EVALUATION OF THE EFFECTS OF COMBINING DIFFERENT SIGNAL PRIORITY RULES AND BUS OPERATION AT THE SIGNALIZED INTERSECTION *

by Pradeep Kumar Shrestha** Fumihiko Nakamura*** Toshiyuki Okamura****

1. Introduction

Recently, many metropolitan governments in the world have invested significant amount of budget in the extension of infrastructures and development of new public transportation system to overcome urban transportation problems specially traffic congestion resulting from ever-growing numbers of automobiles. Among public transportation modes, the public buses have been contributing an important role to provide access to most urban centers serving as a main mode as well as feeder mode for passengers. Thus, the improvement of existing public bus system to provide efficient public bus service is a low capital cost measure for reducing automobile dependence of the metropolitan areas. But, buses share same road with other traffic and need to stop frequently for passenger boarding and alighting. The interaction of buses with other traffic reduces their speed.

Furthermore, most of urban activities and developments are concentrated around intersection. The increased activities make it an ideal location for bus stop, thereby producing heavy pedestrian flow, illegal parking etc. Also, intersection is signalized for improving safety and effective movement of conflicting vehicular and pedestrian traffic flows through the intersection at the cost of delay to traffic. As a result, buses suffer significant amount of delay at signalized intersection. Consequences are reduced speed and highly varied travel time etc.

Transportation experts are exploring different alternatives ranging from space priority; bus vehicle improvement etc. to the application of advanced Intelligent Transport System (ITS) technologies such as bus signal priority, advanced communication systems, automated scheduling and dispatch systems etc. Since Intersection delay is one of the main criteria for evaluating bus performance, Bus Signal Priority (hereafter BSP) have been considered broadly for improving bus service performance by reducing stopped delay of buses at signalized intersection. The form of BSP system in Japan, known as Public Transportation Priority System (hereafter PTPS), has been able to reduce bus delay by providing priority at traffic signals. With invention of new technologies in the field of intelligent transport system, opportunities for new applications are still increasing for better performance. Moreover, improvements to bus services have been considered through number of bus operation controls such as fare payment system, infrastructure improvement such as bus lanes, queue jump lanes etc. Most BSP researches are independent with these bus operation controls. Rare studies have been made considering integrated approach of bus operation control, BSP and road infrastructures management. Combination of those elements of transportation supposed to maximize BSP effectiveness. BSP system is usually evaluated in terms of travel time benefit to bus at the cost of travel time disbenefit to cross traffic. Different combination of the above mentioned elements will have different level of impacts on speed and travel time of bus, traffic on priority direction and traffic on non priority direction. The combination of these elements for different traffic condition, bus demand and different bus priority case is to be analyzed for finding significant benefits to bus with permissible impacts on other traffic.

This paper aimed to consider four different conditional bus signal priority methods for bus stop operation and bus lane priority for different traffic volume. The different combination will have different travel time impacts which were compared for two objective functions e.g. travel time impact for traffic in priority direction and traffic in non priority direction. The CORSIM simulation package was used for the evaluation of those measures and their results were compared among those priority methods. The current...
study considered at a micro level analysis at single intersection level which can be further extended to the corridor level or network level. Also, the long term impacts such as mode shift can also be considered as performance indicators.

2. Existing Problems and Objectives

The interaction of bus with other traffic in mixed flow and delay at intersection results increased bus delay and variation in bus travel time compared to other vehicles. Bus lanes and signal priority are the widely used bus priority methods for improving bus performance. The various bus operations such as bus stop location, fare payment methods are also being implemented to reduce travel time variations. However, the combined approach of bus operation, infrastructure improvement and signal priority has rarely been considered for analyzing bus movement through the intersection. Also, volume capacity ratio, location of stop, different cases of BSP etc will have different degree of impact on bus movement as well as other traffic at the intersection. Hence, the major objective of this study was to study the effects of combining the different case of BSP along with bus stop control and bus lane with reference to performance indicators such as speed, travel time and delay of bus itself, traffic on priority direction and traffic on non priority direction.

