

A CASE STUDY ABOUT THE TRAFFIC PREDICTION UNDER ACCIDENTS USING DYNAMIC TRAFFIC SIMULATION ON TOKYO METROPOLITAN EXPRESSWAY

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ABSTRACT

The aim of this study is to report on the case study of traffic prediction using the dynamic traffic simulation including route choice model on Tokyo Metropolitan Expressway (MEX). Due to recent high demand for accurate travel time information by drivers, MEX has been developing the dynamic traffic simulation model. MEX provides instantaneous travel time by various types of Variable Message Sign Boards (VMS), and the accuracy of instantaneous travel time is relatively high in general traffic condition. However, in case of accidents, its accuracy goes down significantly. In this paper, an outline of the dynamic traffic simulation is presented, and case studies on MEX are shown. The results show that this dynamic traffic simulation is useful for MEX network, even though it requires more verification.

Keywords: dynamic traffic simulation, route choice model, urban expressway

1. INTRODUCTION

Metropolitan Expressway Company Limited (MEX) manages the 295.0 km urban expressway on Tokyo. Its network is relatively complex and it has 2 rings 11 radial routes which are shown in Figure 1. On the other hand, the complex network provides various route choices for drivers. In order to select the most suitable route, drivers want to know travel time on subjected routes. Drivers' requests have been rising year by year against the background of not only the complex network but also advance of information technology. MEX installed various types of VMS and provides instantaneous travel time based on vehicle detectors' data with every minute. Travel time is roundup with 5 minutes, and its accuracy is relatively high on MEX. However, it is not enough for drivers and they frequently feel that travel time on VMS is not accurate. These opinions should come from situations in case of un-expected



Figure 1 MEX network

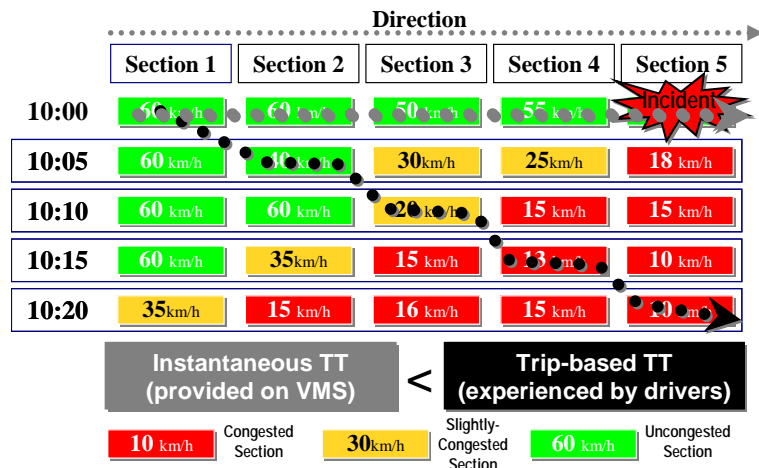


Figure 2 Difference between instantaneous TT and trip-based TT

incidents. Once an accident occurs, the instantaneous travel time should differ from drivers' trip-based travel time. Figure 2 shows this situation; once an accident occurs at 10:00 on section 5, congestion is spread toward upstream, and the instantaneous travel time is much less than the trip-based travel time due to congestion by the accident. In order to provide much accurate travel time under un-expected incidents, MEX has been developing the dynamic traffic simulation, which is based on real-time data and includes route choice model⁽¹⁾. The simulation is named as RISE (Real Time Traffic Information by Dynamic Simulation on Urban Expressway) and it accordance with any incidents; accidents, maintenance works, and broken-down vehicles. There are about 40 accidents per day occurred on MEX, and therefore this corresponding incidents module is an essential component of this simulation. In addition, MEX installed plenty of vehicle detectors, approximately 300m intervals, and data are collected, processed, and provided (renewed) with every one minute, so the simulation can be reflected the latest traffic condition. This Simulation (RISE) will be used in practical at the information call centre and prediction travel time will be provided for drivers from November 2009. In the future, the RISE will be used for not only providing information, but also traffic management and evaluation of projects.

2. OUTLINE OF THE DYNAMIC TRAFFIC SIMULATION (RISE)

The dynamic traffic simulation (RISE) consists of four modules: Base simulation, Corresponding to incidents module, Estimation of traffic volume on on-ramps, and Prediction simulation. Getting latest data from the Total Traffic Information System (TTIS) every minute, the base simulation starts run and prepares the initial condition of prediction simulation. The corresponding incident module starts when an incident is registered on expressway, and it adjusts input data with incidents. Using the results of base simulation, estimation of traffic volume on on-ramps and corresponding incidents module, the prediction simulation does work. This flow of modules is shown in Figure 3. Each module of the RISE is explained in the following section.

