Traffic Simulator As An Evaluation Tool For Policy Making And Its Application

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Abstract Policy makers need to evaluate the economical and environmental impacts of the Intelligent Transport System in Japan. It is currently the national project with rapidly-increasing expenditures. Traffic simulators are used for this purpose. Two characteristics of traffic simulators, DYNEMO & LEGO were examined. DYNEMO is the meso-scopic and fluid model developed and distributed by PTV and LEGO is the micro-scopic model developed at ZPR. Traffic flow patterns over the Tokyo metropolitan area were simulated and compared with observed traffic counts. The limitation and profits were presented based on the benchmark simulations. Traffic simulators are used to evaluate the introduction of the Electronic Toll Collection (ETC) using VISSIM developed and distributed by PTV. The proper construction of ETC is necessary, based on the number of ETC user. The design of the toll-collection area with consideration of the ETC and regular tollgates are examined to maximize the effects. The results indicate the necessity of signal-control adjustments along the affected road. The simulator examined the effects of road-pricing and time-shifting of the demands. The result suggested that re-routing due to road-pricing poses a negative environmental effect but time-shifting prior to traffic congestion has a positive effect. It was shown that traffic simulators can be used as the evaluating tool for policy making. The issue for further studies is summarized.

1. INTRODUCTION

Intelligent Transportation System (ITS) is currently Japan's national project; garnering an increasing portion of the national budget. Policy makers need to evaluate both the economical and environmental effects of ITS.

A simulation technique is used in order to evaluate the ITS impacts. The environmental simulation is based on the micro-scale, meso-scale, and global scales. In this study, the micro-scale model investigates the Electronic Toll Collection (ETC) system. The Traffic Demand Management (TDM) is investigated by the meso-scale model. The traffic simulators' comparison studies are executed prior to the specific simulation.

The traffic control using dynamic route-guidance and the effect of new-road construction have been examined using meso-scale traffic with meteorological models. These results are presented in next paper.

2. COMPARISON OF THE TRAFFIC SIMULATORS

2.1 Background

Traffic simulators are used in order to investigate the traffic flow pattern based on the policy decision, certain scenario of the events, and new technology. Traffic simulators are classified based on the scale and algorithm. Therefore, it suggested to use appropriate simulator in order to evaluate the policy.

Two traffic simulators, LEGO and DYNEMO, are compared using the regional network over the Tokyo metropolitan area. LEGO is microscopic model developed at ZPR, Cologne University. DYNEMO is the fluid model developed at PTV in Germany.

2.2 Simulation

The Tokyo highway network was simulated for this study. The network consists of 29 origin-destination nodes, 41 junction nodes, and 148 links. The link capacity is set as 2200 vehicles per link. The origin-destination matrix is incorporated from the 22nd metropolitan highway origin-destination survey in 1995.

2.3 Results

The simulated traffic flow patterns over the Tokyo metropolitan was compared with the observed traffic counts. The results reveal that the fluid model is better than the microscopic model when traffic counts is high as shown in Figure 1.

When the traffic counts are moderate, both models show similar results as shown in Figure 2. Based on the more-detail results, the microscopic model is better when the daily traffic counts less than 14,000. The fluid model is better in order to simulate the heavy traffic situation like more than 20,000 vehicles per day.

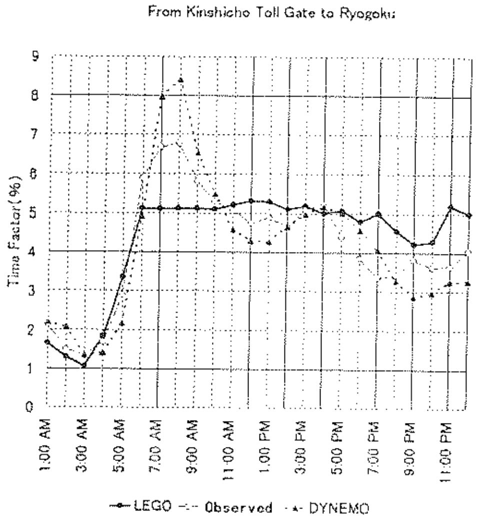

Figure 1. Traffic volume on the Metropolitan Highway Rout #7.

