MODELLING AND ANALYSIS OF THE BUS PRIORITY IMPLEMENTATION

Lydia Hidayati
Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Yogyakarta, INDONESIA
Email: lydia_hidayati@yahoo.com

ABSTRACT

Bus is expected to play an important role in providing a reliable travel in congested conditions. Therefore, it has been widely studied to minimize the travel time and the delay of the bus by proposing bus priority scheme to increase the attractiveness of public transport against private vehicles. Signal timing optimization combined with the bus priority scheme are discussed in this research as the alternatives to improve the intersection performances. Further, identifying the effects of these alternatives towards the general vehicles and public transport system performances were the aims of this research as well.

As the result of this research, bus advance area with pre-signal method is able to reduce the travel time and delay of the bus for routes 2A and 3A by 11%, 23% and 14% , 0% respectively and able to reduce travel time, delay, and queue of vehicles by 25%, 26%, 7% consecutively. Thus bus advance area with pre-signal method is proposed as the best alternative due to its impact to reduce the bus travel times and delay without degrading the other vehicles performance.

Keywords: bus priority, optimizing signal timing, Aimsun simulation, travel time-delay-queue.

1 INTRODUCTION

1.1 Background

Bus is expected to play an important role in providing a reliable travel in congested conditions due to its efficiency in using road space and its ability in carrying passengers. Condong Catur intersection is an intersection which has to be passed by buses to enter the Condong Catur bus station. This intersection is always in congested condition during morning and afternoon peak hour since it is the meeting point of the high flow in Northern ring-road and the flow from Gejayan road. Traffic control by the traffic police officers frequently happens and leads to different treatment between north approach and the other approaches. The north approach is the main road to enter to or exit from the Condong Catur bus station, thus the bus flow in this approach is higher than other approaches. Consequently, with the interference of the traffic police towards the vehicle movement, the delay of bus Trans Jogja becomes longer than its actual delay. If the delay is longer, the travel time will also be longer and it is difficult for a bus to catch up its schedule in time. Considering these reasons, Condong Catur intersection is appropriate to be considered as the study location to model and analyze the implementation of bus priority.

Bus priority strategy has advantages in ensuring the buses run to time and reducing the travel times of the bus, so that the buses are more competitive towards private vehicles. In conducting this research, Aimsun version 6.1 is selected as the micro simulation tool. Micro simulation gives a chance to adjust parameters and obtain result in details up to the vehicles behaviour.

1.2 Objectives

The objective of this research is to develop models and simulate Condong Catur intersection using Aimsun software. Bus priority was proposed as the alternatives for the Condong Catur intersection which simulate as well using Aimsun. This research will be finalised by predicting and analysing the impact of bus priority towards the performance of general vehicles and public transport in terms of travel time, delay and queue.

1.3 Study Scope

In order to make the research more focus, only some limitations are applied. The study area of this research only covers Condong Catur intersection performance during afternoon peak hour in weekdays. Bus Trans Jogja is the only public transport being observed.

2 LITERATURE REVIEW

2.1 Intersection Management

Intersection management is part of traffic management by coordinating traffic signals, optimizing the signal timing, redesigning intersection geometric, and so on, which aims to improve intersection capacity either in a single scale as an intersection or in a large scale as the road network (Anwar, 2008). There are two common ways in managing the intersection i.e. optimizing traffic signal and redesigning the intersection geometric.

The period of signal timing affects the intersection performance; inappropriate signal timing will decrease the intersection capacity, increase the queue length and lengthen the vehicles delay. Thus, traffic signal needs to be optimized to improve the intersection performance. According to Saxena (1989), the purpose in redesigning intersection geometric is to increase the intersection performance and safety, for example by reducing the potential conflict's points, limiting the speed, and prioritizing the major flow.

