Implementation of Transportation Management Strategies using AVENUE for developing countries

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INTRODUCTION

Urban transportation trends are exacting significant costs in cities in both the developed and the developing world. Growth of automobile traffic leading to serious congestion problems is the bottleneck for all developing cities, especially obstructive for cities with high growth potential. Highways have enhanced the mobility of every city although it is a challenge for urban highway system to meet the growing needs of developing cities and keep congestion under control. The most direct approach to reduce congestion is through infrastructure modifications by adding new lanes and bridges, which is by far the most expensive solution. There are other solutions that focus on improving the efficiency of the existing infrastructure. Operational modifications, better incident management, implementation of Intelligent Transportation System, effective utilization of public transit system and other transportation management strategies and few of the available strategies. Unfortunately, there exists no global solution or panacea and each situation is unique and requires customized solution. This solution can be achieved through careful analysis of various feasible alternatives. Use of traffic simulation is the only practical and cost-effective approach to compare alternatives/measures to achieve the most appropriate traffic management solution. This paper would introduce and illustrate how AVENUE, a real-time microscopic traffic simulation model developed and widely used in Japan, enables planners to make more informative and better traffic management decisions.

This paper would introduce and discuss the effectiveness of three traffic management strategies in reducing congestion and provide real life case studies using AVENUE as the simulation tool.

- Traffic Signal Control System
- Transit Management System
- Electronic Toll Collection

TRAFFIC MANAGEMENT AND SIMULATION

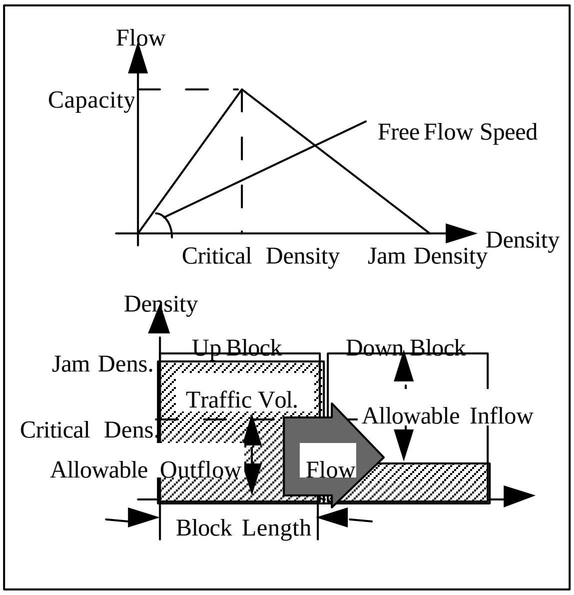
"A toolbox for alleviating traffic congestion"[1] prepared by ITE, provides various strategies of getting most out of the existing system for freeways, arterials and local street. Prior to implementation of any traffic management strategy all feasible alternatives needs to be evaluated to select the desired alternative meeting the needs. This is the main advantage of using simulation tools that provide predictive capabilities. Once a model is developed and calibrated for the base case, it can provide quick runs to analysis multiple future scenarios and compare the measures of effectiveness. Another aspect of traffic simulation is its flexibility to provide programmatic level (macro level) to operational (micro-level) evaluation. Recent advances in technology have made simulation models more and more user friendly and capable to provide better visual representation.

Traffic simulation like any other analysis tool is heavily dependant on the quality of data available. Sometimes collecting data for model calibration could make the use of the model very expensive. Most of the micro-simulation models available commercially require enormous data to calibrate drivers' reaction to unique conditions. As stated in the "Guidelines for applying traffic simulation modeling software", [2] the selection of the analytical tool is the key part of any study. AVENUE is a microscopic simulation model that requires limited data collection requirement due to its unique methodology.