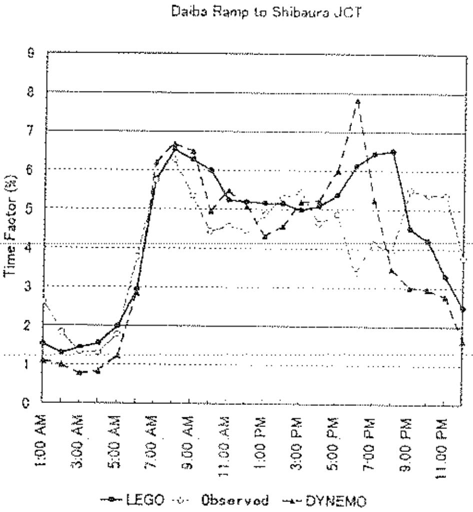

Figure 2. Inbound traffic volume at Rainbow Bridge.

3. EVALUATION OF THE ELECTRONIC TOLL COLLECTION SYSTEM

3.1 Background

Highway networks are now popular in Japan. Thirty-five percent of highway traffic jams have occurred at or near toll-collection areas. Therefore, it is necessary to improve the processing ability of the toll-collection system. Thereupon, introduction of the automatic charge-collection system so-called ETC, allow vehicles to pass through toll collection gates without any delay. The expected results are the mitigation of air pollution and fewer traffic jams.

There shall be however, some expected traffic jams on the local roads due to the construction of the ETC. Therefore, an appropriate introduction plan is necessary to improve the processing ability of the toll-collection area

3.2 Simulation

Traffic simulators are used to evaluate the ETC's construction via using VISSIM2.36. VISSIM is the micro-scopic traffic simulator developed and distributed by PTV in Germany. Simulation was executed for the network that connected to a local road as shown in Figure 3. Factors studied by simulations are the distance between gate and local road, traffic volume on the local road, traffic signal control, location of ETC gate, and the ratio between user and non-user of ETC (popularity).

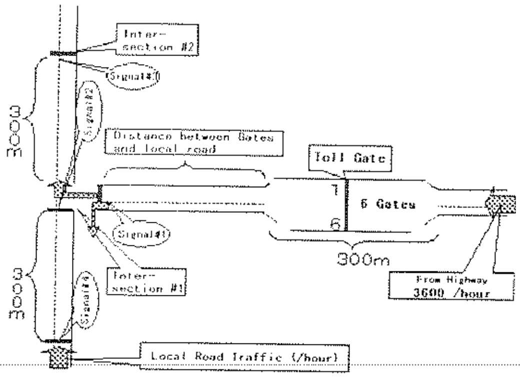

Figure 3. Schematic diagram of the tollgate area.

3.3 Results

The total number of vehicles processed by the tollgates depends on the popularity of the ETC as shown in Figure 4.

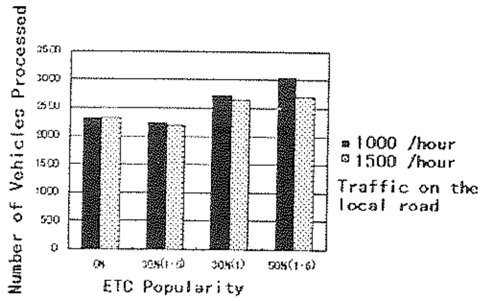

Figure 4. The total number of vehicles processed by the tollgates.

If the popularity of the ETC is 30% and two ETC gates are constructed, the total number of vehicles processed decreases as compared with having no ETC gate. This decrease is considered being 'unbalanced' between ETC gate number and the popularity of ETC user. The total number of vehicles does increase via other conditions. This amount of increase is smaller when the traffic volume is high on the local road as compared with low traffic volume. This is due to the large number of vehicles processed by ETC gates that proceed the local road and enhance the traffic jam there.

Figure 5 and 6 represent total emission of CO and NOx per vehicle, respectively. When the traffic volume is small on the local road, both emissions are decreased by the constructing ETC. These results are considered due to the increase of average vehicle speed. However, both emissions are increased when the traffic volume is large on the local road. These results are considered as increased number of vehicles are passed ETC gates and go into local road and induce the traffic jam on the local road.