2.2 Cycle Length Optimization

Cycle length is the amount of time in which all movements at a signalized intersection are accommodated. Cycle length optimization is important to maintain the cyclic operation so that the intersection capacity is optimal as well (Wahlstedt, 2011). Other aim in optimizing cycle length is to decrease the delay of vehicles. Therefore, in determining the "best" cycle time, the delay of vehicles was taken into account to the formulation. In addition, there are several constraints for optimizing cycle length, those are (Kejun, 2008):

a. The cycle length must be long enough to provide sufficient minimum times for all phases, considering both vehicle and pedestrian requirements. The sum of minimum phase lengths is the lower limit of the cycle length.
b. The cycle length should be long enough to ensure that no approach was saturated.
c. The cycle length should not be so long to avoid high delays.

2.3 Bus Priority

Bus priority is part of traffic management which gives a greater priority access to buses over other road vehicles. The ways of bus priority implementation are by building a specific lane and applying bus signal priority control (BSPC). The common forms of exclusiveness access to a section of road as mentioned in Giannopoulos (1989) are: full or part time with flow bus lane, bus only road, contra–flow bus lane, bus way.

Bus signal priority control aims to give rights for buses to pass intersection with higher priority than other vehicles. BSPC was proposed in order to minimize the delay of public transport so that it is able to improve its efficiency towards the other vehicles. There are several types of BSPC, such as passive priority, pre-signal and active priority (Kejun, 2008).

2.4 Bus Priority in Aimsun

In the AimsunMicroMesoUsers Manual v6.1, bus priority in Aimsun is simulated by using pre-emption function. Preemption, only available in microsimulator, is an additional parameter on signal control plan in Aimsun software which provides the ability to simulate BSPC. Preemption will adjust the signal timing in the signal control plan to foresee the arrival of the bus in order to gives it the right of way at the intersection. Several parameters must be configured to simulate preemption model, those are: Public Transport (PT) lines, Dwell phase, Detector priority request, Detector priority end, Delay, Inhibit, Min Dwell, Max dwell, Reserve, Type.

3 METHODOLOGY

3.1 Research Location

This research is conducted by constructing model using AIMSUN v6.1, beside the main intersection, Condong Catur, the nearest intersection located in front of the bus station is taken into account in order to model the buses behavior when entering and exiting from bus station. Further, for the bus priority the recommendation only focused on the north approach since it is the main access from the bus station. In addition, Condong Catur intersection served four routes of bus Trans Jogja operation, that are 2A, 2B, 3A and 3B so that the bus flow is quite enough to be considered.

3.2 Data Collection

There are two types of data that were gathered, those are primary and secondary data. Primary data collection was conducted for three days during the week days in the afternoon peak hour between 4 - 5 PM. The primary data consists of traffic flow, turning proportion, queue length, time signal and travel times whilst the secondary data consists of geometric layout and routes of Trans Jogja.

3.3 Research Methodology

This research was started by reviewing the literature related to bus priority then followed by conducting survey to collect the data. After all data were collected the next stage is analyzing those data. Data analysis is used to plan the bus priority scheme. The steps for the analysing process include:

a. Model Development and Simulation with Aimsun

1. Creating the network area of study based on the geometric layout gathered;
2. Adding traffic control plan;
3. Inputting the traffic demand data;
4. Adding route and shelter of Trans Jogja as the public transport plan;
5. Creating a scenario and experiment. Each experiment consists of ten replications and one average of the basic model simulation.

b. Calibration and Validation procedures
c. Optimization the traffic signal timing
d. Bus priority plan

After analysis process, the simulation results of basic and alternatives model were then being compared to develop the conclusion of this research.

4 RESULT AND DISCUSSION

4.1 Bus Priority Alternative

Optimization of traffic signal timing is mainly recommended to be implemented before applying bus priority scheme in the case of Condong Catur intersection. The basic idea of optimizing traffic signal timing is to identify the "best" cycle time for an intersection which is considered in maximizing the capacity and minimizing the delay and degree of saturation (DS). Calculation of capacity, DS and delay for all approaches and signal timing optimization using solver function Ms. Excel resulted that the best cycle time for the current traffic in Condong Catur intersection is 176 s with green time period for south, west, north and east approach are 43 s, 45 s, 24s, and 47 s respectively.

