22nd ITS World Congress, Bordeaux, France, 5–9 October 2015

Paper number ITS-2663

Simulation Experiment for ITS on Three Expressway Rings in Tokyo Metropolitan Region

Ryota Horiguchi[1*], Morihisa Iijima[2], Takashi Oguchi[3]
1. i-Transport Lab. Co., Ltd., 3-10 Kanda-Ogawamachi, Chiyoda-ku, Tokyo, Japan,
Phone: +81-3-5283-8527, E-mail: rhoriguchi@i-transportlab.jp
2. i-Transport Lab. Co., Ltd., Japan
3. Institute of Industrial Science, University of Tokyo, Japan

Abstract

This paper describes traffic simulation studies for various traffic management schemes on the expressway network in Tokyo metropolitan region. Preparing for the coming Olympic and Paralympic Games in Tokyo 2020, three expressway rings around Tokyo are now close to complete forming web network. In order to mitigate congestions and to maintain smooth traffic, there are many options for the traffic management such as travel information provision, congestion pricing, ramp metering, etc. To evaluate the effectiveness of those measures on a large scale urban road network, we have developed a dynamic traffic simulation model 'SOUND' which moves discrete vehicles according to the first ordered kinematic wave theory and incorporates drivers' route choice behaviour. In this paper, let us outline our preliminary study for the impact assessment of three expressway rings completion.

Keywords: traffic simulation, ring road network.

Introduction

This paper describes traffic simulation studies for various traffic management schemes on the expressway network in Tokyo metropolitan region. Preparing for the coming Olympic and Paralympic Games in Tokyo 2020, three expressway rings around Tokyo are now close to complete forming web network. Figure 1 illustrates the schematic structure of the expressway network containing three rings closely completed and the years of their completion. The most outer ring ‘Ken-ohdo’ surrounds Tokyo with a circle of which the radius is 40~50 km, while the middle ring ‘Gaikan’ has approximately 25 km and the inner ring ‘MEX (Metropolitan Expressways) C2’ has 8~10 km in their radiuses. The blue sections of the ring roads are now under construction and will be open from 2015 to 2020.

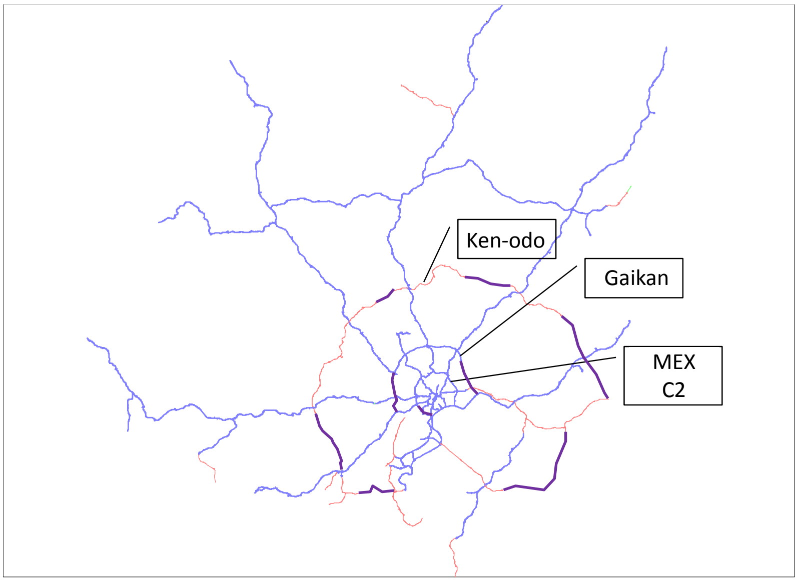

Figure 1 – Expressway network in Tokyo Metropolitan Region

In order to mitigate congestions and to maintain smooth traffic by fully utilizing the performance of those three rings, there are many options for the traffic management such as travel information provision, congestion pricing, ramp metering, etc. To evaluate the effectiveness of those measures on a large scale urban road network, we have developed a dynamic traffic simulation model 'SOUND'[1] which moves discrete vehicles according to the first ordered kinematic wave theory and incorporates dynamic drivers' route choice behaviour considering traffic congestion, toll fare, travel information availability, and so on.