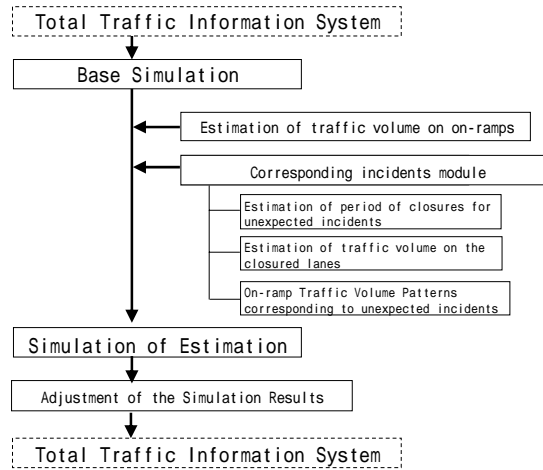


Figure 3 Simulation module flow chart

3. EACH MODULE OF THE RISE

3.1 Base Simulation Module

Base simulation module prepares the initial condition of the prediction simulation. Here, each vehicle model has its characteristic and objection and moves with traffic detector speed on links. The destinations of vehicles are assigned with the modified origin-destination table, which is scaling using detector data on traffic volume of on-ramps. The image of vehicle moving model on this simulation is shown in Figure 4. This simulation employs the logit-model as a route choice model and its function is shown in Equation 1.

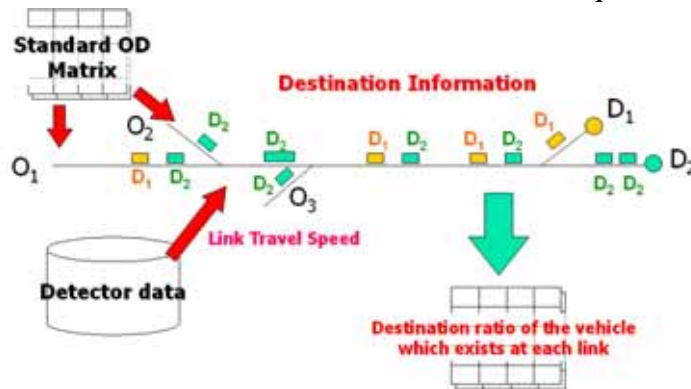


Figure 4 Image of vehicle moving of Base Simulation

$$p_L = \frac{1}{1 + \exp(-\theta(C_R - C_L))} \dots \text{Equation 1}$$

Here, p_L is choice rate of left route, C_R is cost of right route, and C_L is cost of left route. C_R and C_L are calculated by Equation 2. This function is calculated for both route fixed and selective drivers. It employs travel time reliability coefficient and Junction coefficient. The Junction coefficients are installed at the all junction on the MEX. It means difficulty of merging at junction, and therefore JCT coefficients are set at merging traffic flow. The image is shown in Figure 5.

Route fixed model: $c(t) = \frac{3.6L}{v50} + a_1 \left\{ \frac{3.6L}{(v50 - R5)} - \frac{3.6L}{v50} \right\} + \frac{60F}{E}$

Route selective model: $c(t) = T(t) + a_2 \left\{ \frac{3.6L}{(v50 - R5)} - \frac{3.6L}{v50} \right\} + \frac{60F}{E} + JCTCoef \quad \dots \text{Equation 2}$

- $c(t)$: cost on links at the time t
- $T(t)$: Travel Time at the time t
- L : Link length (m)
- $v50$: 50% free velocity of each hour(km/h)
- $R5$: hour(km/h)
- F : toll cost (¥)
- E : value of time(¥/minute)
- a_1, a_2 : coefficient of reliability
- $JCTCoef$: Junction coefficient (sec)

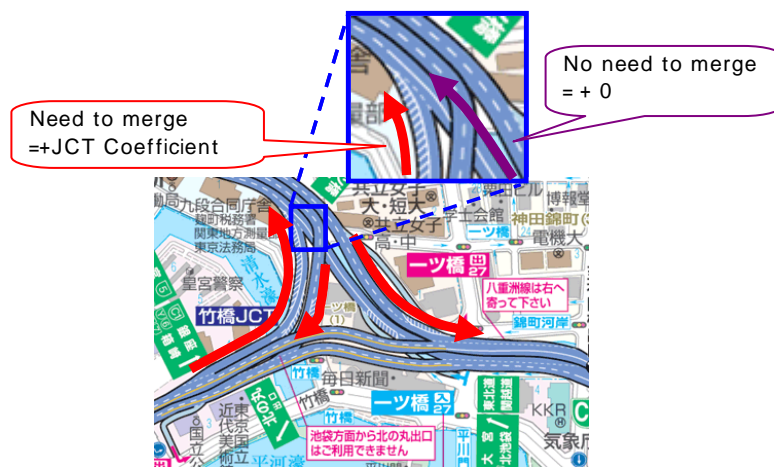


Figure 5 Image of Junction Coefficient

3.2 Prediction of future demand

Future demand is predicted by applying ARMA (Auto-regressive Moving Average) model to the traffic volume measured by the detector at each on-ramp. In order to reduce the non-linearity in the demand coming from daily or monthly variation, the difference of measured volume from the average volume, which is prepared for each day of the week and updated day to day, is to be calculated as for the input time series data to ARMA model. The future time series of the differential data is calculated by (Eq. 3).

