【土木計画学研究・講演集 No.24 (2) 2001年11月】

NETSIM-BASED SIMULATION FOR EVALUATION OF EXPERT SYSTEM FOR DETERMINING BUS PREEMPTION*

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1. Introduction

In the peak period the traffic demand usually exceeds the road capacity, resulting in traffic congestion and loss of time of the commuters. In the case of bus operation in mixed traffic, traffic congestion makes the bus much less attractive than private car. A possible way to increase the efficiency and fairness of road usage is to give priority to the buses due to higher passenger load. However, installation of bus lane into the existing urban road is typically impractical as the recommended minimum number of buses at 60 vehicles per hour, which will justify a reserved bus lane, is too restrictive[1]. In Japan, however, the criterion of at least 50 buses per hour is adopted in general planning practice of bus lane.

Another alternative approach is to give bus priority at traffic signals. Recently in Japan, there has been an initiative, called PTPS project, which is aimed to encourage people to switch from private vehicle to public transportation by giving priority to the buses at bottleneck-signalized intersections. It achieves in 20% reduction of bus delay at signals during the morning peak. However drawback of the current practice is that several tests are needed in order to find out the proper strategy in giving priority, causing severe traffic disruption. In addition decisions whether or how long the preemption should be given is not made according to the level of need for priority, but rather predefined and constrained by minimum time span between two consecutive priorities. The study of Chang et al. is an example of efforts to give selective bus preemption based on performance index, including vehicle delay, passenger delay and bus schedule delay. However, their strategy is designed for use under adaptive signal control environments, which have not been widely put into practice. The attempt made by Rongviriyapanich et al. illustrated how decision to give bus preemption under coordinated signal control environments can be done with consideration on performance index. It showed the potential improvement over the strategy, which has been adopted in the PTPS project.

Evaluations of effectiveness of bus preemption strategies could be made either by conducting a before-and after study test or use of traffic simulation tool[2]. The first alternative, although technically less complicated, imposed difficulties in assessment of the actual effects due to inability to conduct the experiments under controlled conditions. In spite of its obvious benefits, lack of sophisticated features for operation and special treatment of bus in the well-known software has discouraged the transport planners from use of traffic simulation tool for evaluation. Utilization of animation features of the NETSIM for aiding simulation and evaluation of bus preemption strategies, as adopted by Khasnabis et al., is very of limited applicability. The need of more sophisticated tool for the evaluation of strategies for public transportation priorities is apparent.

2. Objectives

In this paper, we therefore aimed to evaluate effectiveness of the scheme for determining level of signal priority needed by approaching buses online so that priority is guaranteed to be given to the right buses at the right time. The expert system, composed of neural networks and fuzzy systems, was created and, at first glance, turned out to be more powerful than the currently used logic in the PTPS project. However, its effectiveness in comparison with the PTPS system still needs to be thoroughly investigated through results of simulations obtained from the TRAF-NETSIM. Extension to the standard version of NETSIM will be done. Consequently, a number of measures of effectiveness shall be used as criteria for comparison of the both strategies.

3. Bus Preemption

Even bus may start moving within a vehicle platoon but due to loading and unloading, it may fall behind the platoon and become delayed at downstream traffic signal[3]. This is a reason why the maximum through band of general traffic may not benefit the buses. Signal priority is given by altering the signal-timing plan in a way that benefits buses. Signal priority treatment can be classified into passive priority and active priority. Passive priority can be used to produce benefits to buses by predetermining timing plan with consideration on the movement of buses. The examples of passive priority are reduction of cycle length, splitting phases and designing of signal offset according to the bus travel time. The advantage of passive priority is that it can help reduce bus delay without any cost of infrastructure. Active priority, on the other hand, is given only when the arrival of bus is detected. Phase extension, early start, special phase and phase suppression are among the most typical example of active priority treatments[4]. Unconditional signal priority means priority is given to the bus whenever its presence is detected. It can

* Keywords: Bus preemption, expert system, TRAF-NETSIM

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excessively increase delay of the cross street traffic. Thus, conditional priority is more preferable because priority is given based on the consideration of various factors, such as schedule adherence, cross-street queue length, current traffic condition, time since last priority[4].

