DEVELOPMENT OF OD DATA-BASED DYNAMIC SIMULATOR

Koichiro Tani 1*, Shiro Kawano 2, Takeshi Setojima 3 and Masayuki Jinno 4

1.2.3 Traffic Facilities and Control Division, Traffic Bureau,
Tokyo Metropolitan Police Department, JAPAN
Address: 2-1-1 Kasumigaseki, Chiyoda-ku, Tokyo, 100-8929, Japan
Tel.: +81-3-3581-4321 (Ex. 7850-5212)
E-mail: S5000014@section.metro.tokyo.jp

2 System & Electronics Division, Sumitomo Electric Industries, Ltd.
Address: 1-43-5 Sekiguchi, Bunkyo-ku, Tokyo, 112-0014, Japan
Tel.: +81-3-5273-7723

Abstract
The Traffic Control System (TCS) of the Tokyo Metropolitan Police Department (MPD) uses traffic data including traffic volume, congestion length, travel time and travel speed collected from vehicle detectors and infrared beacons installed on streets for understanding of the traffic conditions by intersection, by route and by region, as well as for provision of the latest traffic information and implementation of appropriate traffic signal control measures. However, in the event of any singular incidents that heavily impact the road traffic such as massive road works, traffic accidents, marathons, earthquakes, typhoons and other circumstances, the resulting traffic congestion cannot be managed through normal traffic signal control measures and requires policy-based intervention to control traffic signals. Under existing conditions, MPD had to rely on techniques based on simple tests of theories and past experiences, requiring a lot of time to create and verify the data. This paper introduces the Dynamic OD Simulator System developed to address this situation through efficient use of an enormous amount of data including the OD (Origin-Destination) data collected and stored by the TCS to enable prediction of influences of singular incidents including road closure and quick and accurate implementation of policy-based intervention to control traffic signals.

Keywords: Traffic simulator, Origin Destination data, Metropolitan Police Department, MPD

Collection of Traffic Data To Be Used By The Simulator
The TCS of MPD controls the traffic on roads with a total length of approximately 2,825km and approximately 8,000 signalized intersections and constantly monitors the road traffic through approximately 13,000 vehicle detectors as well as infrared beacons installed at approximately 1,900 locations.

The following describes the current state of data collection regarding traffic volume, congestion length and OD data to be supplied to the road traffic simulator.

Traffic volume and congestion length
The traffic volume data are gathered at an interval of 50 seconds to control traffic signals and at an interval of 15 minutes for statistical purposes. Figure 1 shows the trend in the outbound
cross-sectional traffic volume (vehicles/15 minutes) on the Aoyama Street (Route 246) on weekdays. Figure 2 shows the trend in the total congestion length in the Tokyo Metropolitan Area (TMA) on weekdays.

![Figure 1 Daily trend in cross-sectional traffic volume](image1)

![Figure 2 Daily total congestion length in TMA](image2)

**OD (Origin-Destination) data**

Figure 3 shows the trend in the uplink rate of infrared beacons. As of year 2011, the uplink data reaches 2.4 million counts a day with the uplink rate reaching approximately 10%, allowing tracking of the origin and destination of approximately 10% of all the vehicles travelling within TMA. It is considered that input of these data to the simulator enable highly accurate operations.

![Figure 3 Trend in the number of infrared beacons Installed in TMA and its uplink rate](image3)

**Simulator Requirements**

The purpose of deploying the simulator was to reproduce the road traffic status throughout TMA to reproduce and evaluate influences of road traffic regulations, whereas the existing simulator forced traffic controllers to rely on techniques based on simple tests of theories and past experiences. Since it took an immense amount of time to manually create and verify data, quick and precise data entry was essential to make it possible to act and review control measures in an emergency situation, necessitating the following functions.

**Simplification of configuration data**

To simplify the data entry required to run simulations by making use of traffic data and road network data managed by the TCS.

**Ensuring reproducibility**

To automatically adjust the simulation result to match up with the actually measured congestion length for reproduction of the normal traffic condition.

**Connectivity with the traffic signal control function**

To automatically configure parameters for controlling traffic signals by connecting the traffic signal
control function (STREAM) of the TCS with the simulator.

**Result presentation**

To present the comparison before and after the implementation of a measure on maps and charts for easier discovery of agendas which require attention such as prediction of congestion points.

**Acceleration**

To reduce time for estimation.