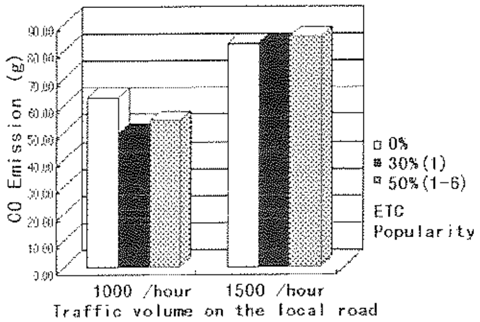

Figure 5. Total CO emission over the tollgate area.

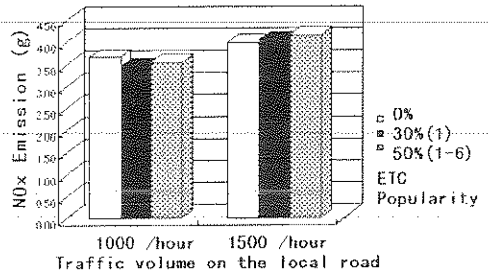

Figure 6. Total NOx emission over the tollgate area.

Figure 7 shows the effects of the distance between tollgates and local road. The difference between before and after ETC construction is small when the distance is short, although total number of vehicles processed by tollgates is increased when the distance from tollgates to signal is long. It is because increased vehicles are trapped at the traffic signal to the local road when the distance is short.

Figure 8 shows the dependence of the traffic signal cycle between local road and approach from tollgates. When the cycle period is 160 seconds, the positive effect of ETC construction is not obtained sufficiently. When the popularity of ETC is 30%, the best signal cycle is 130 seconds. When the popularity of ETC is 50%, the best signal cycle is 100 seconds. Accordingly the decision of such signal cycle is important in order to draw the sufficient effect of ETC.

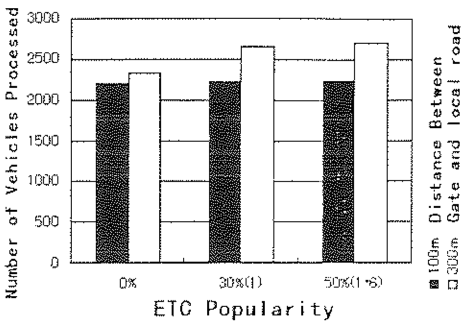

Figure 7. Dependence of the distance between tollgates and local road.

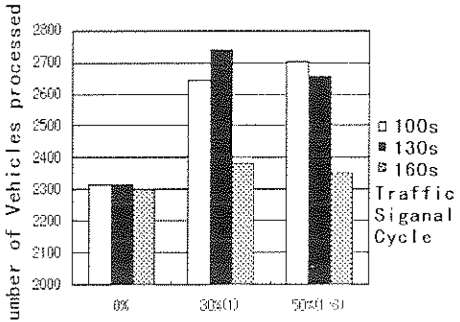

Figure 8. Dependence of the traffic signal cycle.

The blue-time ratio to the traffic signal cycle is adjusted based on the increased traffic volume due to the ETC construction. As shown in Figure 9, the total number of vehicles processed is increased with adjusted blue-time ratio. Similar results are gained for the trip time and waiting length at traffic signal.

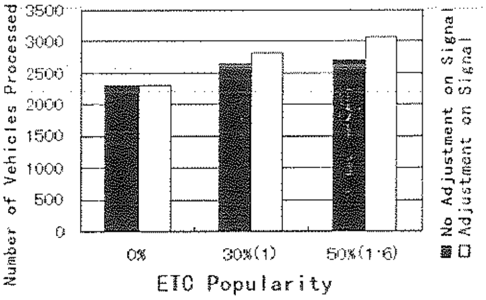

Figure 9. Dependence of the blue time ratio on the signal cycle.

Figure 10 and 11 shows the total emission of CO and NOx over the toll collection area. When no traffic signal adjustment is applied, both emissions are increased. When the traffic signal is adjusted based on the increased vehicle number, both emission are decreased. This is because the total number of vehicles processed are increased due to the ETC gates and waiting length are increased due to no adjustments on the traffic signal.

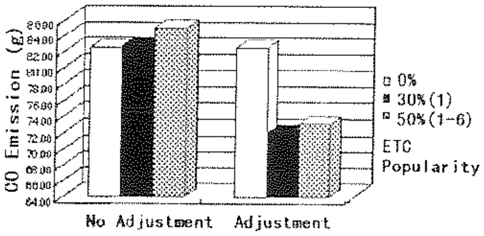

Figure 10. Total CO emission over the tollgate area.