3. State of the Art

Bus priority policy is one of the public transport policies to prioritize qualified buses through signalized intersections so that it can reduce travel time, increases service reliability of bus, and reduce bus driver stress with minimal impact on other traffic. Several studies have reported reductions in average intersection bus delay ranging between 6% to 42%, and reductions in average bus travel times ranging between 0 and 38%. The bus priority policy in Japan, known as Public Transport Priority System (PTPS), has been able to reduce bus delay by providing priority at traffic signal and more than half of prefectures in Japan are implementing PTPS. The use of the PTPS and the reserved bus lane has significant impact on the bus travel times and their variation. New and rapid advances in traffic/bus detection and communication technologies, and well-defined priority algorithms have made Transit Signal Priority (TSP) more appealing or acceptable to more road users of all modes.

Bus arrival prediction and signal priority strategies are two important parts considered for priority decision. The various concepts such as time series, regression, artificial neural network etc. have been applied for predicting bus arrival time for bus signal priority for increasing bus priority performance. Similarly, the two most popular bus priority schemes are green extension and early green. Erampalli et.al considered three types of priority such as restarting signal phase with green, signal phase calculation based on approach volume and starting signal phase with green, and signal phase calculation based on approach volume and extending green phase till bus passes. A conditional signal priority approach that restricts the target bus, and adaptive bus priority system that evaluate priority based on performance indices and signal priority is granted based on minimum green constraints.

The potential adverse impacts of transit signal priority are increased delays and queue lengths for vehicles traveling on cross-streets. Few researches have been done in integrating bus operation system and signal control. Saitennan considered a loss of green time when bus topping to load/unload passengers at nearside bus stop in single lane bus route during green time interval. The various combinations of bus operation and signal priority policies could have different degree of negative impact such as increased delay and travel time on the side street.

4. Methodology

The purpose of this study was to assess the relative effects of combining the different cases of BSP along with bus stop control and bus lane on the priority and non-priority road for different performance factors. Hence, the main components of the methodology are as follows:

- Combine elements of bus operations such as bus stop position and bus lane with bus signal priority,
- Set up different bus signal priority cases based on detection, bus information etc.
- Develop bus signal priority logic which consists of bus arrival prediction and priority scheme selection
Develop simulation model
Evaluation of considered cases

The details of each step will be discussed in detail in the following subsections:

(1) Combination of Elements for BSP
The different combination of elements such as bus stop location, bus ways along with bus signal priority (BSP) offer different level of service and impacts on vehicular traffic and bus. Also, the level of effectiveness varies with different factors such as bus demand, traffic demand, road geometry, passenger volume etc. In this study, average travel time of bus, traffic on bus direction and traffic on cross road were considered as indicators for evaluation purpose. The travel time benefit to bus and traffic on bus direction, and the disbenefit to traffic on cross roads will be studied considering following two combinations cases.

i) Bus stop position (100 m) + Bus lane + Bus signal priority
ii) Bus stop position (100 m) + Bus signal priority

Different types of bus signal priority control can be considered for each combination cases ranging from simple to complex. It is relatively simple and easy to implement priority immediately based upon detection of bus and its arrival prediction, ignoring its disbenefit such as increased intersection delay to other vehicles. The disbenefit due to signal priority could be reduced by providing priority to selected buses depending on bus schedule delay and bus departure information, and using multiple detections. Based upon bus information and detection, different types of bus signal priority cases has been analyzed for each combination case (Table 1). Detail explanation of bus signal priority case is being explained in the section (2) below.

(2) Bus Priority Cases
As explained earlier, the increased disbenefit such as delay, increased travel time, reduced speed etc to vehicles on the non-priority direction can be reduced if selected bus is only given priority with multiple detection and conditional signal priority based upon various factors such as regular bus service, bus schedule etc. In this paper, the four different types of conditional bus signal priority cases were analyzed. They were segregated based upon long vehicle detection; regular bus identification, schedule delay and communication of door closing time i.e. bus departure information from bus stop etc. Each bus priority case adds one more condition from Case 1 to Case 4.