AVENUE – A TRAFFIC SIMULATION MODEL

AVENUE (an Advanced & Visual Evaluator for road Networks in Urban arEas) is a microscopic traffic simulation model developed in Japan [3]. The following features characterize AVENUE:

1) Hybrid Block Density Method for its traffic flow model to enable reproduction of over-saturated traffic conditions.
2) Incorporated drivers' route choice behaviour to meet the recent needs for the evaluation of dynamic route guidance.
3) Drivers' lane choice model according to their turning movements at the intersection further ahead and traffic regulations on road.
4) Designed and implemented in Object Oriented Programming in order to satisfy various users' needs.
5) Graphical user interface with animated traffic images that provide easy operation and persuasive presentations.



Furthermore, the traffic model of AVENUE was verified throughout "Standard Manual for the Verification of Traffic Simulation Models [4]" and validated with benchmark data set prepared and recommended for applying by the Japan Society of Traffic Engineers [5]. Throughout its operation of over 10 years, AVENUE is now the most widely used traffic simulation model for the practical application in Japan [6].

At first, this paper illustrates some of the features of AVENUE, especially focusing on its flow representation and highlighting its advantages in traffic modelling. Then this paper presents the typical application case studies of AVENUE, which estimates the benefit of ITS.

Hybrid Block Density Method as the traffic flow model

Hybrid Block Density Method (HBDM) is based on "block density method [7]", which calculates traffic flow with continuum fluid approximation, and from the sake of simulation utility, it is extended to move discrete vehicle images with various attribute values in accordance with the flow.

In this method, each link is divided into several blocks of which length is equal to the distance that a vehicle runs at the free flow speed of the link during a scanning interval, i.e. 1 second. Normally the block length will be 10 to 20 meters. The in/out-flow and the density of each block are revised at every scanning interval based on the flow-conservation law, i.e. the flows between two adjacent blocks are calculated by a function of the allowable out-flow of the upstream block and the allowable in-flow of the downstream block both of which are determined by the flow-density relationships of the link.

Since the fluid approximation of traffic has some difficulties in handling individual vehicle information, this flow calculation was extended to move not only the continuum traffic density but also the discrete vehicle images containing various attributes such as vehicle types, origins and destinations, route choice criteria and turning movements.

Advantage of Hybrid Block Density Method to Car-following modelling approach

In the recent days, there is plenty of micro-simulation software available for commercial use. Most of them calculate traffic flow with car-following (CF) model, which calculates the acceleration and the deceleration of each vehicle from the spacing and the relative speed between the vehicles. This modelling approach seems to be very natural for the human behaviour and affords the flexibility to the behaviour description.

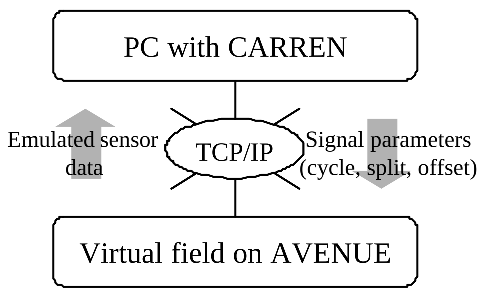
However, CF modelling requires a lot of 'personal' parameters, e.g. desired speed, response delay, maximum acceleration, etc. It seems very difficult to adjust simulation traffic with real traffic, because most of the personal parameters are not easily measurable. Many practitioners using CF based simulation software, which is often made in European countries and US, have suffered with its parameter calibration. Especially for Asian countries, where experience of simulation use is less, we cannot expect the accumulated knowledge on those parameter settings to match, and will face serious trouble to use CF models.

On the other hand, AVENUE requires only few parameters, capacity and free flow speed, to describe traffic flow characteristics. These parameters can be easily measured at roadside. Even though we do not know the exact values of the parameters, the accumulated knowledge in the field of traffic engineering can tell us some appropriate values. Therefore, we believe that AVENUE's approach for traffic modelling has a significant advantage, especially for its application in Asian countries.

