REPEATABILITY ENHANCEMENTS OF TRAFFIC SIMULATOR
BY INTRODUCTION OF TRAFFIC FLOW COMPENSATION
METHODS

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Abstract
A traffic simulator is one of the most effective tools to estimate effects of traffic management and
traffic enforcement such as new road construction, detour route guidance for avoidance of traffic
accident/earthwork or emergency signal control in the event of a natural disaster. And the aim of
simulation is estimation of an assumed situation, and the most important index is the congestion
length on the network. Because when there is no congestion length on the roads, the travel time
does not increase so much, even if the traffic volume increases. However, there are many
difficulties in making simulator results reproduce the actual traffic flow in terms of traffic volume,
especially congestion length and travel time. Therefore, the main data and parameters used in a
simulator such as OD (Origin Destination) data and flow rate can be tuned only by an experienced
engineer and it takes much time. Moreover, this parameter might not be applicable to other
analysis. That’s why the techniques of automatic tuning are required. This paper explains one of
the repeatability enhancement techniques. The algorithm has been installed to SOUND traffic
simulator and it has been utilized at the Traffic Control Center in Tokyo since April 2011.
Keywords: Traffic simulator, SOUND, Origin Destination data

Current Conditions
There were two types of traffic simulators, microscopic model and macroscopic model. However
these days, the speed of CPU and capacity of data memory are functionally improved and this
makes differences between these types obscure. SOUND (Simulation On Urban road Networks
with Dynamic route guidance), which is a base model, is the macroscopic type for simulating a
wide area (like the whole of Tokyo or wider), and it can simulate each vehicle’s behavior at a
level somewhere between micro and macro. This type of simulators is suitable for analysis of
traffic management planning.
On the other hand, if the simulation area is wider, the tuning work becomes more difficult because
all the simulators compute the traffic flow under limited conditions as follows:
1. Due to calculation time required, minor roads are omitted inversely proportional to the size
   of the area.
2. OD is key data, but it is impossible to collect through vehicle detectors. It can be collected
   through questionnaires or probe car information (in the future). So, the current available
OD matrix is assumed from sampled information. These factors cause deterioration in accuracy as explained below.

3. If the intersection is connected to a minor road (to be excluded from simulation), the vehicles that want to make a right or left turn at the intersection cannot do that. This makes these vehicles move to the next intersection connecting major roads on the simulation network. However, the intersection cannot manage extra turn-vehicles, and they block other traffic flow as shown in Figure 1.

4. Generally speaking, drivers tend not to select routes that include turning at an intersection when not congested. Therefore, few vehicles would go to minor or detour routes as shown in Figure 2.

![Figure 1 - Turning behavior](image1)

**Aim of Simulation and Problems**
The aim of simulation is estimation of an assumed situation, and the most important index is the congestion length on the network. When there is no congestion length on the roads, the travel time does not increase so much, even if the traffic volume increases. The problem is that the congestion length is sensitive to traffic demand in simulations as in the actual roads. Figure 3 shows an example of congestion length expanding condition. The inflow is 100 (vehicle/hour) higher than outflow, and the 10% difference represents 1km-congestion in an hour. This fact means the simulation should handle the traffic flow with high precision.

![Figure 2 - Route selection](image2)

![Figure 3 - Example of congestion length expanding condition](image3)

If the network size is limited, the OD data and the flow rate can be adjusted so as to synchronize the congestion length. However, engineers are not able to tune the network of Tokyo in its entirety.

**Ordinary Method for Adjustment**
There are two or more commonly used methods to adjust traffic volume or congestion length. Examples and consideration points are shown below.

*Flow rate tuning*
The traffic flows is often compared to the water flow. For instance, in Figure 4, an actual congestion is longer than the simulation output. On a link subject to be controlled, opening of
Gate 1 upstream or closing Gate 2 downstream (regulating the flow rate) heightens (increases) the water level (congestion length). This method requires repetitious works even if the number of links is limited and the road network is simple. For instance, in Figure 5, the operation at Gate 1 upstream influences the water level of the subject as well as upper links, and therefore if both links request higher level, Gate 1 must remain still while Gate 2 and further upper link should be adjusted instead.

**OD matrix tuning**
In the example of Figure 6, to adjust congestion length (S) to (A), traffic demand must be increased. If vehicles arise in Zone 1-3 as such demand, they will be added to Zone 1-3. However, experience has shown the following:

1. Some vehicles select the expected route, but they cause congestions upstream and fail to reach the subject link in time.
2. Other vehicles select unexpected routes.