**Selection of OD Simulator**

There are two modeling methods used in the simulation: the micro modeling which reproduces the vehicle behavior at one or more intersections in details and the macro modeling represented by TRANSYT and automatic generation of offset that are excellent in handling searches. The micro modeling is suitable for verification of the effect of improvements in intersections and verification of influences of parked cars due to its capability to reproduce minute movements of parking. Macro simulations are used to produce appropriate solutions from a number of combinations for offset design etc due to its ability to alleviate calculation load by treating vehicles as fleets and ignoring vehicles making right or left turns.

In selecting the simulator, MPD chose an intermediate one since the purpose of the simulator was to reproduce the road traffic status throughout the TMA and to simulate and evaluate influences of road traffic regulation and other measures.

The selected simulator is characterized as follows:

- It takes the dynamism of congestion into consideration and is capable of reproducing oversaturated traffic.
- It is equipped with both static and dynamic route selection models, allowing evaluation of various operations in ITS including information provision and dynamic route guidance.
- It treats individual vehicles with car type and other attributes attached, making it possible to evaluate traffic operations on target vehicles. Its macroscopic modeling enables estimation of vehicle movements using the traffic volume-density (Q-K) property assigned to each link with limited computational load making it applicable to large networks.

When interacting with TCS, the simulator takes the traffic volume, vehicle travel speed and OD data entered for major segments of the VICS link which represent the traffic on a certain day to run simulations to predict indexes related to travelling efficiency such as traffic volume, travelling speed, average travel time per route and total travelling distance on the link by applying each possible operation. The target traffic operations to evaluate include, 1) changes in traffic regulations such as no right turn and one-way traffic, 2) influences of road closure and entrance restriction necessitated.
by events, accidents and disasters, etc and 3) effects of traffic demand reduction by provision of information to the driver.

**Implementation of Requirements**

By combining the traffic signal control (STREAM) function of the MPD with the OD Simulator, the MPD built a mechanism to allow traffic controllers to evaluate simulation results on maps and charts on the control console by reflecting changes in road traffic status caused by simulated traffic control into the traffic signal control operation. Figure 5 shows the system configuration of the Dynamic OD Simulator.

**Simplification of configuration data**

The use of traffic data and road network information managed by TCS allowed simplified entry of configuration data to the simulator.

**Ensuring reproducibility**

Reproducibility of the simulation result was improved by making use of the OD data contained in the uplink data gathered through in-vehicle devices equipped with bidirectional communication function and installed in 10% of all vehicles travelling in TMA.

**Connectivity with traffic signal control function**

The traffic signal control function (STREAM) of TCS calculates parameters for controlling traffic signals such as cycle length and splits at an interval of 50 seconds. By introducing a function to synchronize the parameter calculation cycle between the simulator and STREAM to exchange information, mutual control was achieved between the two.

**Presentation of results**

Visual comparison between before and after the simulated implementation of various measures was achieved using maps and charts. Discovery of agendas such as prediction of congestion points was also made easier.

**Acceleration**

In case the output of estimation result is required in a short time, calculation time was reduced by dividing TMA into 24 sections and targeting only the road networks that are expected to be influenced by events such as traffic regulations applied to within the next 60 minutes. In the case of predicting influences of a traffic regulation in a larger area or for more than a 60 minute duration, the
target of calculation was set to the entire TMA in order to prioritize accuracy over speed.

**Functionality of Dynamic OD Simulator**
This system consists of five functions: four simulators and an uplink data analysis function.

**Simulator types of Dynamic OD Simulator**
The Dynamic OD Simulator consists of three simplified simulators that are designed to help deciding measures to implement by conducting simple analyses on changing traffic status till 30 to 60 minutes ahead and a detailed simulator which is useful for evaluating a traffic regulation method and specific locations to apply it by analyzing different cases where influences of a fireworks show, a marathon, large scale road works or a disaster are expected to spread to a large area.

**Incident control simulation (simplified simulator)**
This simulation predicts changes in the traffic status influenced by an incident such as a traffic accident or a disaster. The simulator proposes the data to be used for information provision and traffic signal control to bring the traffic condition under control, presents predicted congestion length with and without the traffic signal control intervention and proposes specific traffic signal control intervention.

**Regulation influence prediction simulation (simplified simulator)**
For a planned lane closure associated with road works, this type of simulation allows to set conditions such as links and time to apply regulation and its details to compare changes in traffic status influenced by such regulation.

**Natural congestion control simulation (simplified simulator)**
This type of simulation is designed for prior evaluation of effects of traffic signal control and reflects the data for traffic signal intervention entered on the control console. It presents the predicted congestion length with and without traffic signal control to allow evaluation of the operation.