4. Expert System

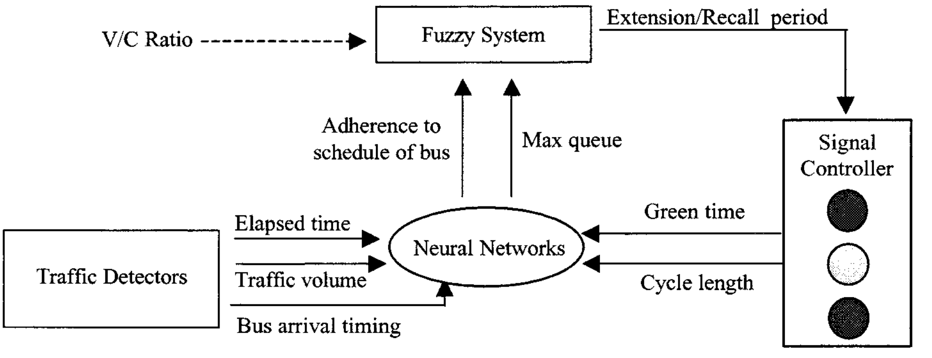

Fig.1: Configuration of the expert system

Here the concepts and approach that were used to develop the expert system by Rongviriyapanich et al. is explained. Fig.1 illustrates the interaction between each component in the expert system. Firstly, necessary data is transmitted from signal controller and traffic detectors to the neural networks. Neural networks were chosen as tools for real time prediction of delay of buses at the traffic signal and maximum queue lengths of inbound direction of priority and cross streets. Due to imprecision associated with estimates from the neural networks, fuzzy logic is used for online determining of appropriate level of priority that should be given to the buses. Input variables are bus schedule adherence and maximum queue length of the both streets, which are outputs obtained from the neural networks, as well as volume-capacity ratio (v/c) of the both streets. The input variables and the level of priority are represented by fuzzy sets as follow.

Volume/capacity: Large, medium and small
Maximum queue length: Very long, long, medium and short
Adherence to schedule of bus: Early, punctual, and late
Level of Priority: Maximum, large, medium, small, do nothing

The boundaries of the fuzzy sets are set according to distribution of the observed data. Fuzzy reasoning is used for determining appropriate level of priority with consideration on both adherence to schedule of the buses and traffic condition. The boundaries of resulting fuzzy set from the fuzzy reasoning are set at the values, which maximize punctuality of the buses. Fuzzy reasoning, which is composed of 8 fuzzy rules, is proposed. Appropriate level of priority, ranging from do nothing to maximum priority, can be obtained grade of membership of the rules. Here we formulate the rules based upon punctuality of the bus and difference between prevailing traffic condition and degree of saturation of the both streets

5. NETSIM-based simulation

NETSIM has been widely accepted as a standard tool for traffic simulation due to its user-friendly interface, ability to reasonably represent traffic movement and the animation output. However, its major drawback is lack of features for public transportation operation. Users can only define the routes and single constant value of headway for the bus service. Another shortcoming of the NETSIM is that traffic detector cannot classify the category of the vehicles, making detection of bus arrival impossible. The developers of NETSIM realize the variety in needs of researchers; consequently the standard NETSIM has been designed to allow the run time extension (RTE) from externally developed algorithms. This feature is a major advantage of NETSIM over other tools for traffic simulation. The RTE shall be written in either FORTRAN or C/C++ code in order to interface with the CORSIM, which is built from FORTRAN. In this study, since our expert system was originally built in FORTRAN code, interface can be done with relative ease. Our RTE can be shown diagrammatically in Fig.2.