**Figure4 – Simulation error**  **Figure5 - Flow rate tuning**  **Figure6 - OD matrix tuning**

**Dials for tuning**
For tuning, either or both of them may be selected. And if there are other methods, they may be combined. In the case of Tokyo, 460 intersections, or approx.1800 approaches, and the OD matrix of 227 by 227 OD matrixes must be tuned.

**Solution**
Due to aforementioned reasons, tuning the OD data and the flow rate only does not achieve the desired objective. Therefore the traffic flow compensation methods are introduced. The following explains its basic idea.

**Steps of simulation**
Following three steps are in simulation analysis:

- **Step 1:** Replicate the actual condition on the simulator
- **Step 2:** Input incidents and estimate the assumed condition
- **Step 3:** Configure measures (ex. signal parameter changes) and estimate the effects.

The traffic flow compensation data is calculated and recorded in Step1, and the data files created in Step1 are used for Steps 2 and 3 with time synchronized.

**Congestion length compensation**
In Step1, this function compares the difference between actual congestion length data collected by
the Traffic Control Center (A) and simulation output (S) on each link every 50 seconds, and if A>S, the function put dummy vehicles into the link, and if A<S, it takes vehicles off the link. These actives are recorded to data files.

Figure 7 - Outline of the congestion length compensation method.

The estimated congestion length on the simulator can be adjusted to actual data in Step 1, and differences between them by incident or measure are reflected in Steps 2 and 3. The differences in indexes such as congestion length, travel time and CO2 emission are compared through relative evaluation.

Right/Left turn vehicle compensation
As aforementioned, the lane blocking by right/left turn vehicles are troublesome phenomenon on the simulation. To solve this matter, the forcible conditions were assumed as follows;

Condition 1: Lane blockings by right/left turn vehicles are not occurring at all intersections in the usual traffic condition (=Step 1).

Condition 2: In case right/left turn vehicles exceeding the capacity limit approach an intersection, they can be assumed to have turned at a minor intersection upstream. The image is shown in Figure 8. In Step 1, if right/left turn bay is full or nearly full of waiting vehicles, the next vehicle passes through the intersection on a supposed lane. These activities are recorded to data files, and the files are used as in the congestion length compensation function.

Figure 8 - Outline of the right/left-turn vehicle compensation method

If a lot of vehicles change their routes because of some incident and they rush into a certain intersection on Step 2, the lane blocking may cause congestion. The simulation result can identify
the possibility.

Introduce the methods to ready-made simulator
These compensation methods were introduced to SOUND simulator, and on doing it, details were adjusted to the logic of the simulator so as not to cause illegal vehicle behavior.
A few examples are shown here.
  a. Dummy vehicles that are entered do not have destination so that their destinations were imitated from neighboring vehicles.
  b. Vehicles that were taken out fail to reach their destinations so that they were returned to the road network again under certain rules.
  c. All traffic simulators must use random numbers in many cases of vehicle behavior determination. To adjust compensation methods, random numbers should be managed sensibly because random numbers give subtle alterations to vehicle behavior to eventually divert the hypothetical future on the simulation.

Some adjustment methods may be as forcible as previous assumptions of the right/left turn vehicle compensation method, and the method that is reasonably suitable depends on the logic of the simulator. The logic of SOUND simulator was analyzed and the optimal or better methods were discussed and selected.

Effective use of the compensation method
This method may look aggressive and rough; however, it can eliminate faults and emphasize strengths of the simulator.
  a. Reduction in time required for parameters tuning enhances the convenience of traffic management planning work.
  b. Automatic tuning further reduces differences in results caused by tuning techniques.
  c. What is most required of the simulator is the provision of the result of relative evaluation, and the method holds this strength.

Figure 9 – What is most required of the traffic simulators?

Needless to say, when differences between A (actual congestion length data collected by the Traffic Control Center) and S (simulation output) on each link are huge, the original OD data loses its value, because ratio of dummy vehicles and escape vehicles on the simulation network increase. This method should serve as a last resort after theoretical and ordinary adjustments. In the future, the methods of theoretical adjustment will be improved and differences between A and S can be minute. Then the compensation method will vanish (A=S) automatically.