Alternative 1

On the first alternative, bus priority scheme that recommended is bus signal priority control (BSPC). Modeling of BSPC in Aimsun is by using preemption facility. Bus priority which proposed is type of bus priority which will give priority as soon as possible to the busses routes 2A, 2B and 3A. This priority is attached to phase 5 of signal control, that is phase for the north approach. Further, it shows that there are three detectors, one priority request detector and two priority end detector, which is installed in the road section in order to receive the signal emitted by buses. The time interval between the moment when bus detected by detector and the priority is activated is set to be 5 s, then the maximum duration of bus priority is 20 s so that if this value is exceeded or the priority end detectors detect bus which ask for priority passing, bus priority scheme will be ended. Further, preemption only allowed one priority request at once, the time in which the additional priority request will be ignored is set to be 10 s. It is due to prevention of frequent priority service. All of these time are defined in the time parameters in Aimsun.

Alternative 2

The second alternative is combination between redesign the geometric layout of Condong Catur intersection and pre-signal bus priority control. Redesign the geometric is proposed by giving divider for the left turn laneThis special lane is dedicated for vehicles which going to turn left and for the buses. The special left turn lane will be combined with bus advance area as special path for buses passing through north section and giving opportunity for buses to queue in the front line of north approach.

In bus advance area, two stop line which controlled by different traffic signal are applied on the north approach where the first stop line control the movement of general vehicles and the second line control both the general vehicles and the bus. Based on the calculation, the distance between first and second stop line is 10 m. The illustration of bus advance area that were proposed, the relationship between pre and main signal of alternative 2 can be seen in figure 1and 2 respectively.

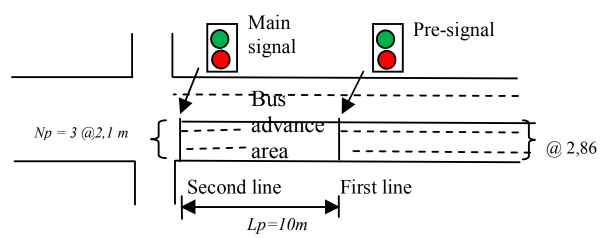

Figure 1. Illustration of bus advance area

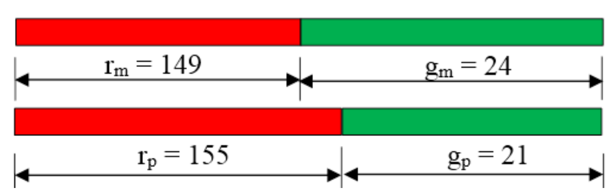

Figure 2. Relationship of pre and main signal at Condong Catur intersection

4.2 Comparison of Performance Result

Comparison analysis is the next data analysis which perform to identify the opportunity and the impact of bus priority towards the performance of Condong Catur intersection. In comparing the simulation result, ANOVA statistical test is conducted to check the significancy level of bus priority impact. Based on the comparison, the impact of bus priority is measured in terms of "reduction" parameters, in which the average value of travel time, delay and queue from basic model simulation are subtracted by those parameters values from the alternatives result. The reduction as is presented in table 1, both the original values or the percentage values, has two different result that is positif and negative impact. Besides showing the reduction values, table 1 is showed the significance level as provide in “sig” row. The same assumption is used as well in presenting the impact of bus priority towards the public transport performance as shown in table 2.