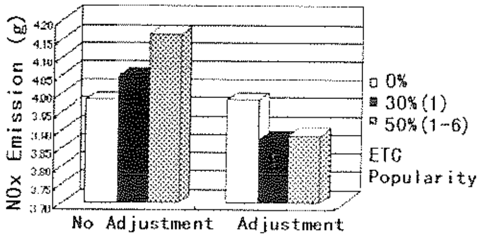

Figure 11. Total NOx emission over the tollgate area.

In order to get the maximum effect of ETC construction following conditions should be considered:

a) the balance between number of ETC gates and popularity of ETC user,

b) traffic volume on the local road especially heavy case,

c) distance between gate area and local road especially short case,

d) blue-time ratio to the signal cycle based on the increased traffic volume.

4. EVALUATION OF TIME DEMAND MANAGEMENT

4.1 Background

The economic loss due to traffic congestion is enormous. And air pollution due to automobile exhaust is a serious problem. The optimization of automobile traffic should attenuate these urban problems. However, optimization of automobile traffic can not be achieve solely via better utilization of existing road networks. It should be able to achieve by controlling the demands of traffic. Thereupon, it is via TDM that executes spatial, temporal dispersion of traffic. TDM is the policy that tries to intend the balance between supply and demand and carry out an appropriate exertion to the demand side of traffic in addition to, the policy of the supply side.

One example of Traffic Demand Management is the modal-shift method that intends the conversion from automobile traffic to public traffic facilities. Another example is the control of area development to harmonize with the speed of road development. The other examples are Road Pricing and Time Shifting of traffic demands. It is very difficult to simulate modal shift due to human behavior. Road Pricing and Time Shifting are investigated in this study.

The effects of Road Pricing and departure - Time Shifting (staggered office hours) are studied in the point view of induced-spatial and temporal dispersion of traffic. Furthermore, NOx emission is computed to evaluate the environmental impacts.

4.2 Simulation

Traffic simulator DYNEMO developed and distributed by the German Company PTV, are used in this study. Rush hour traffic simulation was done between 5:00 and 8:00 a.m. over the Tokyo metropolitan highway networks and major local roads.

The major local roads are required to increase the route selection for the spatial dispersion of vehicles and hence, are included in this simulation. Origin-Destination Matrix data for the test-networks are estimated in order to reproduces the traffic density of only a peak Time Belt from the 22nd traffic census in 1997.

Road Pricing is applied for the time period between 7:00 and 7:30 a.m. to circular roads in the Tokyo metropolitan area. The Road Pricing is simulated as follow:

Cost function = time + charge

The 'charge' is additional time factored by 1.0, 0.5, and 0.3. Due to the cost function, each vehicle recognize the Road Pricing as the heavy traffic on that road, and hence, will choose the alternative road. Road selection will be done by the probability model in the simulator. A vehicle pays a certain pricing fee and hence, selects via probability.

The center-bound traffic applies demand shifting by redistributing O-D matrix toward the center of Tokyo. The shifting of the demand was executed by volume and time zone as described in table 1. The total of 8 cases are examined via simulations.

Eleven scenarios of TDM were simulated and compared with a controlled run without any shifting.

Table 1. Simulation condition for time-shifting of demand

The shifting demand by traffic volume.

Time-shifting case 1, 2: 15% of the demand for 15 minutes
Time-shifting case 3, 4: 30% of the demand for 15 minutes
Time-shifting case 5, 6: 60% of the demand for 15 minutes
Time-shifting case 7, 8: 15% of the demand for 30 minutes

The shifting demand by time belt.

Time-shifting case 1, 3, 5: thirty minutes before and after 7:00.
Time-shifting case 2, 4, 8: thirty minutes before and after 6:00.
Time-shifting case 7: One hour before and after 7:00.
Time-shifting case 8: One hour before and after 6:00.