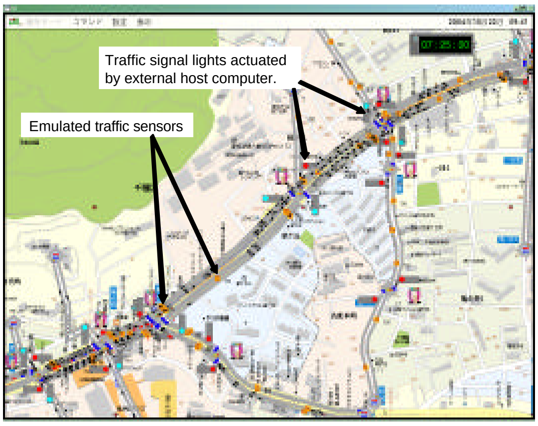
Case Studies of AVENUE for Traffic Management

Traffic Signal Control System

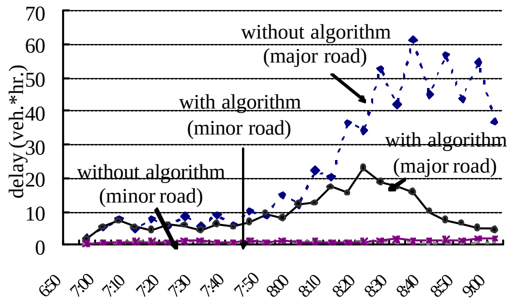
Asano *et al.* used AVENUE for virtual experimentation to validate the effect of their new algorithm for traffic signal control, CARREN [8], which directly measure the delay on the roads with ITS sensors (e.g. image processing detector, automatic vehicle identifier, etc) and minimize the total delay. Another remarkable feature of CARREN is adaptation. Most of the conventional signal control methods would have some key parameters



that greatly affect performance. However, after a long-run, traffic situation may be different from those for which the traffic signal was calibrated, and the parameters may not work well any more. In CARREN, all key parameters are directly measured from the site and updated at every cycle to maintain the expected performance for a long time.



The performance of this algorithm was examined using AVENUE. The experiment was set up such that AVENUE provides the emulated sensor data to external host computer via TCP/IP network. The host computer calculates the optimal signal parameters and AVENUE accepts the parameters to control the traffic signal lights in the simulation.

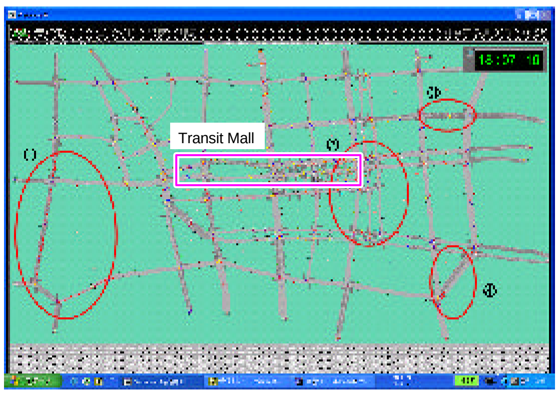


The virtual experiment was conducted with the configuration in real road network. The study area was selected along Nagakute road in Nagoya-city, Japan. The network consisted of 11 intersections over 5 km in length. On this network, we coordinated a couple of case studies by varying the traffic demand, incident yielding lanes, etc. Throughout the experiments, CARREN illustrated its capability to reduce total delay by 10 to 30 percent as compared to conventional signal control algorithm in Japan.

National Police Agency of Japan coordinated the virtual experiments using AVENUE not only for CARREN but also for other new algorithms proposed by other companies. The use of AVENUE was helpful for them to verify and validate the reliability of those algorithms in advance prior to the real world implementation in field.

Transit Management System - Transit Mall in CBD

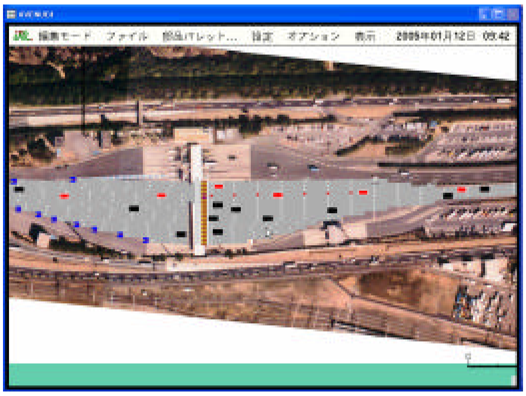
In order to improve the safety and comfort in CBD area, Ministry of Land Infrastructure and Transport in Japan is now promoting ‘Transit Mall’, which operates light rail transit running in ‘vehicle free’ zone. At the planning stage, however, there is always a controversial issue whether the traffic condition in the surrounding areas would worsen or not. Traffic simulation is the ideal tool available to estimate the impact of Transit Mall on traffic congestion.