Table 1 Combination cases and signal priority cases

<table>
<thead>
<tr>
<th>Combination cases:</th>
<th>Bus Signal priority</th>
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<tr>
<td>Combination 1</td>
<td></td>
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<tr>
<td>Bus stop (100m) + Bus lane</td>
<td>(i) <strong>Case 1:</strong> Long vehicle detection</td>
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<tr>
<td>Combination 2</td>
<td></td>
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<tr>
<td>Bus stop position (100 m)</td>
<td>(ii) <strong>Case 2:</strong> Long vehicle detection + Identify regular buses</td>
</tr>
<tr>
<td></td>
<td>(iii) <strong>Case 3:</strong> Long vehicle detection + Identify regular buses + Schedule based condition</td>
</tr>
<tr>
<td></td>
<td>(iv) <strong>Case 4:</strong> Long vehicle detection + Identify regular buses + Schedule based condition + Communication of door closing time</td>
</tr>
</tbody>
</table>

In the first case, detection system identifies long vehicles and gives priority. Second case, upon detection of long vehicle, system decides whether it is regular bus of bus route or not. In third case, upon detection of the bus at the bus stop, the signal controller checks schedule adherence of arrived bus. Bus qualifies for priority only when bus has suffered significant delay (> 2min in this study). Fourth, the type of priority is considered by providing means to communicate the bus and signal controller in such a way that bus is detected immediately after it leaves the bus stop. When bus is ready for departure and its door has been closed, the information is conveyed to signal controller. This will reduce variability in arrival prediction due to variability in bus dwell time. Thus reducing bus being failed to receive priority and thus, negative effect to non priority traffic will supposed to be less.

(3) Signal Priority Logic
Signal priority logic is developed to change traffic signal parameter in order to give priority to buses according to four cases of priority discussed in 4(2). The priority logic includes bus detection at user specified distance, prediction of time at which bus will arrive at intersection stop line or join intersection
queue, decide bus priority scheme according to bus arrival time and granting priority as shown in Figure 1. As for example if case 4 is considered, the priority logic can be explained as follows:

1. The detector routinely checks long vehicle or bus arrival.
2. Upon detection of bus, it will check whether it is regular bus or not.
3. The bus arrival time at bus stop is estimated by the bus arrival prediction method.
4. The system will check schedule arrival time to determine bus delay. Bus qualifies for priority only if bus is delayed for more than 2 min.
5. If bus is qualified for priority, the control system will monitor the bus departure from bus stop.
6. Bus arrival time at intersection is estimated by the bus prediction model explained in sub section 4(a).
7. The control system will determine signal priority strategy based on time at which bus arrives at intersection (section 4(b)).

(a) Bus Arrival Time Prediction

For all case of priority, it is necessary to know when bus will arrive at intersection since its first detection so that appropriate signal priority scheme could be selected. The time of detection of approaching bus, its speed, dwell time data and other traffic data such as queue at intersection, queue discharge headway, signal status etc. are important factors which affects bus arrival time at intersection. Dwell time estimation in turn affected by boarding and alighting activities, door opening and closing time etc.

An attempt was made to model bus arrival time for bus signal priority considering signal state. The estimation will be modified for signal state and accumulated queue at intersection by the similar concept used by Li, et al5). For the intersection as shown in Figure 2, 3 and 4, a bus will stop at bus stop for boarding/alighting before passing the signalized intersection. It considered bus stop with under saturated intersection and queue would not back up over the advance loops. The travel time $T$ of a bus is the sum of travel time from detector to bus stop, bus dwell time and travel time to intersection.

$$T = T_{sa} + D_a + T_{ai}$$ (1)