1.2 Results

Twelve kinds of simulations were executed and their results were compared with various viewpoints. The Figure 12 shows the traveled distance per vehicle. Based on this figure, Road Pricing increase as the traveled distance per vehicle. It is conceivable that the increasing traveled distance is due to Road Pricing, for drivers avoid the link that was under Road Pricing. On the other hand, the traveled distance is reduced for the majority of cases that carried out Time Shifting of demand. It is conceivable that drivers can chose the shortest route because of Time Shifting from Time Belt of congestion.

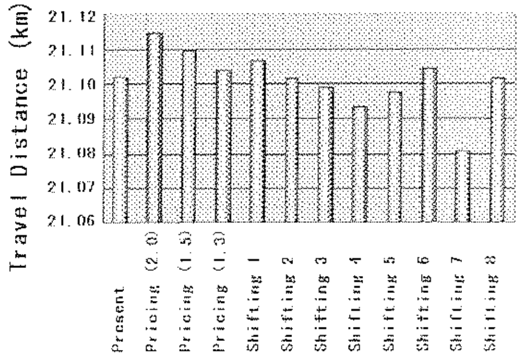

Figure 12. Comparison of the average travels distance per vehicle.

When the Time Shifting of demand is done around 6:00 a.m., rapid Traffic Shifting is more effective versus gradual and prolong Traffic Shifting is more around 7:00 a.m.

Figure 13 shows the travel time for each case. The travel time was not improved by Road Pricing but was improved largely by Time Shifting of demand. Comparing cases #1,3, and 5 with the cases #2, 4, and 6, Time Shifting around 6:00 is more effective than 7:00. From point of travel time, large shifting around 6:00 and gradual shifting around 7:00 is better for travel distance.

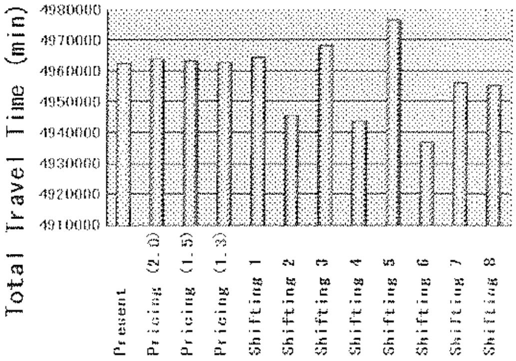

Figure 13. Comparison of the average travels time per vehicle.

Figure 14 shows the average speed of each case. It is clear that the average speed is increased by both Road Pricing and Time Shifting as compared with the present condition. That means these smoothing of the traffic are done by the TDM, e.g., Road Pricing and Time Shifting.

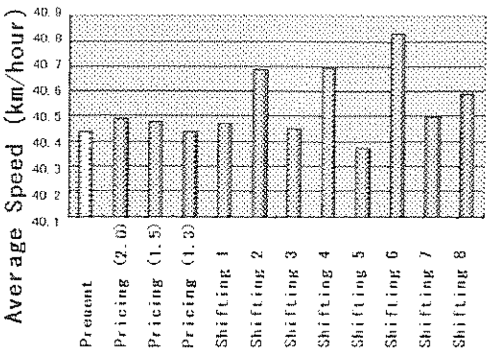

Figure 14. Comparison of the average speed for each case.

Figure 15 shows NOx emission per vehicle for each case. Because traveled distance is proportional to Road Pricing, total NOx emission is increased. Among the Time Shifting case, the large Time Shifting around 6:00 and large is the most effective.

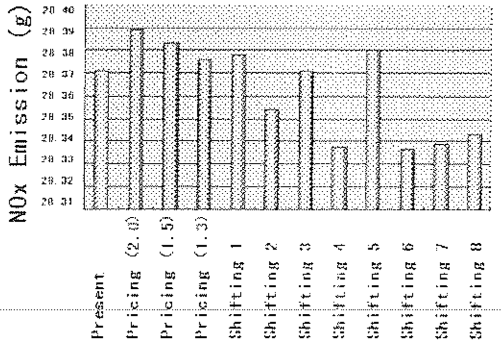

Figure 15. Comparison of the NOx emission for each case.

The NOx emission is compared via the specific link in Figure 16 to investigate the detailed effect of Road Pricing. The NOx emission was decreased by Road Pricing from the circular link around the center of Tokyo, especially in the clockwise direction due to avoiding this link for Road Pricing, smaller traffic volume and increased average speed.