$x(t) = a_1x(t-1) + a_2x(t-2) + \Lambda + a_mx(t-m) \dots \text{Equation 3}$

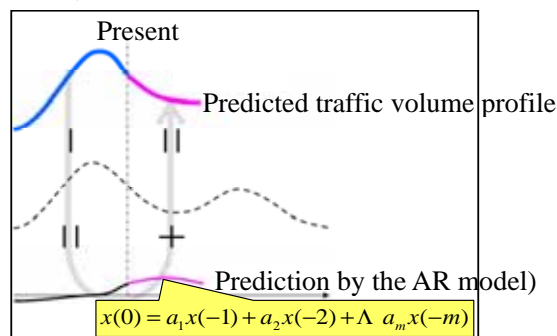


Figure 6 Image of estimation on-ramps traffic volume

3.3 Prediction Simulation

The prediction simulation employs [Large Network Traffic Simulation Model SOUND/A-21⁽¹⁾] which is based on Kinematic Wave logic. It sets capacity constraint both sides of links and treat vehicle moving on links as point queue. It employs approximated volume-density relation (Q-K) as triangular relation. The image of vehicle moving on prediction simulation and its Q-K relationship are shown in Figure 7. This model can express shockwaves with increasing or decreasing traffic jam, but cannot express micro vehicle behavior such as lane changes or overtaking. Advantage of this model over car-following model is less number of parameters.

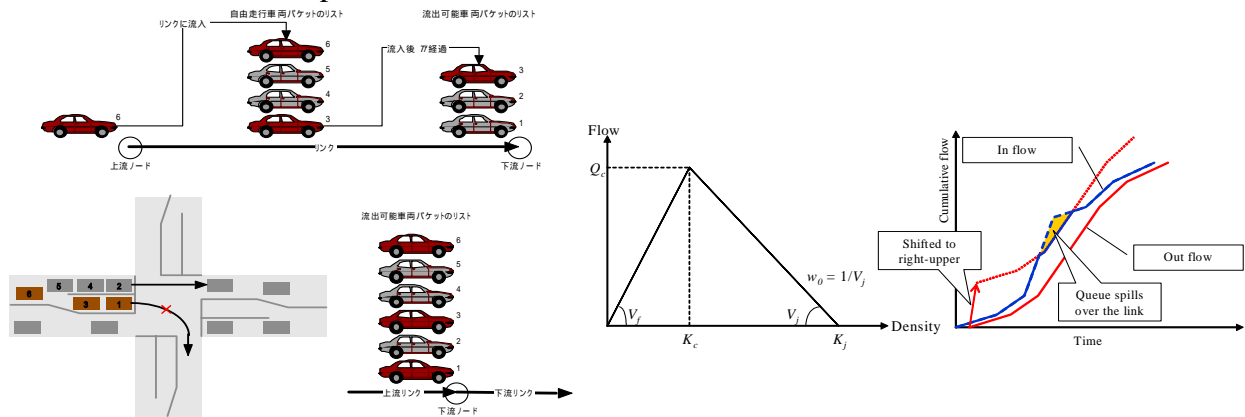


Figure 7 Image of vehicle behavior of the Prediction Simulation

The Q-K relationship of each link is set up for bottleneck points and the others, separately. The Q-K on the general links is triangular shape shown in Figure 8 with solid line, which is identified with a slope of the free flow speed (V_f), a slope of jam side, and the jam density (K_j). At the bottleneck points, the Q-K line is anti-lambda shape with capacity constraint at the end of link, which is shown in Figure 8 with dotted line. These Q-K lines are set up from one month 5 minutes data on each links.

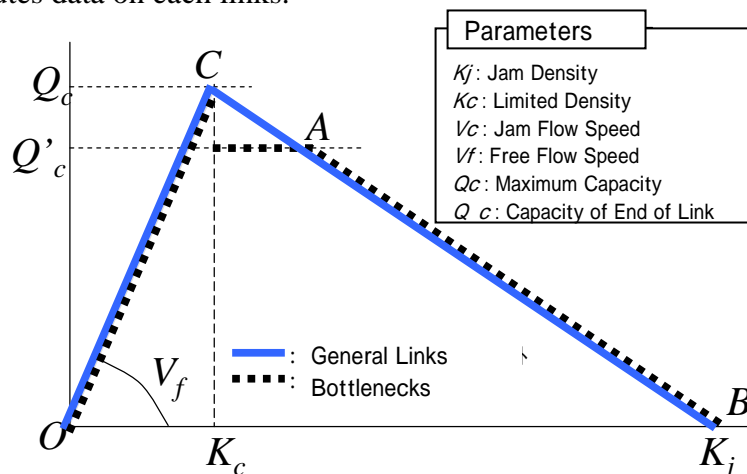


Figure 8 Q-K relationship on Links (RISE)

3.4 Corresponding incident module

The corresponding incidents module estimates (a)period of lane closures, (b)degraded traffic capacity, and (c)diverted traffic patterns on each on-ramps in case of certain incidents, such as accidents, broken-down, and maintenance works. The flow of these modules is shown in Figure 9.