Where, Travel time $T_{sa}$ and $T_{ai}$ are expressed as linear relationship with distance. The coefficient ‘$α$’ can be considered as reciprocal of average speed of bus, and the coefficient ‘$β$’ account for variation in travel time. Thus,

$$T_{sa} = α_1 L_{sa} + β_1$$ (2)

$$T_{ai} = α_2 L_{ai} + β_2$$ (3)

Bus dwell time at a bus stop, considering boarding takes longer time, can be estimated as per Equation (4)

$$D_a = λ_a \times [t_k - t_{k-1}] \times t_{boarding}$$ (4)

Where, $D_a$ = Bus dwell time for boarding at stop A, $t_k$ and $t_{k-1}$ = arrival time of bus ‘k’ and bus ‘k-1’, $λ_a$= passenger arrival rate at stop A, $t_{boarding}$ = Average boarding time per passenger.

In most cases, buses have to join a queue, wait in the queue, and then discharge with the queue. In order to initiate priority, the time when bus reaches at intersection stop line or time when it joins at the end of queue is necessary. The number of queuing vehicles can be estimated based on the arrival and departure counts from loop detectors.
(i) Signal state is green when bus is detected: The remaining green time can be calculated as;

\[ G_{\text{remain}} = G(p) - G'(p) \]  

(4)

Where \( G(p) \) and \( G'(p) \) are green time and elapsed green time of phase ‘p’, the difference of the counted arrival and the estimated departure counts gives the queue length, and the corresponding queue discharging time can be calculated as:

\[ q_{\text{discharge}} = \frac{[D(t) - A(t)]}{\text{Saturation flow}} \]  

(5)

If \( q_{\text{discharge}} \leq G_{\text{remain}} \), bus arrival time will be equal to Equation (1).

If \( q_{\text{discharge}} > G_{\text{remain}} \), bus arrival time can be obtained by subtracting \( (q_{\text{discharge}} - G_{\text{remain}}) \) time from Equation (1).

(ii) Signal state is red when bus is detected: If signal stage is red at the time bus was detected, the end of queue is to be determined. Then, time when the bus will join intersection queue is calculated by,

\[ T_{ai} = \alpha_2 X_{ai} + \beta_2 \]  

(6)

Where, \( X_{ai} = L_{ai} - \text{Queue Length} \)

If \( T_{ai} > R_{\text{remain}} \), then bus arrival time is

\[ T_{ai} = \alpha_2 X_{ai} + \beta_2 \]  

(b) Bus Priority Scheme

Green extension and early green are two major priority logics considered for this study. The green extension is used when the upper level of priority can be accommodated by extending green. To extend the green phase until the priority window ends, the force-off point, the point where end of phase can begin, of the main street phase with the green extension strategy, \( T_{\text{ext}} \), is set at the upper value as shown in Figure 5(b). Thus, the green extension can be used for the bus that arrives at the intersection between upper and lower value shown in Table 2. The maximum green time of extension ‘\( G_{\text{max}} \)’, is the difference between cycle time, and the minimum green time ‘\( G_{\text{min,i}} \)’, the change interval (Ii) of all non-priority phases which is sum of Amber time (Yi) and all Red time (Ai) , and green time (Gi) of main road, can be shown in the form of Equation (7)\(^4\). Where, i, C, G, Y, A and I are phase, cycle time, green, yellow, amber and change interval.

\[ G_{\text{max}} = C - G - \left( \sum_{i=2}^{2} G_{\text{min},i} + \sum_{i=1}^{2} (Y_i + A_i) \right) \]  

(7)

For the phase diagram shown in figure 1, the phase 2 and phase 4 is very short and minimum green time for phase 3 is 30 sec. Only, green time from phase 3 is only used for providing green at main street. The maximum green time from Equation (7) will be \( G_{\text{max}} = (130-47-\{30 + (2+9+2+9)\}) = 31 \). The upper and lower values of green extension can be calculated as per Table 2. Thus, if bus arrives at intersection between 47 and 78 sec, green extension is activated.