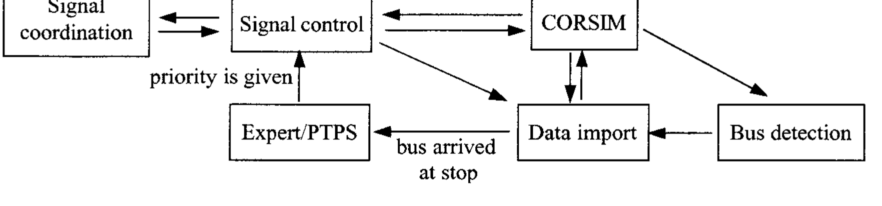

Fig.2: Interaction of subroutines in the RTE with CORSIM

6. Data and methodology

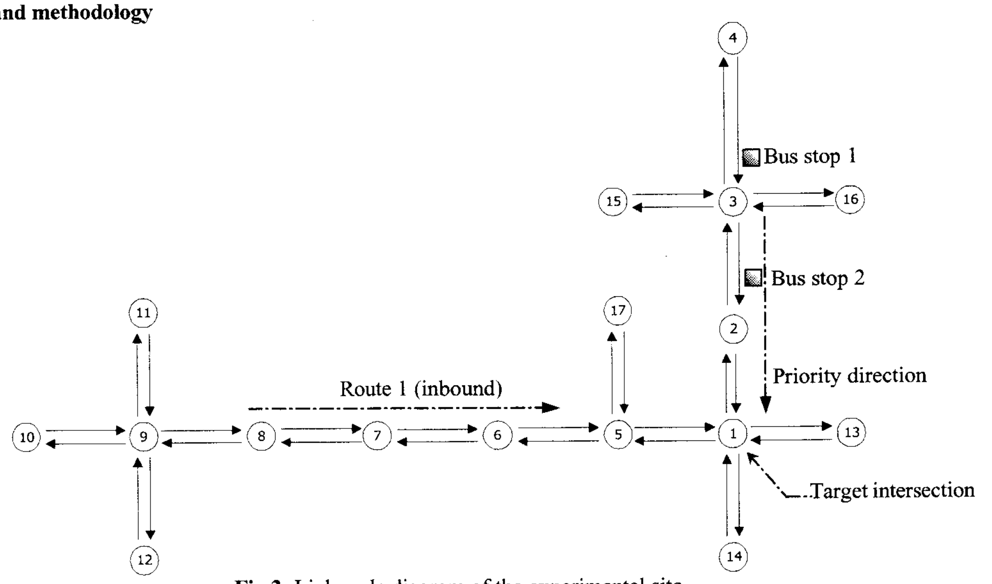

Fig.3: Link node diagram of the experimental site

Table1: Input data for NETSIM

Link	Lane Configuration		Length	Traffic volume	Turn %			Cycle timing (sec)		Offset
	No.	Right pkt	(m)	(veh/hr)	L	T	R	Length	G/R/(RT)	(sec)
2-1	2	1	60	1050	5	88	7	130	36/82/12	110
3-2	2	-	140	1050	-	100	-	130	97/33	22
4-3	2	1	600	1100	5	90	5	130	88/32/10	12
5-1	1	1	180	850	9	73	18	130	70/48/12	110
6-5	1	-	150	650	-	100	-	130	97/33	80
7-6	1	-	160	650	-	100	-	130	97/33	60
8-7	1	-	260	650	-	100	-	130	97/33	40
9-8	1	-	300	650	-	100	-	130	97/33	20
10-9	1	1	270	720	5	90	5	130	77/41/12	0
14-1	2	1	450	1050	8	82	10	130	36/82/12	110
13-1	1	1	400	820	15	67	18	130	70/48/12	110

Fig.3 and table 1 above show the layout along with data on road traffic and signal timing of the experimental site, which is necessary as inputs for the NETSIM to simulate traffic state of the site. Node 1 represents the target intersection for the bus preemption. The major parameters for calibration of the NETSIM such as queue discharge headway, start-up lost time, average headway and dwell time at stops of the buses or average vehicle occupancy are set according to the observed data. The period of simulation is set at 2 hours, in order to cover the 2-hour morning peak during 7.00 until 9.00 of weekdays, at which buses are operated with 90-second headway and average 40 passengers on board.

By using the external signal control algorithms, the effects of the bus preemption strategies, either PTPS or expert system, can be compared with each other and with base case. Among measures of effectiveness (MOEs), that can be obtained from the NETSIM, we have chosen the average travel time of buses as well as person delay and vehicle delay of the streets along route 1 and the priority direction, which are directly affected by the change of signal control strategy, as criteria for evaluation of the effectiveness. In addition, on-time performance of the buses over the entire period of simulation and maximum queue lengths at every cycle of signal, obtained from our RTE, are also taken into account.

