{iL}) \qquad (9)$$

Here, P_{iL} denotes the probability that the OD pair i passes through Link L, this probability of choosing a route provided by traffic simulation model.

Moreover, the fitness f of GA is defined by the formula (10) for error in estimation of traffic conditions.

$$f = \sqrt{\sum_{j=0}^{L} (dQ_j - dT_j)^2} \qquad (10)$$

Here, T_j denotes the target value of Link j, provided by the target volume module.

Therefore, in this method, the gene (OD flow) which makes the fitness f (traffic estimation error) smaller is searched by GA.

3. Result of OD estimation

In order to validate for this OD estimation method, we estimated OD flow for the Toyota-city, Aichi Pref. which is a middle-scale city, and predicted traffic conditions by our traffic simulation model using this estimated OD flow.

The calculated traffic volume was verified as compared with the observed traffic volume found by actual investigation. The calculated value of travel time was verified as compared with actual travel time of the sections measured by investigating vehicles.

Figure 4 shows the road network used in this validation. The network consists of 307 nodes, 932 links and 198 signals with actual signal light patterns. The simulation time zone is 6:00 - 10:00 of a weekday.

The initial OD flow was estimated using the "The 3rd person trip survey in Chukyo area zone" (1991), and classified every 30 minutes. In this initial OD flow, the quantity of vehicles is not accurate because of few investigation samples. But the tendency of traffic demand, for example, in the morning, there is much traffic demand form suburb to urban area, is nearly accurate. So, it is necessary to use the tendency of the initial OD flow. Therefore, Estimated OD volumes were searched in the range of 1/3 times to 5/3 times of initial OD volumes in OD Estimation Model. For that reason, the accuracy of the estimated OD flow depends on the

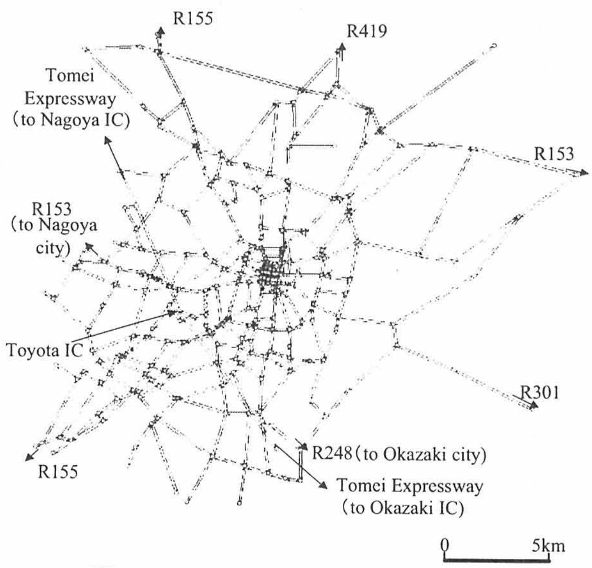

Figure 4. The network of Toyota-city

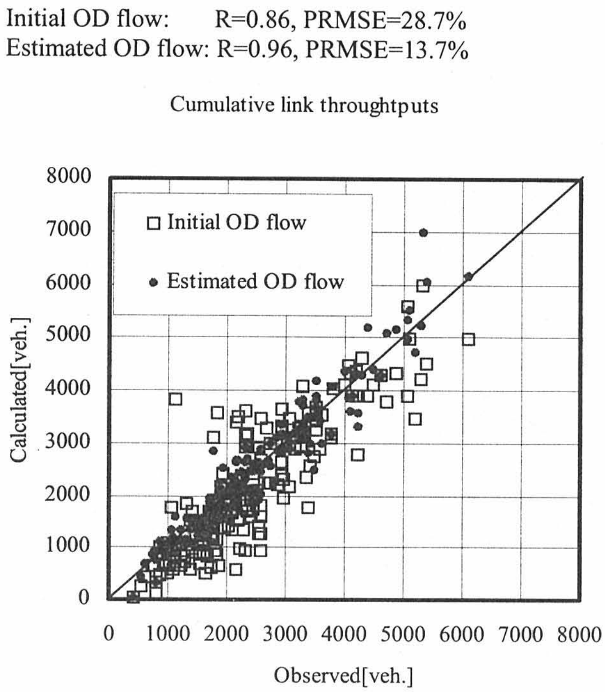

Figure 5. Correlation between calculated and observed cumulative link throughputs