Similarly, if a bus is expected to arrive during the red signal and upper level of priority cannot be accommodated by green extension, then the non-priority phases is shortened to allow the main street to receive a green earlier than normal. The early green depends on the number of non-priority phases between the current phase at which bus arrives and the main street phase. The current phase is stopped or provided the minimum green, and its change interval initiated. The maximum early green time is the difference between the cycle time, and phases that has already been served, the maximum of elapsed green of the current phase \( (t_k) \) and its minimum green\( (G_{\text{min,k}}) \), and minimum requirements of phases \( (G_{\text{min}, i}) \) as shown in Equation (8)\(^4\).

\[ G_{\text{early}} = C - \left( (G_i + I_i) + \sum_{i=2}^{2} (G_i + I_i) + \left( \max\{G_{\text{min},4}, t_4\} + I_k \right) + \sum_{i=1}^{2} G_{\text{min},i} + I_i \right) \]  

(8)

\[ G_{\text{early}} = C - \left( (G_i + I_i) + (G_i + I_i) + \left( \max\{G_{\text{min},3}, t_3\} + I_k \right) + (G_4 + I_4) \right) \]  

(9)

Where, ‘i’ and ‘k’ are numbers of phases and the phase during which bus will arrive, respectively. It is to be noted that the phase 2 and 4 are very small for the target intersection and only phase 3 can contribute to the early green time. Thus, early green is calculated as in Equation (9).
If bus arrived in phase 3, the elapsed green time of phase 3 is 40 sec, then, early green can be calculated as $G_{early} = \{(130-(47+2)+(5+4)+\{\max(30,40)+2\}+(5+4)\}) = 31$. The upper and lower values of early green are 130 and 99 sec as per table 1. Thus, if bus arrives at intersection beyond 78 sec, early green is activated.

5. Simulation Study

(1) Significance of Study

The bus signal priority is only needed at certain intersections and there is benefits and disbenefits associated with it. In the case of the major intersection, non-priority street can be affected severely for providing priority on the main road along bus direction. The selected intersection for study purpose is the major intersection serving National Highway 1 as side street. Compared to other intersection along the bus route, the effect on the side road in this intersection will have greater significance. The author’s assumption is that the various combinations of bus operation control, signal strategies and infrastructure will have different degree of impact to non-priority vehicles. Since, the effect to side street is sole contribution of the priority on main road, the study considering signal intersection will be enough to draw out the extent of impact on priority and non-priority road due bus signal priority in the micro scale.

(2) Selected Study Site

The target study area with four phase signalized intersection was shown in Figure 4 above. The selected intersection is the only major intersection along the route in which any priority given to main road can have significant negative impact on the side road there by increasing travel time. Thus, this study attempted to assess the effects of the different cases of BSP on priority and its relative impact on non-priority road. This data was collected at Fujisawa City in Japan by Rongviriyapanich 7) for similar kind of study. This study has attempted to extend his study. The bus route is considered in only one direction with bus stop located at a distance of 100m. It was also analyzed for additional bus lane. The basic data used for modeling are road geometry data, main and cross street traffic volume of 1050 veh/hr and 720 veh/hr, queue discharge headway = 2.4 sec, mean dwell time = 15 sec with bus headway = 300 sec. Some important assumptions made particularly for this study were min. green time of 30 sec for through flow, only one signal priority per cycle and bus is regarded as delayed if it is late for more than 2 minutes.

(3) Simulation Model

CORSIM is a microscopic traffic simulation program that combines two separate programs one for modeling arterial streets, called NETSIM, and other one for modeling freeways, called FRESIM. Before proceeding with simulation, the CORSIM should be calibrated and validate for its measures of performances (MOEs) so that they can match those in the field. The CORSIM was calibrated for capacity, traffic volume and travel time to represented field conditions. The parameter considered for alterations were mean discharge headway, mean startup delay, reaction time and mean free flow speed etc. The calibration process is the iterative process as altering a parameter could cause one factor to calibration target where as other factor move away from target value. The iterations were repeated until the calibration MOEs were within 15% of field value. The CORSIM Run Time Extension (RTE) capability was used to model and simulate the signal priority logic considered. The four priority cases for bus stop at 100 m evaluated for traffic volume and capacity ratio of 0.3, 0.4 and 0.5, and signal priority with bus lane. Then, simulation is carried out to find measures of effectiveness (MOE) with regard to various cases of BSP systems such as delay, average travel time, speeds of bus and other vehicles along priority and cross road.
6. Analysis and Results