7. Results

Table2: Results of simulations under different control strategies and headway of the buses

Control logic	Vehicle delay (priority/cross) (veh-min)	Passenger delay (priority/cross) (pass-min)	Avg. delay of buses (sec)	Avg. signal split (priority/cross) (sec)
Fixed	11500/11100	24500/14500	170	43.0/63.0
PTPS	10000/9400	19600/12000	120	43.9/63.8
Expert	7000/12900	14300/16500	93	42.6/64.1

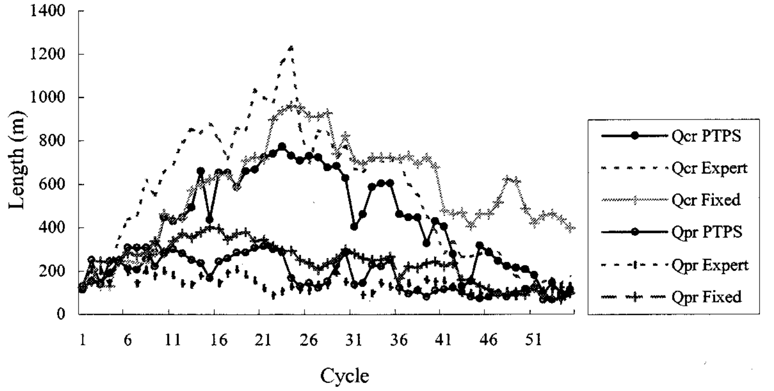

Fig.4: Max queue lengths over the period of simulation under different control strategies

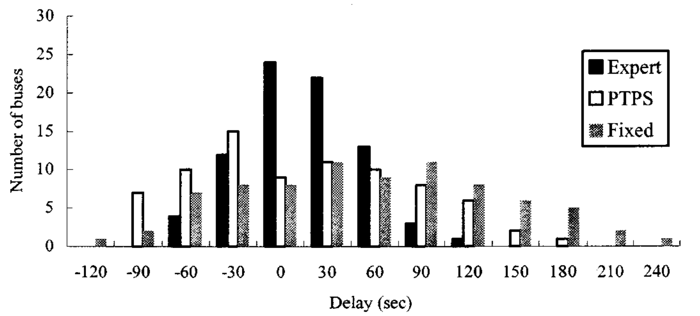

Fig.5: On-time performance of the buses over the period of simulation under different control strategies

Table 2 summarized the MOEs obtained from the simulation results of the signal control strategies. When signal split is equivalent, all the control strategies are almost in par with each other in terms of the overall vehicle delay. However, PTPS and the expert system are superior as seen from reduction in average delay of the buses and the total passenger delay, with bigger saving achieved from the expert system. Fig.4 and Fig.5 show the effects of the control strategies on the maximum queue lengths and adherence to the schedule of the buses. The figures make clear the reasons why the expert system works out. First, it avoids giving priority to the buses, which are already ahead of the schedule, and gives only when necessary. Secondly, smaller signal split for the cross street during the first hour, resulting in longer maximum queue length, was sacrificed for more priority to the buses, which would be otherwise late. Longer signal split, that was afterward compensated, helps bring the maximum queue length of the cross street back to normal level.

8. Conclusions

This study is aimed to show quantifiable effects of the bus preemption strategies. NETSIM was chosen here due to its capability to interface with the externally developed algorithms. Various MOEs, for instance vehicle or passenger delay and maximum queue lengths are used as criteria for comparison of the effectiveness of the preemption strategies. It was revealed that the expert system could considerably reduce the network-wide delay, not to say that of public transportation. Besides, on-time performance of the buses also significantly improved by the expert system as priority is given only to the buses, which are likely to be behind the schedule. Effects on the cross street traffic are within acceptable limits with less than 20% increase in delay. This is outweighed by the 30% decrease in delay of the priority traffic. It is clear that flexibility in giving signal priority achieved through the expert system can assist the public transportation without excessive demerits to the cross street traffic even at the extremely short headway of the bus service.

9. References

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