OD VOLUME FLUCTUATION ANALYSIS FOR TOKYO METROPOLITAN EXPRESSWAY BY ETC DATA

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1. Background and Introduction

Expressway traffic congestion is one of the most serious problems in Tokyo area. To reduce the congestion condition, OD volume analysis is necessary to show an inside view of expressway network. A reliable OD volume estimation model can be used by traffic managers to provide more reasonable control strategies to optimize Tokyo Metropolitan Expressway (MEX). Based on OD demand analysis, some OD volume estimation models are developed by establishing the relationship between link flow and OD flow[1)−2)]. However, in case of MEX, the high fluctuation of OD volume causes the difficulties to predict OD volume accurately. Some studies utilize ETC data of MEX which includes valuable individual information of travellers and vehicle to develop OD volume estimator and improve the prediction accuracy[3)−4)]. However the fluctuation is still a challenging problem to impact reliability of the estimators.

This paper focuses on OD volume analysis to explore characteristics and reasons of the high fluctuation. Firstly, vehicle types are classified to find out the reason of the fluctuation and compare characteristics of vehicles for different use purposes. Secondly, an artificial neutral network model is developed to simulate the fluctuation which is the basic step for the OD volume estimation. The study focuses on MEX by using ETC data.

2. OD Volume Fluctuation By Vehicle Types

(1) OD pair and study period

Fig.1 shows the selected OD pair for volume analysis from Yoga main road toll gate to Kawaguchi main road exit. This OD pair has significant volume with long distance 40.9 kilometres. Fig.2 shows the OD volume fluctuation in 24 hours of a weekday. The OD volume is defined as the number of vehicle departing from the origin to the destination per hour. Considered the fluctuation characteristics of this OD pair, the analysis period focuses on the morning peak hours from 6:00 to 8:00. We analyse the fluctuation by vehicle types for one month, July 2006, by using ETC data.

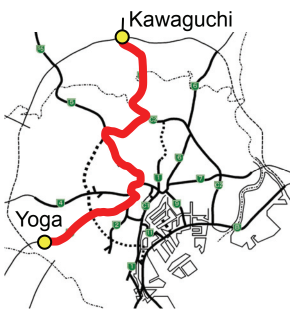

Figure1: OD pair, Yoga to Kawaguchi

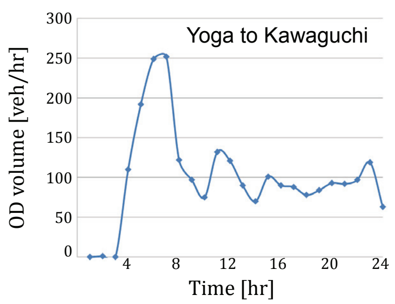

Figure 2: OD volume fluctuation in 24 hours

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(2) Vehicle classification

Fig.3 shows that passenger cars and trucks taking 89% of total OD volume of morning peak hours in July 2006. The majority of trucks are normal sizes (Fig. 4) which maximum load is over 5 tons. The most passenger cars are small and normal sizes (Fig. 5). Therefore, the further analysis focuses on normal trucks and passenger cars.

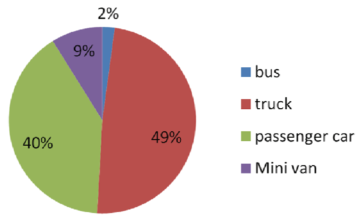

Figure 3: Vehicle classification

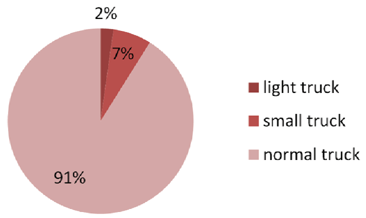

Figure 4: Truck classification

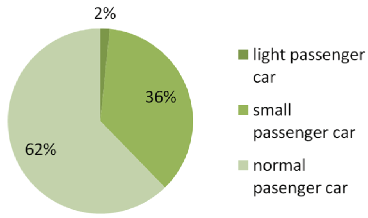

Figure 5: Passenger car classification

(3) Commercial and non-commercial vehicles

Fig.6 shows the OD volume fluctuation of commercial and non-commercial normal size trucks of 31 days, July 2006. The vertical axis shows the average OD volume of the morning peak hours from 6:00 to 8:00 of each day. Based on the observation, the commercial truck OD volume is much greater than non-commercial truck OD volume and commercial truck OD volume is changed by day of the week regularly. For example, July 2nd which t equals 2 in Fig.6 is Sunday. The OD volume increases gradually from Monday to Thursday and decrease after that, except July 13th which t equals 13 in Fig.6 since no ETC data recorded. Sunday is always with the lowest OD volume. On the other hand, Fig.7 shows that the OD volume of commercial passenger car is much less than that of non-commercial passenger car and that the OD volume of passenger car fluctuates randomly without any periodicity.

