SHORT - TERM TRAVEL TIME PREDICTION USING LINEAR MODEL*

By Chong WEI**, Takamasa IRYO***, Yasuo ASAKURA****

1. Introduction

Recent year Expressway Corporations are providing travel time information of some major segments using VMS. Generally, these travel times information are only so-called *instantaneous travel time* (ITT) of the segment. Instantaneous travel time is a simple accumulation of link travel times which is calculated as the length of a link divided by the current velocity of the link include in the segment. If traffic flow is stable and the link travel time is constant, the instantaneous travel time is equal to the *real travel time* (RTT). However, the link travel times may change due to the traffic conditions, therefore the instantaneous travel time is not equals to the real travel time (**Figure 1**).

Table 1

Methodology	Fault
Artificial neural network 2)	High computational load and difficult to transplant
Kalman filter 3)	High computational load and difficult to get error matrix
Regression 4)	Lack of theoretical and logical analysis
Simulation 5)	Difficult to estimate parameters and difficult to transplant

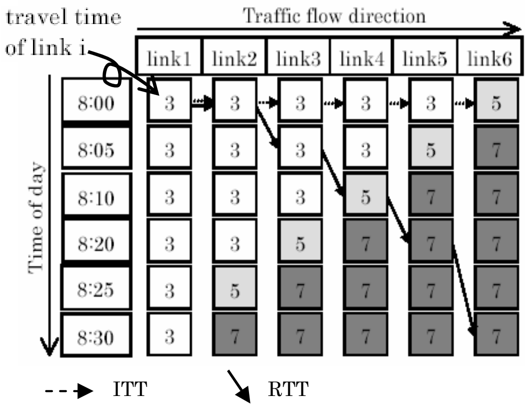

Figure 1 (by 1))

2. Methodology description

There have been many studies on the topic of travel time prediction. The methodologies used in the previous work were concluded by **Table 1**. The major fault of previous works is that the method can not be transplanted to other place easily. For example, Artificial Neural Network method generally needs choice the variables according to the local status, so that neither structure nor parameters can be transplanted to the other application. Simulation method also confronts the same problem that the parameters have to be estimated again when applying at the other place. The main purpose of this article was to describe a method of real travel time prediction. The purposed method is not only simple in pursuing the accuracy but also consider the implementation issue.

*key word: travel time prediction, linear model and weighted least squares
**non-member of JSCE, Master of Engineering, Graduate School of Engineering, Kobe University
(1-1, Rokkodai-cho, Nada,Kobe, 657-8501, Japan, TEL: +81-78-803-6360, FAX: +81-78-803-6360)
***member of JSCE, Doctor of Engineering, Department of Civil Engineering, Kobe University
(1-1, Rokkodai-cho, Nada, Kobe, 657-8501, Japan, TEL: +81-78-803-6360, FAX: +81-78-803-6360)
****member of JSCE, Doctor of Engineering, Graduate School of Engineering, Kobe University
(1-1, Rokkodai-cho, Nada,Kobe, 657-8501, Japan, TEL: +81-78-803-6360, FAX: +81-78-803-6360)

(1) The relationship between ITT and RTT

Let ITT and RTT represent instantaneous travel time and real travel time respectively. Let analyze the relationship of RTT and ITT at t moment. RTT and ITT are two different conceptions that

trouble us to directly analyze the relationship of RTT and ITT. For solving this problem, RTT is transformed into ITT first. As shown in **Figure 2**, the equation follows:

$$RTT(t) = ITT(t + gap\_t) \quad (1)$$

Where t is the moment of the vehicle entering the highway segment. At $t + gap\_t$ moment the vehicle meet with the congestion.

(2) The relationship between $ITT(t + gap\_t)$ and $ITT(t)$

The relationship can be described as:

$$ITT(t + gap\_t) = f\left(C(t), gap\_t\right) \cdot ITT(t) \quad (2)$$

Where $f(.)$ is an unknown function. One natural consideration is that the value of the function $f(.)$ is decided by gap_t and one measurement which can describe the change of ITT. Here $C(t)$ is used as the measurement.

$$C(t) = \frac{ITT(t)}{ITT(t - 5\min)} \quad (3)$$

$$gap\_t = \frac{x}{V_{free} + V_{extent}\left(C(t)\right)} \quad (4)$$

Where x is the distance between the entrance of the highway segment and the tail of the congestion correspond to t. V_{free} is the velocity of the vehicle at free flow and can be considered as a constant, V_{extent} is the speed of the increase or decrease of the congestion extent and can be decided by $C(t)$.

(3) The relationship between RTT and ITT

As the analysis above, we can find the relationship between RTT and ITT as following form:

$$RTT(C, x) = F(C, x) \cdot ITT(C, x) \quad (5)$$

Where function $F(C, x)$ has a similar structure as function $f(.)$ but the independent variables are different. The value of function $F(C, x)$ is determined by the value of C and x correspond to t. Different t may have the same value of C and x. If the couples of RTT and ITT which correspond to the same value of C and x are selected from the database, the equation (5) can used to describe the relationship of the selected sub data set.

Now we can consider that RTT and ITT have the linear relationship which have the same value of C and x. The value of $F(C, x)$ can be calculated by the linear regression method.