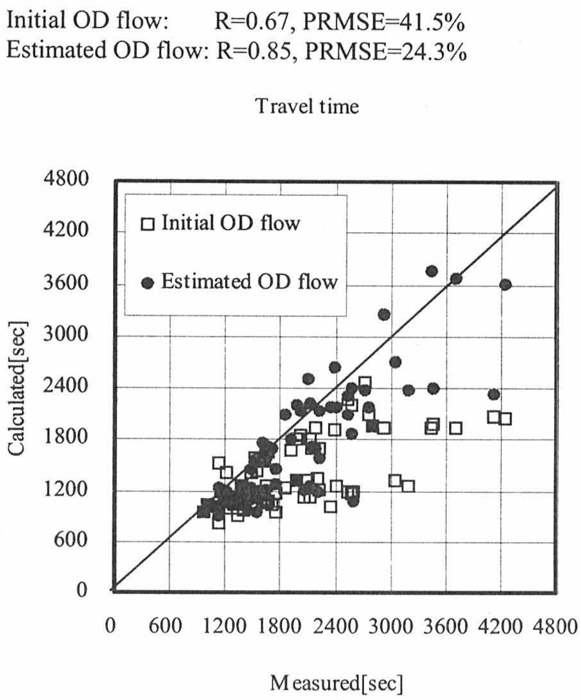

Figure 6. Correlation between calculated and measured travel time

initial OD flow.

From traffic investigation of 27 intersections in June, 2001, the traffic volume of 168 links was obtained, and this observation data was used as the observed traffic volume of OD traffic estimation. This was classified every 15 minutes.

Since the density has not been measured, we used average speed of sections instead of the density. Average speed of each section was obtained on the basis of the travel time data by the investigating vehicles. And when average speed was 10 km/h or less, the link was judged to be the congestion range. Otherwise, it was judged as the free flow range. 47 links of 168 links were monitored to determine whether they were in the congestion range or the free flow range every 15 minutes. The other links were all treated as being in the free flow range, since there was no travel time investigation data.

In the Traffic Simulation Model, the link capacity was set to 1800[veh/h] and jam density was set to 140[veh/km] in all links. The scanning interval was 1 second and γ was set to 0.25[1/min].

Search by GA was performed on 40000 generations, and traffic simulation and OD estimation were repeated 16 times pre time period. Then, the OD flow of the time when error was the smallest was made the optimal result. Processing time was about 8 hours using a 2GHz Intel Pentium4 processor.

First, we compared cumulative link throughputs calculated from initial and estimated OD flow.

Figure 5 shows the correlation between calculated and observed cumulative link throughputs. The correlation coefficient between the link throughputs calculated with estimated OD flow and observed traffic volume shows as good as 0.94.

Moreover, Figure 6 shows the correlation between calculated and measured travel time in 6 sections. The correlation coefficient between travel time calculated from estimated OD flow and measured travel time indicates as good as 0.85. Especially calculated and measured travel time shows good agreement in congested conditions.

4. Conclusions

In order to predict the traffic conditions with good accuracy, we have developed the method of estimating accurate OD flow by minimizing the difference between calculated and observed traffic volume.

As the validation, we have applied this developed method to the prediction of traffic conditions at Toyota-city, and demonstrated that the accuracy of prediction has been improved by this method. We found that estimation of travel time during congested condition especially improved.

In the future, we aim to develop on-line and real time OD estimation method to realize a system which offers the information of predicted traffic with good accuracy.

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