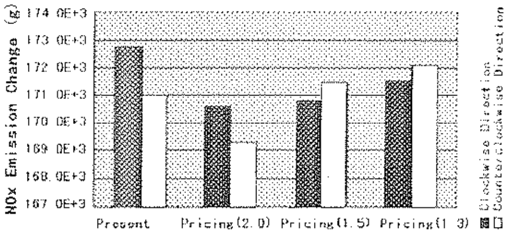

Figure 16. Comparison of the NOx emission for the specific link 1.

Investigating the detour pass of vehicles that avoid the circular link around the center of Tokyo, the following relationship was found in Figure. Figure 17 shows the increase of NOx emission at highway #9 (Fukagawa) link, Daiba link, and Wangan link.

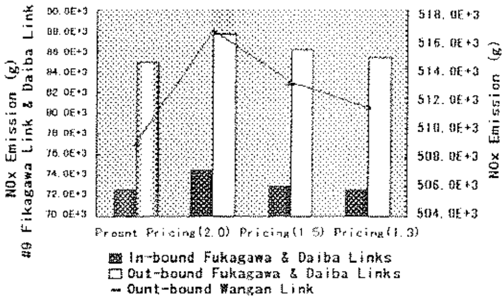

Figure 17. Comparison of the NOx emission for specific link 2

This result suggests that vehicles that detour the circular road, go to Fukagawa. Daiba and Wanagan links. This traffic pattern is presented schematically in Figure 18. The traffic volume on the light-colored link was decreased and traffics volume on the dark-colored link was increased.

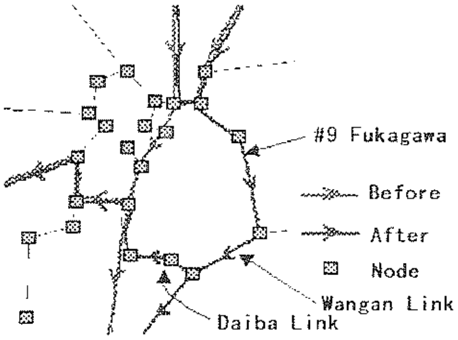

Figure 18. An example of the dispersion of the traffic due to the road-pricing.

Although Road Pricing increases the traveled distance due to detour the vehicle, the average speed was increased. The Time Shifting departure around 6:00 was more effective than shifting around 7:00. An effect differs largely by the volume of shifting demand and time zone. It is most effective to quickly shift many vehicles from the Time Belt when a big change of the demand occurs.

Road Pricing and Departure Time Shifting were able to smooth the traffic flow meaning the increasing average vehicle speed. However, Road Pricing increases the travel distance and hence, increases NOx discharge volume. Departure Time Shifting was able to improve the traveled distance, time, and average speed. The effectiveness of Road Pricing depends on the applied time. Time Shifting just before the traffic rash hour is most effective as compared with the other Time Belt.

5. CONCLUSION AND RECOMMENDATION

The traffic simulators were used as the evaluation tool of traffic policy. The capability of the simulators were confirmed in this study. From the comparison study of the simulators, LEGO and DYNEMO show similar results when the traffic counts are moderate. Results suggest that the microscopic model is better when the daily traffic counts are less than 14,000. Also, results suggests that the fluid model is better for simulating heavy traffic more than 20,000 vehicles per day.

The ETC construction expects a reduction of CO and NOx emissions, reduction of the trip time, and an increase of vehicle-number processing, if the appropriate condition are satisfied. In order to get the maximum effect, the following conditions should be considered:

a) the balance of the number of ETC gates versus the popularity of ETC;

b) the traffic volume on local roads, especially heavy cases;

c) the distance between gate area and the local road, especially short cases; and

d) the blue-time ratio to the signal cycle based on the increased traffic volume.

The effects of TDM such as Road Pricing and Time Shifting of demands were examined by the simulator. The results suggested that re-routing due to Road Pricing have a negative effect with respect to the environmental aspects but the Time Shifting have some positive effects, particularly in the early shift prior to the traffic congestion. However, the Road Pricing may induce Time Shifting of demand instead of the spatial dispersion within a same period. Therefore, TDM has the greater potential for improving traffic condition.

Additional data is required in order to execute a more-detailed simulation. They are 1) finer road network, 2) origin-destination matrix for finer road network, and 3) emission inventory for industry and household.

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