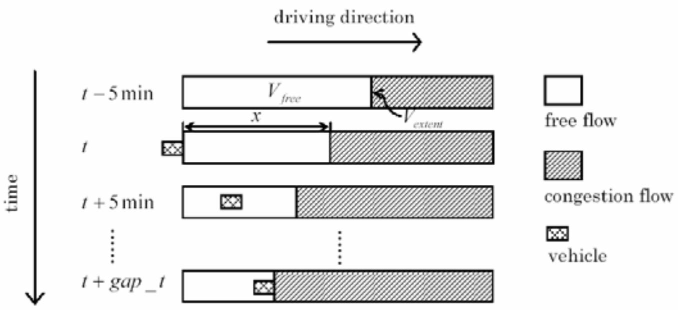

Figure 2

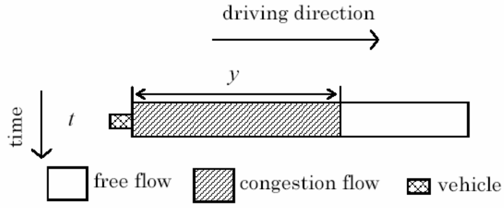

Figure 3

Congestion is not always as described in **Figure 2**, it may happen at the entrance of the highway segment at t moment as shown in **Figure 3**. At this time, y will be used instead of x, where y is the distance between the entrance of highway segment and the head of congestion correspond to t.

(4) Varying-coefficient linear model

Considering a linear model based on the analysis above:

$$RTT(C,x) = \beta_0(C,x) + \beta_1(C,x) \cdot ITT(C,x) + \varepsilon \tag{6}$$

Where $\beta_0(C,x)$ and $\beta_1(C,x)$ are the parameters of the linear model and the parameters of linear model vary with the value of C and x. Because of the variance of the linear model is not equal, the weighted least squares (WLS) to estimate the parameters β_0, β_1 is used.

3. Case study

The method is applied on Hanshin expressway. The study segment was 6 km long. We use data from period 2003-3-2 to 2006-05-31 as the study data pool. Total 182 times tests were carried out and traffic condition is under heavy congestion (0.2hour<ITT<0.5hour) for each time. We use Mean Absolute Percentage Error (MAPE) as the quantify standards to evaluate our prediction model ($R\hat{T}T$) and ITT as travel time information.

$$MAPE_{R\hat{T}T} = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|R\hat{T}T - RTT\right|}{RTT} \cdot 100\% \tag{7}$$

$$MAPE_{ITT} = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|ITT - RTT\right|}{RTT} \cdot 100\% \tag{8}$$

Figure 4 exhibits the MAPE of ITT and the MAPE of the proposed method group by different time segment. The MAPE of the proposed method is lower and stable (near the 25%), which does not increase with the increment of the MAPE of ITT. **Figure 5** depicts the MAPE of ITT and the MAPE of the proposed method group by the different value of ITT. The MAPE of ITT obviously increase where the traffic is under very heavy congestion. On the other hand, the MAPE of the proposed method not be influenced by the degree of traffic congestion and keeps stable (whether high or low of ITT).

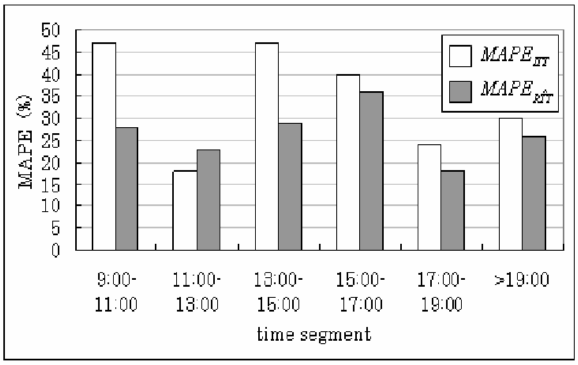

Figure 4

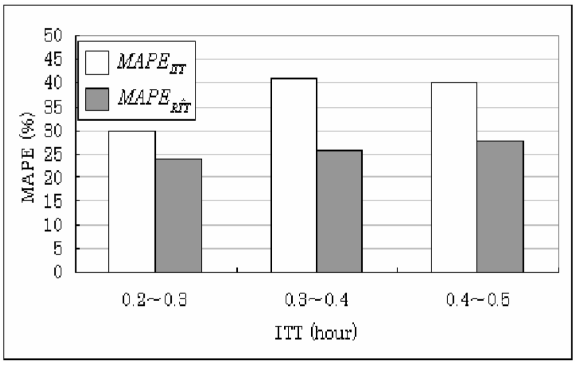

Figure 5

4. Conclusions

From the results, it was identified that the proposed model can provide the stable and acceptable travel time prediction under heavy traffic congestion condition. Compared with ITT as currently using information to the users on this expressway the proposed model is not only more accurate but is also independent to the degree of traffic congestion.

Acknowledgements

The authors would like to thank Hanshin Expressway Corporation for providing the data used in this research.

References

1)Isii, Yasuhiro. (2006) ITS Technology of Hansin Expressway. 2th Shanghai-Osaka expressway management symposium. Osaka. (In Chinese / Japanese)

2)Park, D., Rilett, L. (1999) Forecasting motorway link travel times with a multilayer feedforward neural network. Computer-Aided Civil and Infrastructure Engineering 14: 357-367.

3)Chien, S., Kuchipudi, C. (2002) Dynamic travel time prediction with real-time and historical data. Transportation Research Board, Washington DC. Remarks: Paper 02–2548

4)Zhang, Xiaoyan., Rice, John, A. (2003) short-term travel time prediction. Transportation Research Part 11 C (3), 187-210

5)Kaumann, O., Froese, K., Chrobok, R., Wahle, J., Neubert, L., Schreckenberg, M. (2000) Online simulation of the freeway network of NRW. Traffic and Granular Flow '99, 351-356, eds. Helbing, D., Hermann, H.J., Schreckenberg, M., Wolf, D.E. (Springer,2000)