**Planned incident simulation (detailed simulator)**
At the planning stage of a large-scale road construction or an event (marathon, fireworks shows, etc) with details and the scope of traffic regulation predetermined, the simulator allows definition of each parameter of details of regulation, the scope of influences, date and time etc and runs three kinds of simulations without traffic restriction (normal case), with traffic restriction (supposed case) and with traffic signal control intervention (traffic signal control case) to evaluate results before applying any measures.
**OD data analysis (uplink data analysis function)**

The OD table is described as combinations of the origin and destination. In this simulation, TMA is divided into 227 segments to render the OD of each vehicle in an array of 227 rows and 227 columns to aggregate the total traffic volume in every 15 minute timeframe. This allows comparison of differences in inbound traffic heading to the center of Tokyo and outbound traffic heading to the suburbs between weekdays and Sundays as shown in Figure 8, and enables analyses of the traffic converging to and dispersing from a certain point as well as the route and the arrival rate of the traffic by aggregating converging and dispersing travel trajectories of vehicles.

**Application to traffic control measures and verified reproducibility of congestion simulation in large-scale disaster settings**

The operation of Dynamic OD Simulator was launched in April 2011 to be used for evaluation and enforcement of various traffic measures. The following illustrates simulations of planned incidents conducted in the Sumida River Fireworks and Great East Japan Earthquake settings.

**Sumida River Fireworks**  
(28 July, 2012)

The simulation result predicted congestion caused by vehicles bypassing links that are under traffic regulation. Based on predicted congestion at nodes of specific arterial roads as shown in Figure 10, the MPD gave advance notice of such congestion-predicted points through traffic information signs and web pages. As a result,
the actual congestion reduced from the simulation result as shown in Figure 11 and the measure contributed to alleviation of road traffic congestion around the venue.

*The East Japan Earthquake (11 March, 2011)*

Tokyo’s 23 wards (central Tokyo) have ring roads such as Meiji Dori and Loop Road No.7 and radial roads such as Sakurada Dori (Route 1) and Mito Kaido (Route 6) with the Imperial Palace sitting at their center. Due to regulation on inflow to express ways and full suspension of train services after the earthquake, large numbers of people going home in vehicle and on foot significantly increased congestion in the outbound direction. And expressways were closed down, causing vehicles to flood surface streets.

The MPD recreated influence of this earthquake by the simulator to infer what was actually happening with the road traffic that day.

The following conditions were simulated.

- Express ways were closed down immediately after the earthquake and all vehicles flowed out of the nearest exit. Within two hours, no vehicle was allowed to drive along expressways.
- On general roads, vehicle flow from expressways, additional traffic demand by homeward vehicles, influences of pedestrians on zebra crossings, influences of vehicles trapped in intersections on crossover roads etc were factored in.

The output of a simulation of traffic for 12 hours following the earthquake almost matched the actual congestion length. Ban on entry to metropolitan express ways and the outflow to general roads enforced from 3 p.m. were factored in. In running the simulation, the parameter of saturated traffic flow rate was adjusted. The traffic flow at 4 p.m. and 10 p.m. was adjusted to 35% and 50% of the normal traffic flow of 1500 (vehicles/hour) per lane to reproduce the actual congestion length.
What caused the adjustment above of the saturated traffic flow rate by different time slot can be explained as follows:

As shown in Figure 14, the vehicle kilometers travelled which is an indicator of the total traffic volume in TMA remained lower on 11th, March (the day of the earthquake) than a week ago. In other words, it was found that the traffic flow to be processed immediately after the occurrence of the earthquake was lower than usual but the situation reversed in the period between 9 p.m. and 10 p.m.

This result indicates that the relationship of traffic volume to be processed > the traffic volume generated which occurred in the time slot accelerated the decline in congestion and caused the change in the flow rate which is a parameter in the simulation.

For any future simulations to be run for the occurrence of a large-scale disaster, the MPD will refer to the saturated flow rate obtained from this simulation output.

**Conclusion**

The newly developed dynamic OD simulator made it possible to quickly and accurately implement traffic control measures and traffic signal control intervention even during a large-scale event or a disaster such as an earthquake. This helps ease congestion at an earlier stage, with expected reduction in influences over the traffic flow. The simulator is going to be utilized positively for strategic examinations in future.

In case of suffered huge disaster in the center of Tokyo, Loop Road No.7 becomes the cordon line, and inbound traffics are inhibited. These impacts related by day or time are simulated. For further practical utilization, MPD will consider adding an automatic traffic signal control intervention function which uses the simplified simulator to improve traffic control operations and will increase the accuracy of the Dynamic OD Simulator by improving the infrared beacon uplink rate and further accumulation of the OD Data.

**References**