AVENUE provides an extension module to simulate exclusive lane use and exclusive signal control strategies for certain vehicle type, making it applicable for such impact analysis. The figure above illustrates the simulation project conducted in Nagoya-city, which plans to construct a Transit Mall at the centre of the city. In this case study, added to the impact analysis of diverting all vehicular traffic from

Transit Mall, the effect of reducing the impact with signal control and routing strategy was also evaluated.

Electronic Toll Collection - Design of toll plaza with ETC exclusive lanes



In Japan, electric toll collection system (ETC) is rapidly becoming popular due to the discount scheme of toll fare. The latest report shows that approximately 50% of traffic crossing tollbooths use ETC in urban area. The road administrators are anxious to enhance traffic safety and provide smooth operation of the traffic in the vicinity of toll plaza. AVEUNE was selected to evaluate the geometric design of toll plaza as well as the operation of ETC gates and separation strategies from non-ETC vehicles.

For this case study, precise video survey was conducted to extract successive trajectories of vehicles crossing the Narashino toll plaza in Chiba, Japan by using a set of video cameras [9] covering the entire area (500 meters) of the toll plaza. From the extracted trajectories of more than 1000 vehicles, special lane change model in the toll plaza was identified and implemented into AVENUE.

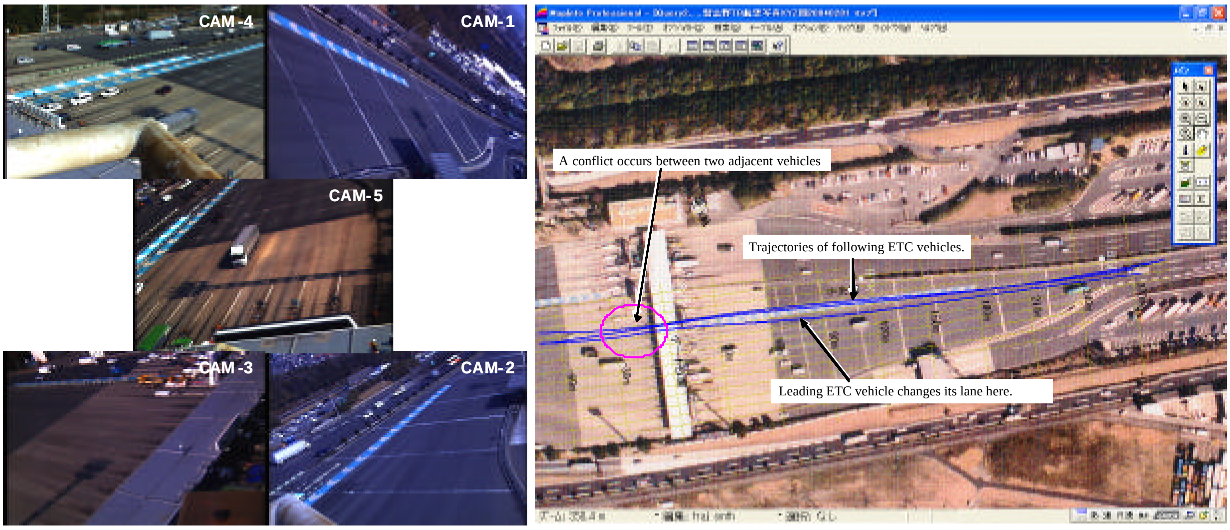


Figure 1. Successive video survey and extracted vehicle trajectories at Narashino Toll Plaza