Utilization for Road Network in Tokyo
Background
In Tokyo, approximately 13,000 overhead vehicle detectors and approximately 1,900 infrared beacons are installed on main roads.
The data from Vehicle detectors is used for traffic volume count and congestion estimation as shown in Figure 10. The congestion information is refreshed every 50 seconds and stored as historical data.

![Figure10 - Congestion data](image)

Approximately 10% of vehicles carry in-vehicle units in Tokyo. The unit can send the up-link data to the infrared beacons and receive traffic information from the beacons. The up-link data is used for vehicle route estimation and creation of the OD matrix. The OD matrix consists of 227 by 227 zones with the time slice of every 15 minutes. To help understand the image, inbound and outbound demand trends are shown in Figure 11. The inbound traffic demand represents the traffic flow from suburban Tokyo or surrounding prefectures to Chiyoda-Ku, and the outbound demand represents the reverse flow.

![Figure11 - Example of OD matrix](image)

**Analysis of the earthquake impact**

Japan suffered a huge earthquake at 2:46p.m. 11, Mar.2011 and the traffic in the area was greatly disrupted. Expressways were closed down and all train services stopped in Tokyo, causing vehicles and pedestrians to flood surface streets. The simulator was used to reproduce the situation in Tokyo.

Simulation step1: Reproduced the usual traffic condition. The OD matrix, traffic volume and congestion data were entered into the simulator to calculate traffic flow compensation data.
Simulation step2: Estimated the condition of 11, Mar.2011. The OD matrix, traffic flow compensation data calculated by Step1 and influences of the earthquake were entered into the simulator.

In Step2, a hypothesis of the influences of the earthquake was formed from clear and unclear conditions as shown in Figure13.

**Closing of express ways**

- **3 p.m.- 5 p.m.**
  - Express ways
  - Surface Streets

- **5 p.m. - 3 a.m. (Next day)**
  - Express ways
  - Surface Streets

**Flow rate changing at intersections**

- **3 p.m.- 4 p.m.**
  - Usual: 1500 (veh./green 1 hour/lane)
  - 65% less: 525 (veh./green 1 hour/lane)

- **4 p.m.- 10 p.m.**
  - Usual: 1500 (veh./green 1 hour/lane)
  - 65% less: 525 (veh./green 1 hour/lane)

- **10 p.m. - 3 a.m. (Next day)**
  - Usual: 1500 (veh./green 1 hour/lane)
  - 50% less: 750 (veh./green 1 hour/lane)

**Figure13 - Assumed influences of earthquake**

Clear condition: Entrances to express ways were closed just after the occurrence of the earthquake and all vehicles went out to surface streets from immediate exits, and all vehicles were cleared out from express ways after a few hours (it was assumed 2 hours).

Unclear condition: The condition of surface streets was complicated; many factors were involved as follows:
- Vehicles from expressways
- Additional traffic demand for picking up family
- Traffic blocking by pedestrians on crossings
- Turn vehicles spilled over, blocking other traffic at intersections
Due to these conditions, flow rate was tuned on the simulator to be 65% less (525) from 4 p.m. and 50% less (750) from 10 p.m.
The simulation output was compared with actual congestion of 11 March, the result is shown in Figure 14. Simulation output described congestion changes over 12 hours after the earthquake, successfully matching actual changes.

The flow rate of 65% and 50% was adjusted manually to make simulation output closer to actual congestion. However, these were the only elements manually tuned.

The purpose of simulation is comparison between before (usual condition) and after (incidents occurring), and if the before output is close to actual traffic conditions, the after output is not so far from the actual one, because the compensation method can make the conditions that bottleneck points of output correspond to actual points and simulate queues expanding from these points.

![Figure 14 - Comparison between actual congestion and simulation output (23-ku area)](image)

**Conclusion**
To estimate the impact on a wider area with easier adjustments is the initial goal of the simulation and one solution was presented in this paper.

However, there is much room to improve the traffic simulation, such as calculation time, estimation of CO2 emissions, and most importantly, the modeling of drivers’ behavior. On the analysis of earthquake influences, the driver’s behavior i.e., failing to reach a destination because of road damage or traffic restrictions had not been modeled on the simulation. The behavior was defined in such a manner as returning to the origin as the first option and traveling to a point closer to his destination as the second option and terminating the travel if both failed. Thorough review and analyses of specific problems are required to reach the next goal.

**References**