Therefore, OD volume fluctuation is affected by the use purpose of different types of vehicle significantly. Since we explore periodicity of the OD volume of most trucks, the random fluctuation of the OD volume of passenger car is the main reason which leads to the OD volume fluctuation of the selected OD pair.

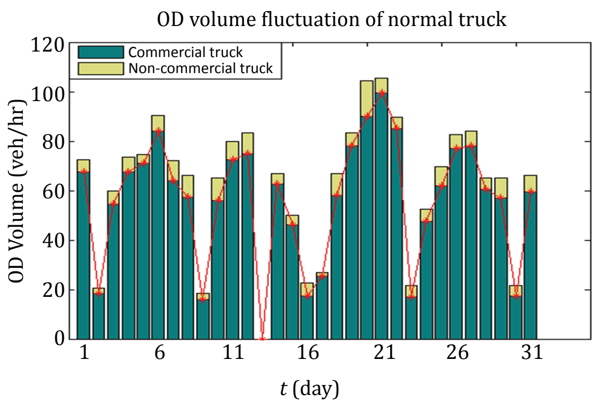

Figure 6: Commercial and non-commercial trucks

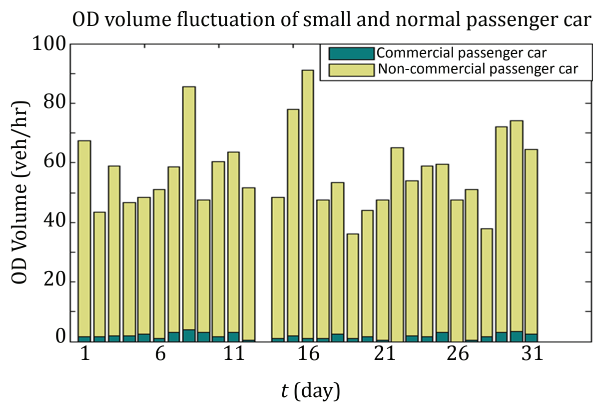

Figure 7: Commercial and non-commercial passenger cars

3. OD Volume Fluctuation Analysis By Using Neutral Network

(1) Neural network

An artificial neural network, usually called neural network, is a mathematical model or computational model based on biological neural networks[5]. Since neural network has advantages of nonlinear estimation, it can be an appropriate methodology to develop an OD volume estimator. Neural network has been used for traffic condition forecasting and travel time prediction in traffic engineering fields[6)−7)]. A fluctuation simulator is developed by feed-forward back propagation neural networks to explore the characteristics of the fluctuation of the selected OD pair.

(2) Feed-forward back propagation model

The Feed-forward neural network is basic type of artificial neural network devised. In this network, the information moves in one direction, forward, from the input nodes, through the hidden nodes and to the output nodes. Back propagation is a common method of teaching artificial neural networks how to perform a given task.