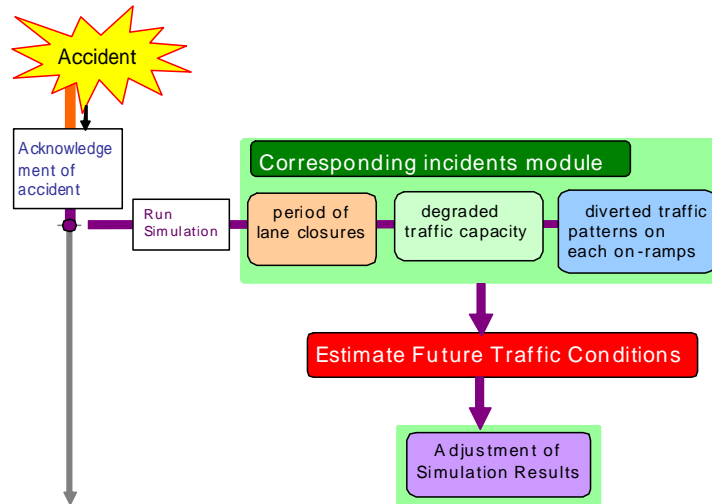


Figure 9 Flow chart of the Corresponding Incident Module

(a) Estimation of lane closure period

Due to unexpected incidents such as accidents, lane closures should be occurred. The period of these lane closures should be depended on some conditions: time, weather, location, route, types of accidents, number of injuries, level of injuries, number of involving vehicles with accidents and existence of ambulance car. From analyzing these past accident cases, the period of lane closure due to unexpected incidents is expected by statistical analyses. The initial estimation of lane closure period is 60 minutes which is average of all accident cases, and it is renewed according to updating details of accidents, such as number of injuries. This update image is shown in Figure 10.

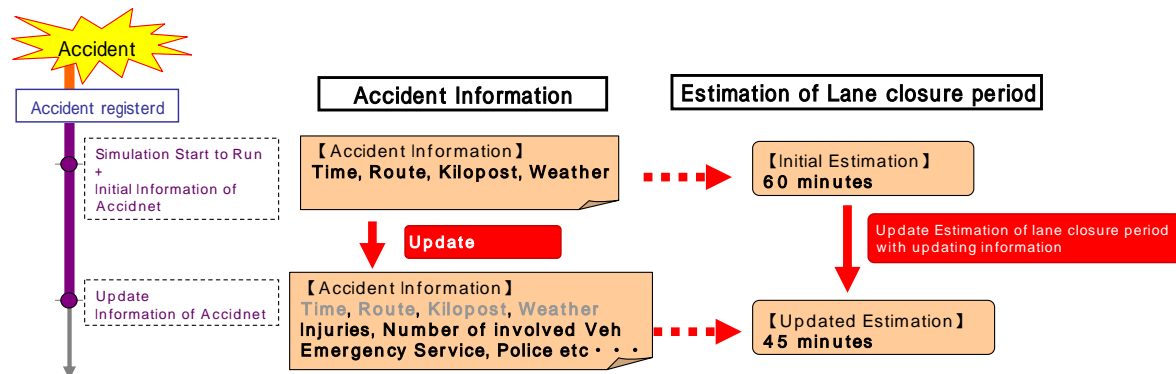


Figure 10 Update image of lane closure period

(b) Estimation of degraded capacity due to incidents

When a certain incident occurs and lane closure happens, the subject link capacity might be

degraded. Under the congested condition, the degraded capacity is identified by the degraded traffic volume after an accident is registered. For example, case A of Figure 11 shows traffic volume-time graph. Once an accident occurs and it is registered, traffic volume drops suddenly. This traffic volume is set up as a degraded traffic capacity in case of the incident. This capacity will continue with estimation lane closure period. On the other hand, when there is no congestion occurred with incidents, the degraded traffic volume is not identified. Then, in this case (case B of Figure 11), the degraded traffic capacity is simply set by the number of opened-lanes.

Case A: Jam occurs due to incident

Case B: No Jam occurs due to incident (eg. at night time)

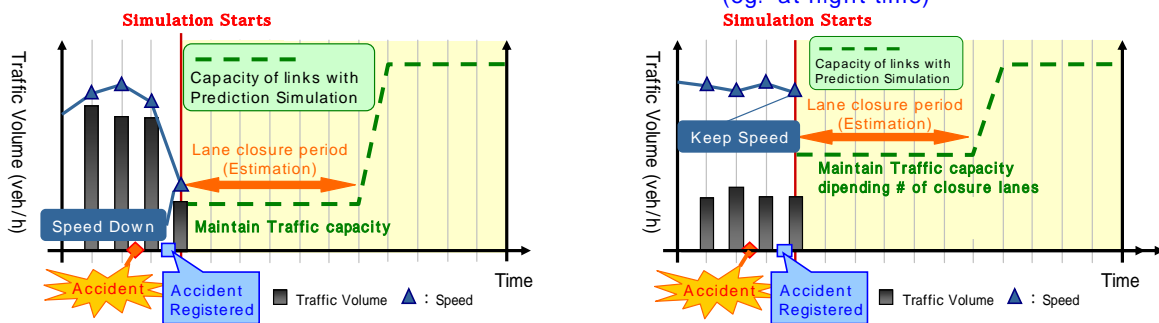


Figure 11 Images of degraded traffic capacity due to incidents

(c) Estimation of diverted traffic patterns on each on-ramps

Traffic volume on on-ramps changes certain patterns depending on days and time. However, when a certain incident occurs and congestion due to that incident occurs, some drivers might avoid congestion and change their ramps. This diverted behavior is seemed with a certain pattern as well. For example, when one accident occurs on Section 6 and congestion due to this section occurs around upstream sections which includes A and B on-ramps, some drivers who generally use A and B ramps avoid congestion and change their on-ramps to C and D ramps. Using one year on-ramps traffic volume data and accident records, a changed-pattern of onramps is identified when an accident occur on a particular section. If traffic volume on an on-ramp, in which congestion occurs in downstream of that section, exceeds a standard deviation of the traffic volumes, the traffic pattern of that on-ramp is changed into the different pattern. The image of this function is shown in Figure 12.