From Table 1, it is found that the highest significance reduction of travel time is happens to east as much as 28% for the alternative 2. Table 1 also show negative impact of bus priority towards the general vehicles in north which could be seen by negative (-) sign in the reductions row. Negative impact means that the implementation of bus priority increase the travel times of general vehicles in the north as much as 12% for alternative 1 and 24% for alternative 2. Even though both alternatives have negative impact, yet for the alternative 1 the changes is not significant which means that the performance of alternative 1 is similar to the performance of the existing condition. However the alternative 1 increase the travel time of existing condition by 40%. In addition for the delay and queue comparison, the highest reduction is happens in east while the lowest reduction is happens in south approach. Like the travel time which show negative impact, the delay and queue in north become worse by the implementation of bus priority, especially for alternative 2. Whereas on the alternative 1, the delay and queue of west approach increase as well.

Table 2 shows that the reduction impact towards the travel time and delay of public transport is experienced by Trans Jogja route 2A and 3A. Yet, the travel time and delay for route 2B and 3B of Trans Jogja increase. For route 2A, the highest siginificance reduction of travel time and delay are resulted by the alternative 2 that is 23% and 25% respectively. In Trans Jogja with route 2B, both alternatives result unsignificant impact towards travel time and delay. Like on the route 2B, route 3A is not experience any significant impact as well. In route 3B, alternative 2 decrease the value of travel time and delay by 12% and 27% respectively eventhough it is not significant, while due to alternative 1, route 3B significant increase its travel time and delay by 28% and 63% respectively.

4.3 Challenges in Implementing Bus Priority

There are some challenges which being addressed in giving priority for the bus, those are:

a. There will be equipments that need to be provided and maintained to support its implementation.
b. There will be difficulties in changing the driver behaviour.
c. There will be social complaint as the public respons towards bus priority implementation, since their performances were degraded while the bus were being prioritized.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Some conclusions that can be drawn from this research are:

a. It is found that the exiting signal timing of Condong Catur intersection is not effective in accommodating the traffic flow shown by high delay and queue in almost all approaches. The optimized cycle time proposed in this research is 176 seconds with green time period for south, west, north and east approach being 43s, 45s, 24s, and 47s respectively.
b. There are two recommended alternatives of bus priority schemes; the first is bus signal priority control and the second is bus advance area combined with pre-signal timing. The performance comparison before and after the bus priority implementation:
c. The result of this research shows that the highest reduction of the travel time, delay and queue are 25%, 26%, 7% consecutively for the BSPC method and 28%, 30%, 8% consecutively for the bus advance area method at East approach.
d. For the public transport system performance, the BSPC method shows an insignificant reduction for the travel time and delay for routes 2A and 3A of 11%, 23% and 14%, 0% respectively, yet it increases the travel time and delay for route 3B by 28% and 63%. For the bus advance area method, route 2A experienced reduction value of travel time and delay of 23% and 25%, while the other routes have not experience an impact of bus priority since the reduction values are insignificant.
e. General conclusion that can be withdrawn by this research is that alternative 2 of bus priority scheme is recommended to be implemented considering it result which able to decrease the delay and travel time of bus up to 29% without severely impact the general vehicles performances.
f. Regardless the limitation of Aimsun in constructing the network model, it functions as a micro simulation tool to model the existing condition and predict the condition for the alternative scnario implementation provide accurate and useful result for the planner.

Table 1. Names of styles used in the paper manuscript

Approach	value	Travel Time (s)		Delay (s)		Queue (pcu)	
		alt1	alt2	alt1	alt2	alt1	alt2
South	reduction	25.396	19.772	25.390	19.800	2.000	1.100
	% reduction	17%	14%	18%	14%	9%	5%
	significance	sig.	sig.	sig.	sig.	sig.	unsig.

Approach	value	Travel Time (s)		Delay (s)		Queue (pcu)	
		alt1	alt2	alt1	alt2	alt1	alt2
West	reduction	-36.274	7.456	-36.250	7.436	-2.825	1.200
	% reduction	-40%	8%	-44%	9%	-13%	6%
	significance	sig.	unsig.	sig.	unsig.	sig.	unsig.