In this paper, the features of SOUND are briefly introduced at first. After the outline of the data and the parameter settings for the simulation study, let us summarise our preliminary result to demonstrate the strategic pricing scheme to induce detouring traffic for the ring roads. In place of conclusion, our future tasks will be discussed to propose efficient traffic management scheme.

Brief Introduction of SOUND – a Mesoscopic Network Traffic Simulation Model

SOUND (Simulation On Urban road Networks with Dynamic route choice) was originally developed by the University of Tokyo and revised as a commercial software product[2] by i-Transport Lab. Co., Ltd. It is a mesoscopic traffic simulation model which moves discrete vehicles second by second according to the fundamental diagram of traffic flow. The vehicles running on a link are treated in a physical queue which can reproduce shockwave propagation by implementing the simplified kinematic wave algorithm (K-wave) proposed by Newell[3]. As the computational cost of K-wave is much lighter than of car following model which update vehicles' positions and speeds in sub-second, SOUND has an advantage to other microscopic traffic simulators for the applicability to large scale road networks.

As for the drivers' behaviour modelling, SOUND incorporates stochastic route choice model with dynamic user optimal (DUO) principle. It implements Dial's assignment algorithm[4] to avoid time-consuming path enumeration process and can revise the route choice probability for every interval normally designated as 5 – 15 minutes to ensure the modelling capability of various ITS measures.

Simulation Study with the Tokyo Metropolitan Road Network

By using SOUND, we have conducted the preliminary simulation study to assess the impact of the completion of three expressway rings. Figure 2 shows the study network containing both expressways with blue lines and arterial roads with other colours. The network spreads over the Tokyo Metropolitan Region and surrounding prefectures with approximately 200 x 200 km2 area and contains approximately 186K nodes and 410K directional links. In the preliminary study, let us assign the default capacity to each link according to the limit speed and the number of lanes.

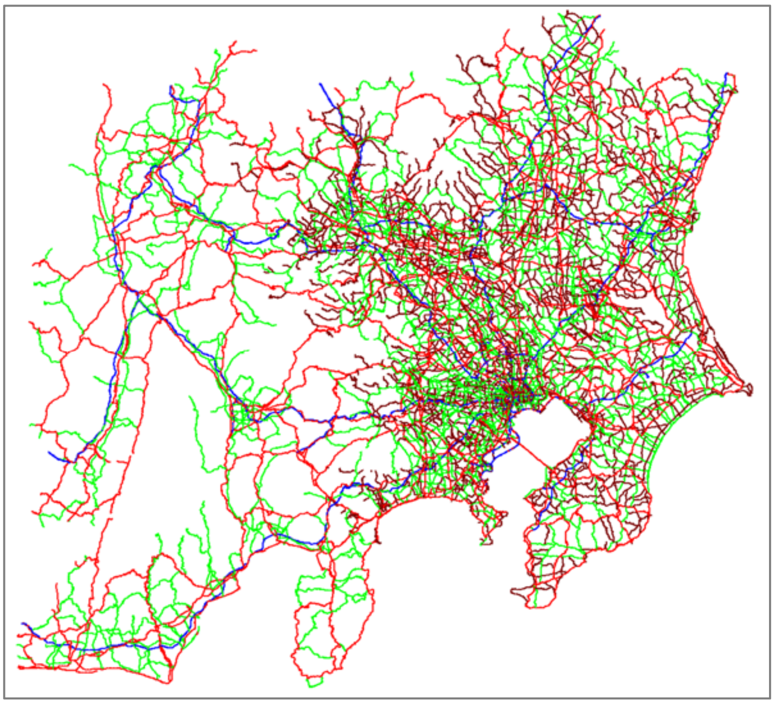

Figure 2 – the study network over the Tokyo Metropolitan Region and surrounding prefectures