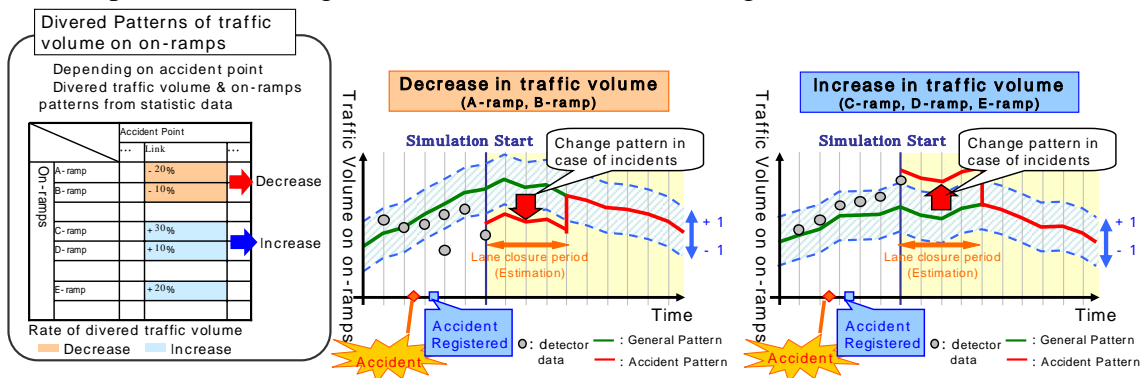


Figure 12 Traffic pattern on on-ramps due to incidents

3.5 Adjustment of the prediction simulation result

This module adjusts the prediction simulation results, comparing with the latest detector data. If the differences between the simulation results and the latest data are over a certain level, the results are modified in 2 hours using triangular distribution.

4. CASE STUDIES

This simulation (RISE) is applied to a few case studies. In this report, two cases of them are introduced: case 1 is normal traffic condition and case 2 is traffic condition with accident. Case 1 is presented in 4.1, and Case 2 is presented in 4.2. Both cases are applied into the same route; inbound of the KAWAGUCHI Route (Route number “S1”). Route S1 connects intercity motorway on north and central circular route on south. Route S1 is shown in Figure 13.

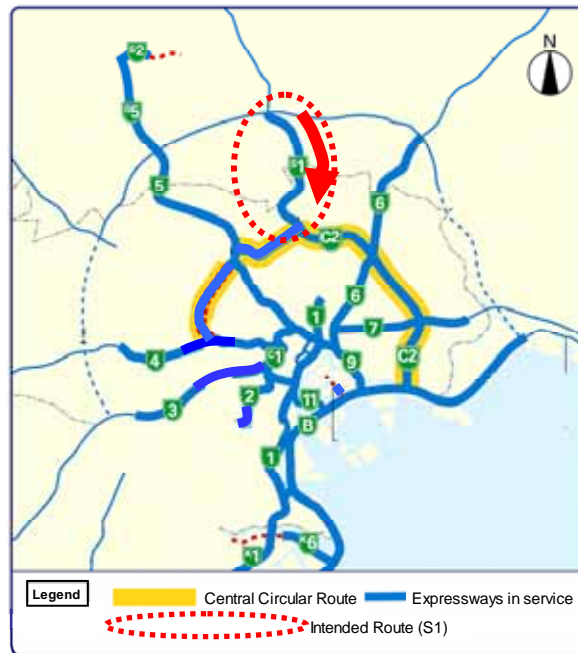


Figure 13 Intended Route KAWAGUCHI Route; Route S1

4.1 Case 1 – normal traffic condition without accidents -

The intended day and time is the end of March (Monday) from 7:00 to 9:00, which is the morning peak hour. There was no accident on the intended route at that time. In-flow traffic volume should affect the simulation results, and therefore the most large in-flow traffic volume was checked, comparing with actual traffic volume and cumulative traffic volume from the inter-city motorway. Two hours prediction results and actual traffic volume are shown in Figure 14, which includes in-flow traffic volume from inter-city motorway with line chart and cumulative traffic volume with bar chart. Actual traffic volume has large fluctuation and it seems different from prediction traffic volume. However, as for cumulative traffic

volume, error of prediction results is approximate 200 veh/2hour, and therefore its results seem to be relatively well prediction.