Approach	value	Travel Time (s)		Delay (s)		Queue (pcu)	
		alt1	alt2	alt1	alt2	alt1	alt2
North	reduction	-11.233	-23.096	-11.224	-23.233	-0.767	-3.650
	% reduction	-12%	-24%	-14%	-27%	-5%	-23%
	significance	unsig.	sig.	unsig.	sig.	unsig.	sig.

Approach	value	Travel Time (s)		Delay (s)		Queue (pcu)	
		alt1	alt2	alt1	alt2	alt1	alt2
East	reduction	23.669	26.754	23.639	26.741	1.342	1.625
	% reduction	25%	28%	26%	30%	7%	8%
	significance	sig.	sig.	sig.	sig.	sig.	sig.

Table 2. Bus priority impact towards public transport performance

Route	value	Travel Time (s)		Delay (s)	
		alt1	alt2	alt1	alt2
2A	reduction	90.274	188.121	87.584	187.471
	% reduction	11%	23%	12%	25%
	significance	unsig.	sig.	unsig.	sig.

Route	value	Travel Time (s)		Delay (s)	
		alt1	alt2	alt1	alt2
2B	reduction	2.009	0.546	1.043	-0.098
	% reduction	1%	0%	1%	0%
	significance	unsig.	unsig.	unsig.	unsig.

Route	value	Travel Time (s)		Delay (s)	
		alt1	alt2	alt1	alt2
3A	reduction	40.038	-0.637	39.803	-1.214
	% reduction	14%	0%	19%	-1%
	significance	unsig.	unsig.	unsig.	unsig.

Route	value	Travel Time (s)		Delay (s)	
		alt1	alt2	alt1	alt2
3B	reduction	-43.886	18.990	-46.207	19.386
	% reduction	-28%	12%	-63%	27%
	significance	sig.	unsig.	sig.	unsig.

5.2 Recommendations

Based on the analysis there are several recommendations for further research. First in using Aimsun software for simulating the condition of traffic in Indonesia, a study to model the motor cycle behavior properly is necessary, since motor cycle is a type of vehicles which has big proportion on the road. Another recommendation is related to the bus priority scheme plan. In this research, the signal timing optimization only considered the delay of vehicle in pcu. For further research, it would be better to take into account the passenger delay by considering the vehicles occupancy due to the index performance of public transport such as travel time and delay experienced by the bus passengers , where the capacity of bus to carry passengers is higher than passenger occupancy level of general vehicles.

Although by optimizing traffic signal and bus priority the performance of Condong Catur intersection improves, they are not the long-term solution in solving the congested problem due to the high rate of vehicles growth. Therefore it is recommended to start limit the number of vehicle on road to prevent over-saturated condition in the future.

REFERENCES

Anwar, Y., 2008, "Optimasi Waktu Siklus Di Simpang Dengan Menyediakan Fasilitas Belok Kanan Bagi Pengemudi Sepeda Motor", *Thesis of Magister Sistem dan Teknik Transportasi, Universitas Gadjah Mada,* Yogyakarta.

Giannopoulos, G. A., 1989, "Bus Planning and Operation in Urban Areas: A Practical Guide", Athenaeum Press Ltd., Newcastle, Great Britain.

Kejun, L., 2008, "Bus Priority Signal Control at Isolated Intersection", *International Conference on Intelligent Computation Technology and Automation*, Journal published in IEEE, pp 234 – 237.

Saxena, S. C., 1989, "A Course in Traffic Planning and Design (For Bachelor, Diploma and Post Graduate Student)", DhanpatRai& Sons 1682, NaiSarak, New Delhi.

TSS-Transport Simulation Systems, 2010, "Microsimulator and MesosimulatorAimsun 6.1 User's Manual", TSS-Transport Simulation Systems, S.L.

Wahlstedt, J., 2011, "Impact of Bus Priority in Coordinated Traffic Signals", Published by Elsevier Ltd., *Procedia Social and Behavioral Sciences 16*, pp 578 – 587.