As part of this study with AVENUE, a couple of scenarios were evaluated by fluctuating traffic volume, changing the percentage of ETC vehicles, varying the positions of exclusive ETC tollgates, etc. The evaluation uses the indices regarding the spatial distribution of speed and interference in toll plaza. Figure 1 illustrates the video survey that was conducted at Narashino Tollbooth to extract the trajectories of vehicle. Upper portion of Figure 2, displays the spatial distribution of vehicle speed in the toll plaza and the lower portion shows the distribution of interferences for two adjacent vehicles. For this illustration, the tollgate #0, #1, and #-8 are operated as exclusive ETC lanes. Along the ETC exclusive lanes, we find the slower speed sections for around 80 meters upstream of the tollgate. There were high occurrences of interferences observed for this section. Also, there were high interferences at the sections about 220 meters upstream of the tollgate due to high frequency of lane changes.

The result of this case study provides a helpful finding for the road administrators helping them to take proactive decision. This study illustrates the following:

- When the number of ETC vehicles becomes large, the capacity bottleneck will not be apparent at the tollgate section but at around 70 to 80 meters upstream section.
- To reduce the high interference at around 220 meters in the toll plaza, we have to provide proper lane guidance signs further upstream.

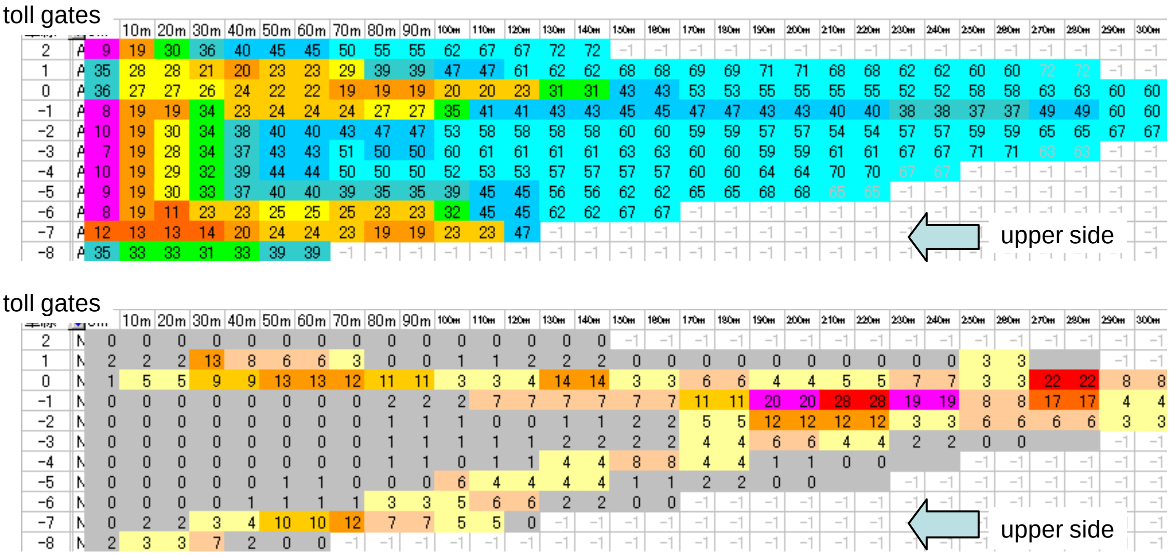


Figure 2. Spatial speed (upper) and interference (lower) distributions in toll plaza.

CONCLUSIONS

This paper introduced a traffic simulation model based on the Hybrid Block Density method, summarizing the benefits of using a tool that would require minimum data collection and calibration efforts to simulate traffic conditions in Asian countries. With three different case studies for implementation of Traffic Management Strategies, this paper illustrates how a simulation model can effectively be used to provide valuable information to decision makers and road administrators and help them undertake cost-effective solutions. Potential solutions could be through the use of enhanced traffic signal control system or through the introduction of an innovative transit system along congested corridors. To reduce congestion at tollbooth sections, adequate number of exclusive ETC lanes with proper signage could be considered to smoothen its operation. Such effective use of traffic simulation can be extended to developing countries where better traffic management strategies would help alleviate traffic congestion.

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