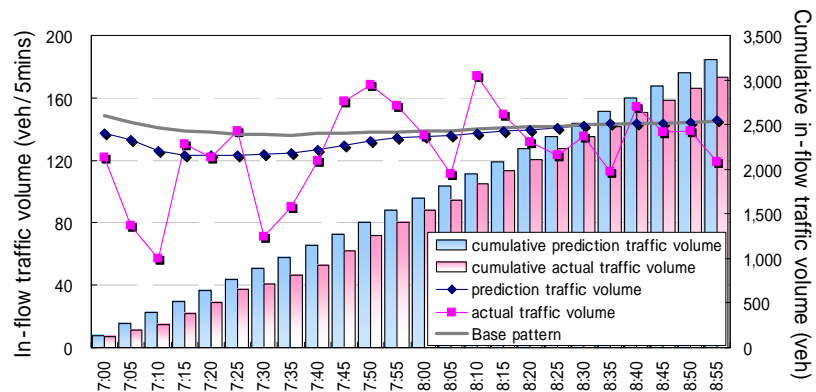


Figure 14 Prediction and actual in-flow traffic volume from inter-city motorway(Case_1)

Comparison between actual travel time and prediction travel time is shown in Figure 15, in which actual travel time is solid line and prediction travel time is dotted line. Accuracy rate of prediction travel time is 90% within +/- 5minutes, and 95% within +/- 10minutes

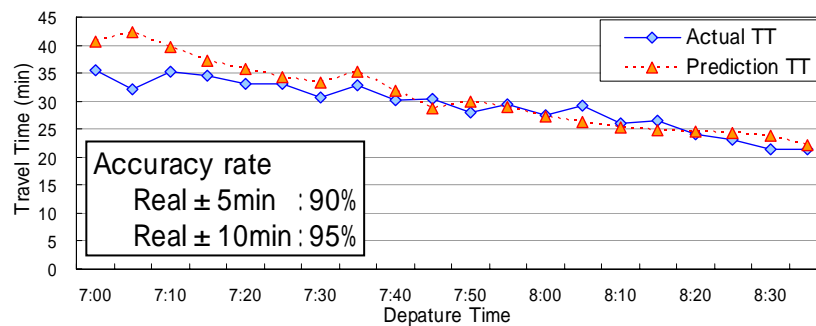


Figure 15 Comparison between actual TT and prediction TT(Case_1)

The prediction speed on each link is shown in Figure 16. Speed is ranked as follow:

- Congested links: speed less than 20km/h, which is colored in red
- Slightly congested links: speed between 20km/h and 40km/h, which is colored in yellow
- Un-congested links: speed over 40km/h, which is no-colored

The actual speed on links is upper table and the prediction result is below table. Both tables show each link on row and time on column. Bottleneck link is link_6, and from 7:00 to 8:20 congestion occur links 11-20. From the prediction results, error congestion occurs from 7:20 to 7:45 on links 13-15, and from 8:15 to 8:14 on links 19-20. On the other hand, intermittent congestion, such as links 11-18 around 8:10 and links 13-18 around 8:45, does not predict correctly. Otherwise, speed ranks of prediction are duplicated well.