Figure 3 shows the zones of which number is 1,112 used for the O-D investigation in the traffic census conducted by the Ministry of Land use, Infrastructure and Transportation (MLIT). For this region, MLIT aggregates the result of O-D investigation and provides daily traffic demand (the census O-D matrix) of which total trip generation is approximately 26,775K vehicles per day, whereas dynamic traffic simulation requires time-dependent O-D matrix. In the preliminary study, let us simply divide the census O-D matrix with the departure time profiles according to the vehicle type and the direct direction from origin zone centre to destination zone centre, as shown in Figure 4. Here, the ‘inbound’ represents the direction towards the emperor palace in the centre of Tokyo.

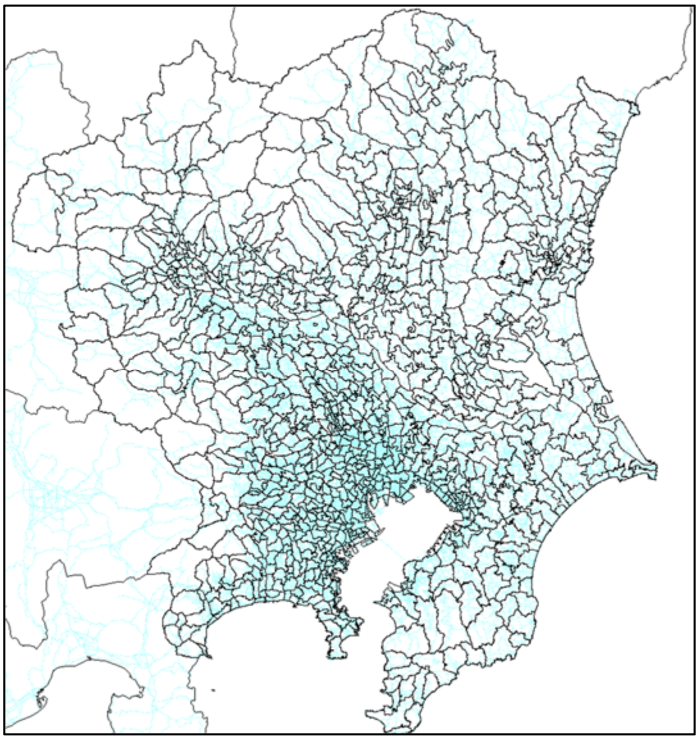

Figure 3 – the zones used by the O-D matrix (census B-zones)

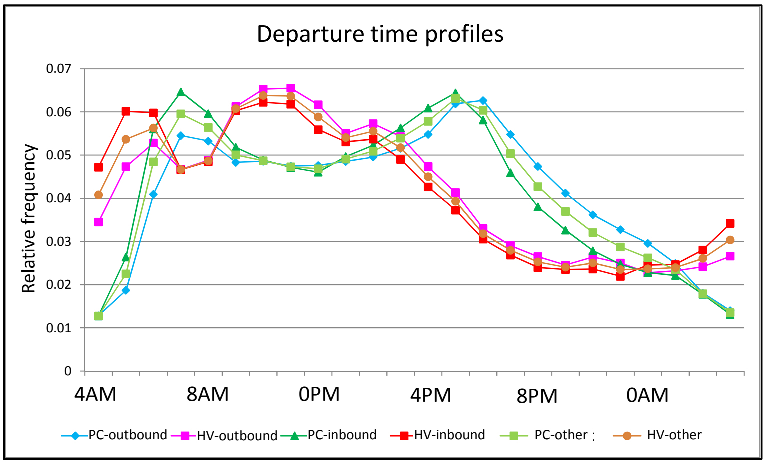

Figure 4 – the departure time profiles

As for the route choice model parameters, let us follow the conventional settings[5] as follows;

$c = 0.5D/V_E + 0.5T + 30N_L + 60N_R + 0.67F$

where c: generic cost from a link to a destination
D: distance to the destination [m]
V_E: expected travel speed from statistics [m/sec]
T: present travel time reproduced in the simulation [sec]
N_L: number of left turns
N_R: number of right turns
F: toll fare [yen]

In this case, all generic costs are updated for every 5 minutes.