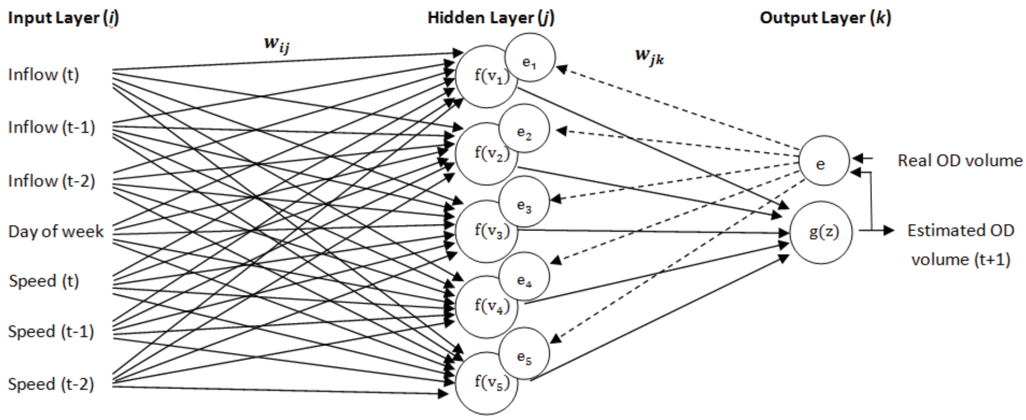

Figure 8: Feed-forward back propagation model

Fig.8 shows feed-forward back propagation model which consists of three layers, input, hidden, and output. The purpose is to use historical and current traffic state to estimate the next time OD volume. In the input layer, on-ramp inflow, day of week, and average speed near the on-ramp are considered as the main factors impacting OD volume of this OD pair. OD volume is not only dependant on the current traffic state but also affected by previous traffic conditions, so the historical data of the inflow and speed is also included in the input layer. Hidden layer consists of five nodes defined as log sigmoid transfer function. Output layer is simple linear transfer function to obtain estimated OD volume.

(3) Learning process

Firstly, the input data goes into the input layers. Between each input variable and each node of hidden layer, initially a parameter weight is set randomly in the range [0, 1]. w_{ij} is the weight between ith input variable and jth node of hidden layer where i=1,2…7 and j=1,2…5. w_{jk} is the weight between jth node of hidden layer and output layer. Since there is only one node in the output layer of this model, k equals to 1. Weights are updated during the learning process to store the information into the model. Secondly, the inputs go through the hidden layer defined as log sigmoid transfer function and the outputs of the hidden layer are

$$f(v_j) = \log sig(v_j) = \frac{1}{1+e^{-v_j}} \qquad where\ v_j = \sum_{i=7} w_{ij} x_i \tag{1}$$

The third step of the feed forward learning is using outputs from hidden layer to obtain the estimated OD volume.

$$g(z) = z \qquad where\ z = \sum_{j=5} w_{jk} f(v_j) \tag{2}$$

Fourthly, comparing the real OD volume and estimated one, we can find the error e. The error of each node of the hidden layer is calculated by $e_j = w_{jk} e$. Then, all the weights will be updated by the following equation (3) and (4), where η is the learning rate in the range of [0, 1].

$$w'_{ij} = w_{ij} + \eta e_j \frac{df(v_j)}{dv_j} x_i \tag{3}$$

$$w'_{jk} = w_{jk} + \eta e \frac{dg(z)}{dz} f(v_j) \tag{4}$$

Based on the updated weights, we can repeat the learning process till the error between the real OD volume and estimated volume converging at an acceptable range.

(4) OD volume fluctuation

Fig.9 shows the comparison between real OD fluctuation and estimated fluctuation of morning peak hours of two months, July and August 2007. The vertical axis shows the average OD volume of the morning peak hours. Since the ETC data is not available for some special days, 56 days were tracked in total. The root mean squared error of the estimated result is 16.3 [veh/hr].

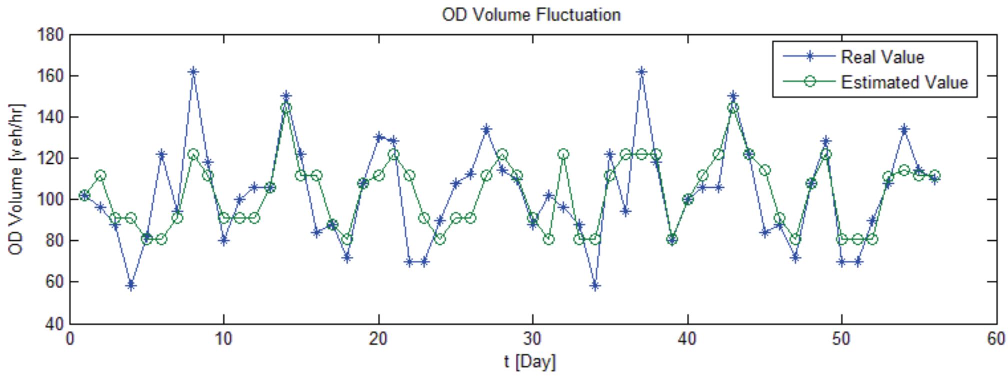

Figure 9: OD volume fluctuation of morning peak hours of two months

4. Summary And Conclusion

OD volume fluctuation has been analysed by vehicle types and the neutral network model. In the first part, OD volumes for specific vehicle types were analysed. Since the OD volume of most trucks (commercial trucks) are changed periodically, the random fluctuation of passenger car which takes 40% of the total OD volume is the main reason to cause the OD volume fluctuation of the selected OD pair. In the second part, feed-forward back propagation approach has been used to develop the fluctuation analysis model. In the further study, based on the neutral network model, an estimator will be developed to separately predict the OD volume by different type of vehicle and improve the prediction accuracy.

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