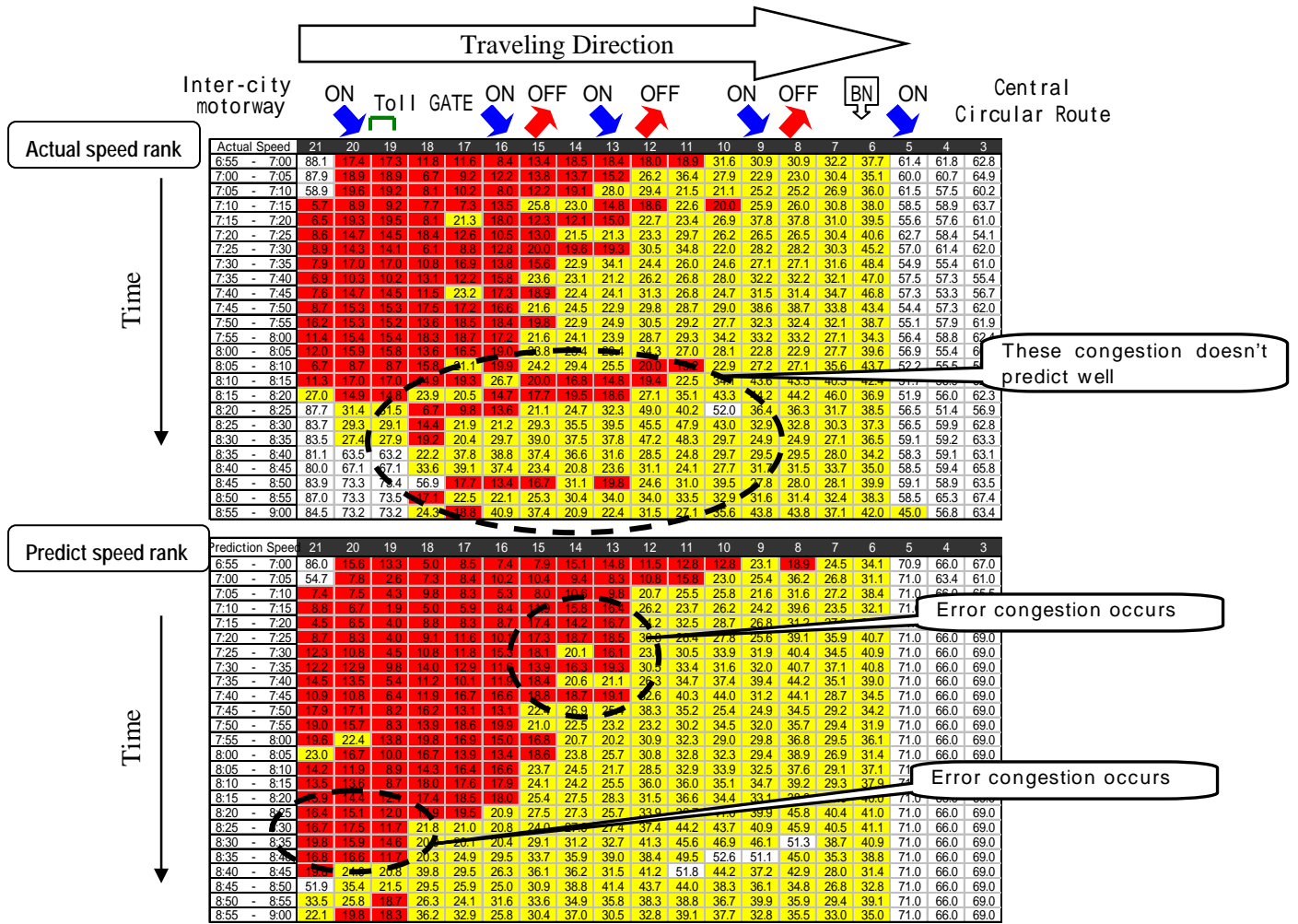


Figure 16 Prediction and actual speed rank tables (upper: Actual, below: Prediction)(Case_1)

4.2 Case 2 – un-expected traffic condition with accident –

The intended day and time is the end of April (Wednesday) from 16:40 to 18:40. Generally, there is no congestion in this route at this time. An accident occurred on link 11 at 16:40. Details of this accident are shown in Table 1 and the module conditions corresponding with this accident are shown in Table 2.

Table 1 Accident details

Accident Details			
Day	End-April (Wed)	Weather	Fine
Route	S1	Link #	11
Receiving Accident Info	16:31	Clearance Time	17:43
Lane-closure period	78(min)	# of closure lane	1
Closure of On-ramps	No	# of involved veh	2
Existence of ambulance car or fire engine	No	Existence of service vehicle	No

Table 2 Conditions corresponding with the accident

Conditions corresponding with accident (at 16:40 prediction start)	
Prediction of lane-closure period	50 (min)
Capacity of degraded lane	690 (veh/h·lane)
diverted traffic patterns on each on-ramps	Inter-city Motorway: A ramp: +25% B ramp: +7% C ramp: +16%
diverted traffic patterns on each off-ramps	(No divert on OFF ramps)

The traffic volume (and cumulative traffic volume) from the inter-city motorway are compared between actual and prediction. The result is shown in Figure 17. Actual traffic volume declined less than half in accordance with the accident. The diverted traffic pattern on-ramp module run and decline traffic volume in-flow traffic volume, but it is not enough

level comparing with actual traffic volume. As for cumulative traffic volume, error of prediction result is approximate 1200 veh/2hour, and seems to be relatively large.

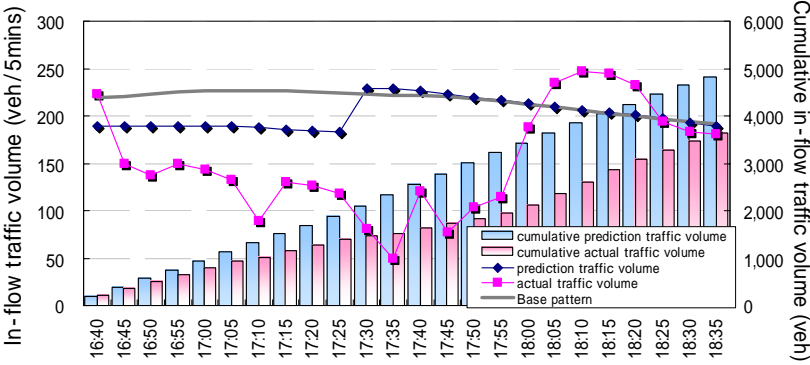


Figure 17 Prediction and actual in-flow traffic volume from inter-city motorway (Case_2)

Comparison between actual travel time and prediction travel time is shown in Figure 18. Accuracy rate of prediction travel time is 45% within +/- 5minutes, and 100% within +/- 10minutes. The ratio within +/- 5minutes is low, but in case of accidents drivers could accept slightly large error for travel time information on VMS. The prediction travel time seems to be quite reliable information in case of accidents.