The important measures of performances such as bus and other vehicle delay, travel time and speed were summarized from the simulation for evaluating the priority measures. The average speed, delay and average travel time of vehicles on priority and non-priority road, and bus were obtained for the four cases of priorities separately from CORSIM simulation analysis. This study compared average speed, average travel time and delay for bus, traffic priority direction and traffic on non-priority direction for the combination of bus operation, bus lane with four case of bus signal priorities.

(4) Performance Evaluation

The results for all four cases from simulation were aggregated for bus, vehicles on priority direction and vehicles on non-priority direction. The Figure 6 and 7 shows percent increase/decrease in delay and average speed due to bus signal priority for combination case 1 and 2. Since only buses are permitted to use bus lane, Case 1 i.e. long vehicle detection case i.e. case 1 is not considered for combination 2. In general bus signal priority resulted reduced delay to buses and other vehicles on priority direction while increased delay to vehicles on non-priority road as shown in Figure 6. The Case 1, in which priority is activated once long vehicle is detected, has resulted highest delay (111%) to traffic on non priority direction and less benefit to bus (25%). The Case 4 resulted least delay (17%) to non-priority vehicles with 8% and 13% reduction in delay vehicles on priority road and bus respectively. The further reduction to delay was observed for the case 4 with bus lane (10%).

The similar pattern of negative impact to non-priority road for average speed was observed as shown in Figure 7. The highest reduction in speed about 13% for both Case 1 and Case 2 for combination 1. With bus lane, impact is reduced but still, Case 2 has resulted highest impact to side street. Bus speed in case 2 has increased to higher extend (13%). It is obvious as most regular bus might receive priority in this case.

While comparing both performance indicators, the Case 3 and 4 has least negative impact to non-priority direction. Thus, it is recomendable that with improved detection and bus operation, bus signal priority can provide significant benefit to buses with least negative effect to non-priority vehicles.

(5) Sensitivity Analysis

The average speed, average delay and travel time of bus, vehicles on main road and side road were calculated for the above mentioned four cases of priorities separately from CORSIM simulation analysis. Also, the sensitivity of the results on average speed, average travel time and delay for bus, traffic priority direction and traffic on non-priority direction for the combination of bus operation, bus lane with four case of bus signal priorities were studied for three volume capacity ratio of 0.3, 0.4 and 0.5 respectively and shown in Table 3, 4 and Figure 8. It was observed that when volume capacity ratio increases, it results to
increase in delay and decrease in average speed of bus and other vehicles in all direction. It means that the priority works well at lower volume capacity than higher volume capacity. For example: if we compare case 4 from Table 3, average speed of bus, priority and non-priority direction is 17.6 kmph, 28.4 kmph, 27.0 kmph for V/C ratio of 0.4 where as 15.4, 25.3, and 26.3 kmph are that for V/C ratio of 0.5. Similarly, if we compare case 3 Table 4, average delay of bus, vehicles on priority direction, and non-priority direction are 88.3, 39.7 and 51.0 sec/veh for V/C ratio of 0.4 where as 137.5, 68.7 and 55.8 veh/sec for that of V/C equals to 0.5.