Simulation Studies

Present case

Figure 5 shows the daily traffic volume of each link in the result of the ‘present’ case, which gives the baseline of the study. The calculation time takes almost 30 hours by using the Intel Corei7-3820 CPU with 64GB RAM.

Future case after the three rings completion

Figure 6 shows the differences in daily traffic volume after the three rings completion. It is normally expected that any impacts of the network completion can be positive and preferable to reduce congestion, however it is sometimes happen to induce unexpected congestions at different places. In this case, the new congestion will be arise by heading to the new junctions at the crossing points of the Ken’odo and the Gaikan-do with the radial expressways.

Strategic Pricing with ‘toll-free’ Ken’odo

Figure 7 shows the differences in daily traffic volume if the toll fare of the Ken’odo sets to free. In this case, some accessing sections to the Ken’odo increase their traffic, but most of the inner Ken’odo links reduces traffic. It is expected that the congestion in the Tokyo city centre will be mitigated.

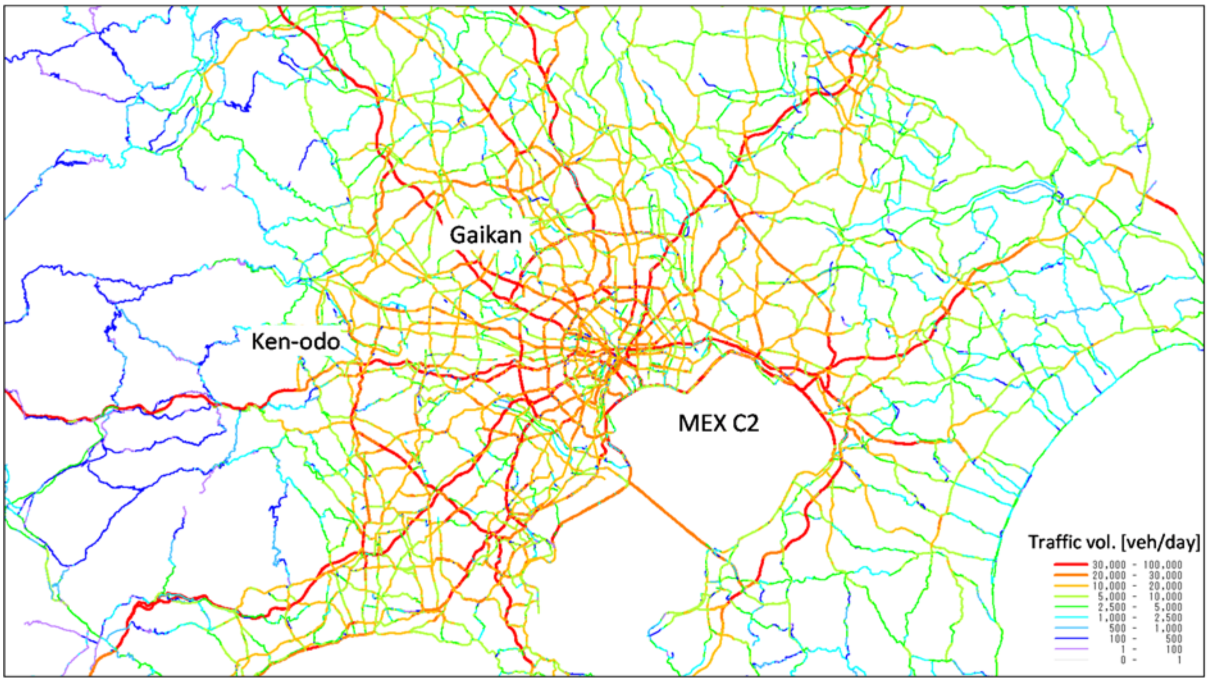

Figure 5 – the daily traffic volume of each link for the present case

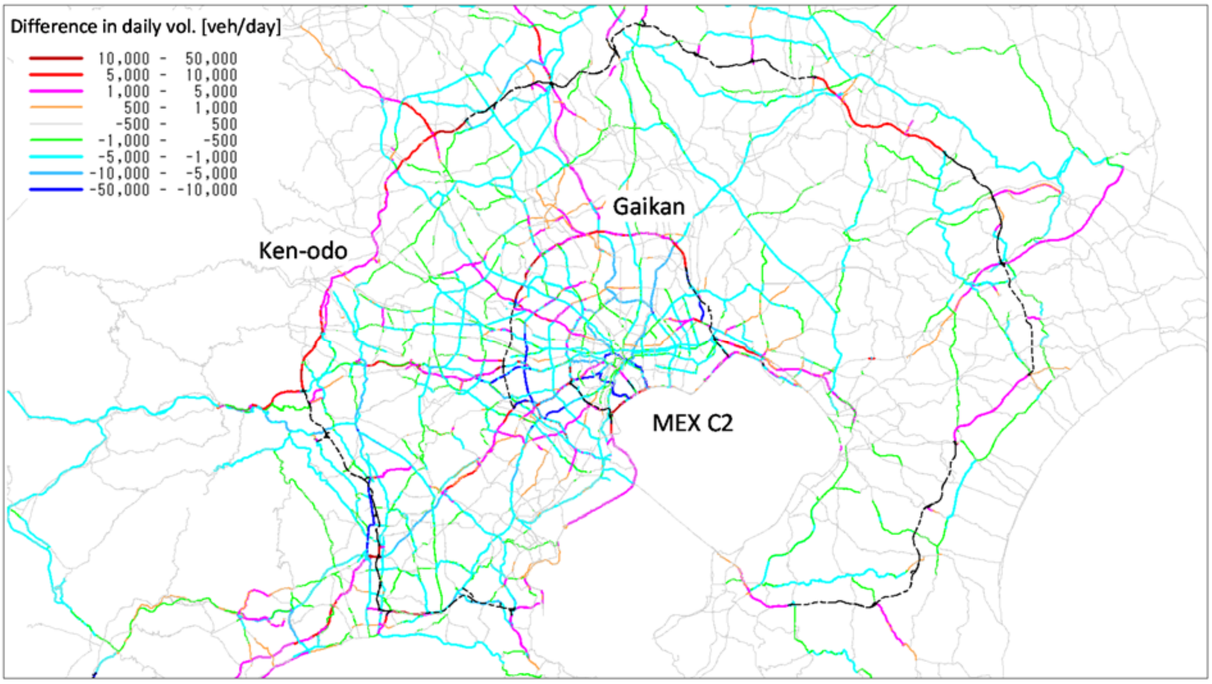

Figure 6 – the differences in daily traffic volume after the three rings completion