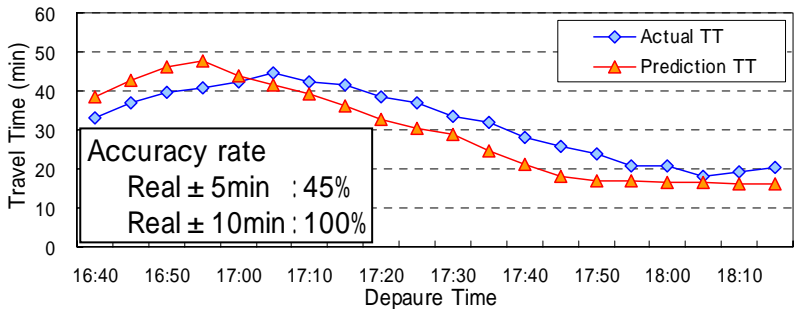


Figure 18 Comparison between actual TT and prediction TT(Case_2)

The prediction speed on each link is shown in Figure 19. The accident occurred on link 11 at 16:40. From the prediction results, error congestion occurs around 17:00 on links 19-21, and congestion due to the accident disappeared quickly. Otherwise, speed ranks of prediction are duplicated well.

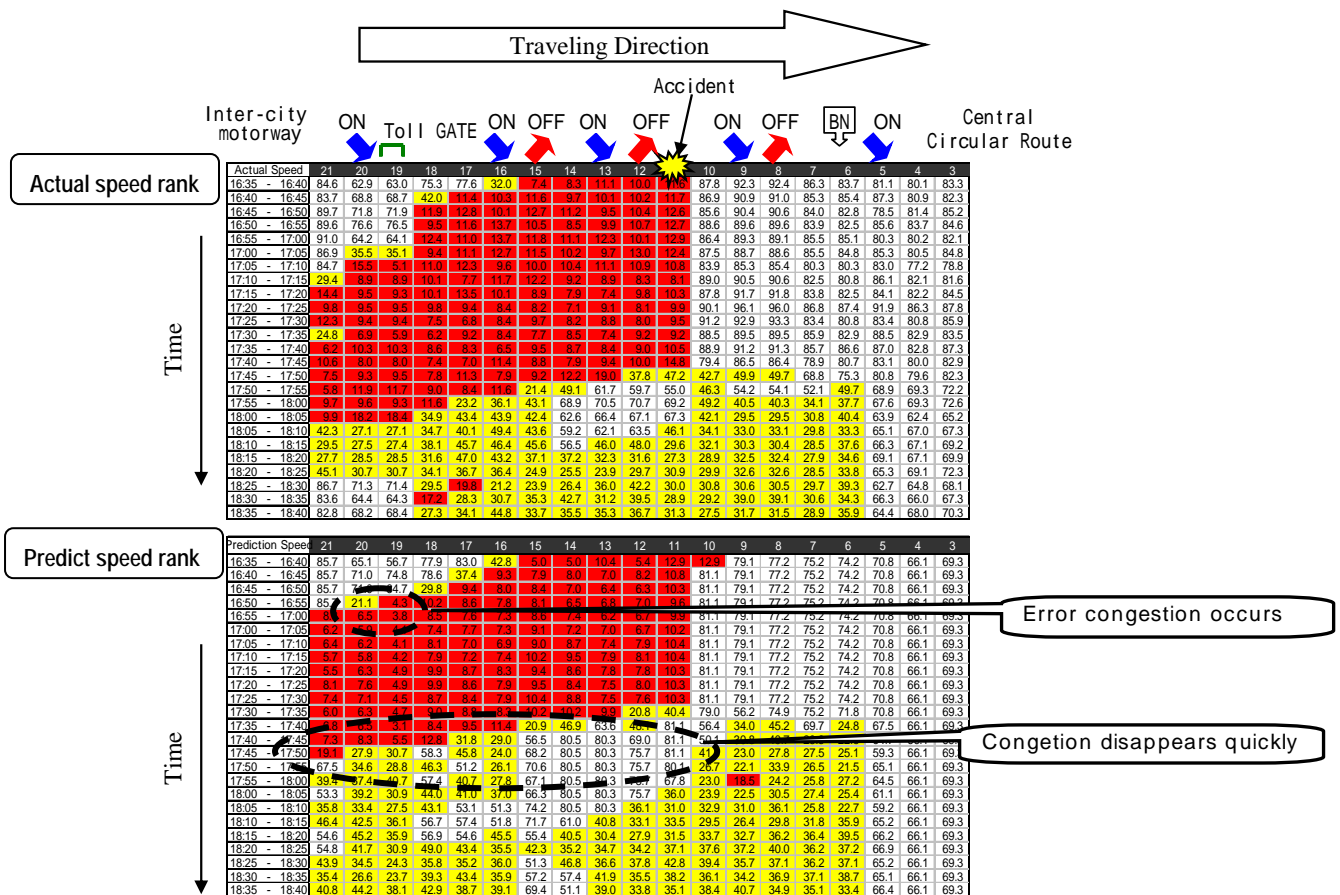


Figure 19 Prediction and actual speed rank tables (upper: Actual, below: Prediction)

5. CONCLUSION

The RISE simulation has developed with reasonable accuracy. Metropolitan Expressway Co., Ltd., will start to use RISE in test-service from November 2009. The current accuracy is reasonable level for test-service, but in order to achieve more accuracy enhancement the following matters should be considered.

- On-line fitting method with Q-K parameter,
- Junction parameter fitting for different tendency (weather, time, day),
- Parameters estimation method when new routes open,
- Nonlinearly Q-K model of congested area.

REFERENCES

- (1) <http://www.i-transportlab.jp/products/sound/index.html/>
- (2)
- (3)