Table 3 Average speed (km/hr)  

<table>
<thead>
<tr>
<th>V/C</th>
<th>MoE of</th>
<th>WOP</th>
<th>Case 1</th>
<th>Case 2</th>
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Table 4 Average delay (sec/veh)  

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<td>80.1</td>
<td>NA</td>
<td>62.1</td>
<td>74.1</td>
<td>74.4</td>
</tr>
<tr>
<td></td>
<td>Priority road</td>
<td>36.7</td>
<td>NA</td>
<td>34.1</td>
<td>35.6</td>
<td>35.9</td>
</tr>
<tr>
<td></td>
<td>Non-priority</td>
<td>41.8</td>
<td>NA</td>
<td>56.3</td>
<td>46.5</td>
<td>46.3</td>
</tr>
</tbody>
</table>

(6) Comparison of Travel Time Effects
The travel time effects on priority road and non-priority road due to signal priority shows that travel time of two roads are complementary. The vehicles on priority road get benefited from extra green time provided for bus thereby resulting disbenefit to vehicles on non-priority road due to reduced green time. These two travel time functions can be used for comparing extent of impact while combining bus operations, signal priorities and infrastructure management. It will help to decide best priority that can be applied with minimum disbenefit to non-priority vehicles. From Figure 8, general trend shows that the reduced travel time on main road due to signal priority has resulted increased travel time at non-priority road. For example Case 1 priority (Figure 8A), about 45% increase travel time were observed for 3.2% decrease in travel time at priority road where as for
Case 4, 12% increase in travel time for non-priority road with 1.2% decrease in travel time for priority road. The priority case 1 is the simple priority in which priority is activated once long vehicle is detected. The priority case 4 is improved priority based on bus information and detection. The bus which is not actually necessary to get priority might also receive priority in Case 1. The improved priority has been able to reduce travel time on non-priority vehicles. Thus, Case 3 and Case 4 has least negative impact for all four case of V/C ratio. With increase in volume capacity ratio, general trend is increase in negative impact on non-priority road. For example, 1.2%, 4% and 7% increase in travel time for V/C ratios of 0.3, 0.4, and 0.5 respectively. Travel time impact is relatively less for combination with bus lane. While comparing the Case 2 for V/C = 0.4, 13% increase in travel time for bus lane while without bus lane case 35% increase in travel time was observed.

7. Conclusion

In general, the concluded results from previous researches show that bus signal priority provides benefits to bus with disbenefits to other vehicles. However, the extent of negative impact to non-priority vehicles has rarely been discussed. The author's assumption is that the various combinations of bus operation control, signal strategies and infrastructure will have different degree of impact to non-priority vehicles. At the same time, the inclusion of different elements in the signal priority will have different degrees of travel time and delay impact for bus and other vehicles. Thus, the different cases of signal priorities ranging from simple detection of long vehicle and activating priority to the improved method of selective priority considering bus information were examined to study trend of benefit to bus, vehicles on priority road and non-priority road through simulation analysis using CORSIM. Since, the effect to non-priority street is sole contribution of the priority on main road, the study considering signal intersection will be enough to draw out the extent of impact on priority and non-priority road due bus signal priority. Selective BSP with more conditions and detection is best approach for reducing negative impact to other vehicles as in this case priority will be activated only when there is need. The use of bus lane and selective BSP had least negative impact to traffic on non priority direction than to selective BSP only. In the future, the cost for operating such signal priority with different combination cases can be considered.

References

2) CORSIM Documentation, FHWA, US Department of Transportation.
Evaluation of the Effects of Combining Different Signal Priority Rules and Bus Operation at the Signalized Intersection

By Pradeep Kumar Shrestha** Fumihiko Nakamura*** Toshiyuki Okamura****

Bus signal priority (BSP) effects on bus and other vehicles varies for different combinations of conditional BSP rules, infrastructures and bus stop operations under different demand. This paper analyzes four cases of conditional BSP for given bus stop operation and bus lane with varying demand using CORSIM. BSP rules considered are long vehicle detection, identifying regular bus, amount of schedule delay, door closing time. The impacts are evaluated for two objective functions i.e travel time for priority and non-priority direction. The method will be beneficial to find combination of strategies with benefit to bus and acceptable disbenefit to non-priority direction.