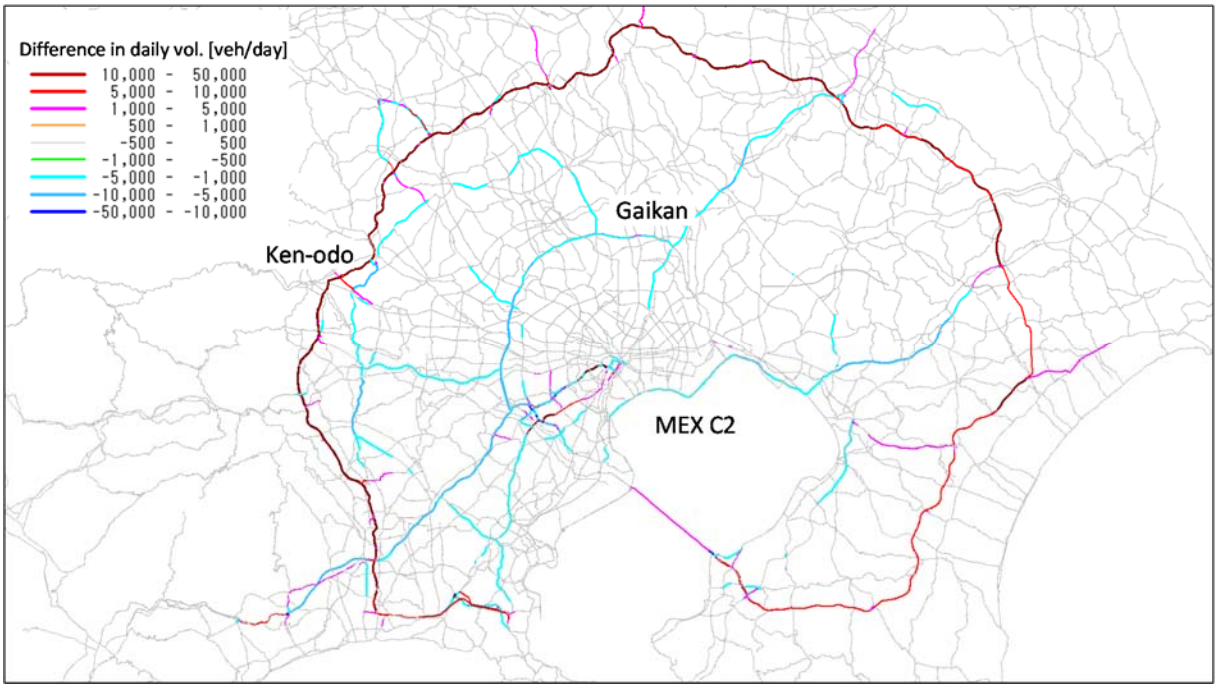

Figure 7 – the differences in daily traffic volume for the toll-free Ken'odo case

Future Works

The preliminary studies described above were conducted to demonstrate the assessment using dynamic traffic simulation. We also need to calibrate the link parameters to reproduce traffic congestion properly. The route choice model parameters are to be identified though the analysis of probe car data. For the further study, more dynamic ITS measures, such as dynamic road pricing, predictable traffic information provision, variable shoulder lane use, etc. are to be modelled and implemented in SOUND.

References

1. Yoshii, T. Kuwahara, M. (1995). *SOUND: A Traffic Simulation Model for Oversaturated Traffic Flow on Urban Expressways*, Preprint at 7th World Conference on Transportation Research, Sydney.
2. SOUND product page (visited in July 2015). *http://www.i-transportlab.jp/product/sound* (in Japanese).
3. Newell, G. F. (1993). *A simplified theory of kinematic waves in highway traffic, Part I: General theory*, Transportation. Res.-B, Vol. 278, No. 4, pp. 281-287.
4. Dial, R. B. (1971). *A Probabilistic Multipath Traffic Assignment Algorithm Which Obviates Path Enumeration*. Transportation Research 5, pp. 83-111.

5. Tamamoto, G. Horiguchi, R. Kuwahara, M. (2004). *Application of Traffic Simulation SOUND to the Large Network*, Proceedings of 30th Infrastructure Planning (in Japanese).

6. Hanabusa, H. Shiraishi, T. Koide, K. Horiguchi, R. (2011). *Development of a Hybrid Traffic Simulation Framework for Environmental Evaluation for ITS Applications*, Proceedings of the 18th World Congress on Intelligent Transport Systems, Orlando.

7. Horiguchi, R. Hanabusa, H. Kuwahara, M. Tanaka, S. Oguchi, T. Oneyama, H. Hirai, H. Hayashi, S. (2010). *Validation Scheme for Traffic Simulation to Estimate Environmental Impact 'Energy-ITS Project'*, Proceedings of 17th World Congress on Intelligent Transport Systems, Busan, Korea.