A PRACTICAL APPROACH FOR DESIGN OF BUS SIGNAL PRIORITY STRATEGY

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ABSTRACT

In this paper, we propose the application of Door Open and Closure Information (DOCI) in design of Bus Signal Priority Strategy (BSPS) for urban signalized intersections. Current BSPS methods most likely involved location information collected by vehicle detector or GPS (Global Positioning System) technologies only. It is difficult to take the uncertainness of bus dwell time on bus stops in proper considerations. The proposed design is validated by a practical case study through microscopic traffic simulation. The results show that, with no unbearable burdens on other traffic modes, our proposed method can significantly improve the delays of buses at a signalized intersection located in Seoul, South Korea.

Keywords: bus priority, signalized intersection, traffic simulation

1. INTRODUCTION

In order to improve the quality of service of buses, Bus Signal Priority Strategy (BSPS) has been implemented in many cities worldwide. The prior BSPS deployments have shown the effects of BSPS by reducing bus intersection delays and improving bus service schedule adherence. Especially, as the cost of information and communication technologies decreasing, there is a noted potential of extending BSPS application in developing countries as well (Shrestha, P. K., 2009).

However, many of current BSPS practises adopt some vehicle detection means that sense the presence of an approaching bus only at a fixed location. It is difficult to obtain the exact bus arrival time to an intersection in such practises (Li, M, et al., 2008). Even Global

Positioning System (GPS) based Automatic Vehicle Location (AVL) systems are installed, it is still difficult to predict the variance of bus dwell time on near side bus stops, which are often caused by random passenger arrivals at and departures from the bus stops (Shrestha, P. K., 2009).

Therefore in this paper we propose a new BSPS by applying Door Open and Closure Information (DOCI), through a new technology called Radio Frequency IDentification (RFID). By DOCI of a bus, we can learn their current status, passengers are still boarding on or leaving from the bus (doors are opening), or it is ready to move again (door closed). We want to prove justify the advantages and potential of applying BSPS that utilizes not only the position information but also DOCI of buses.

In this paper, the concept and technical details of BSPS applying DOCI is firstly described. Then the field survey on a signalized intersection in Seoul, South Korea and the corresponding traffic simulation study is introduced. We also analyze the cost/benefit evaluation of the proposed BSPS before the final conclusions.

2. BUS SIGNAL PRIORITY STRATEGY APPLYING DOCI

2.1 The Basic Concept

In this paper, we assume a situation of near side bus stop, i.e., the bus stop is at the upstream side of a signalized intersection. As show in Figure 1, when passenger service finished and all doors of a bus are closed, door closure information is submitted to the control center of traffic signals where the closure information is appreciated as the bus approaching information under the proposed BSPS.

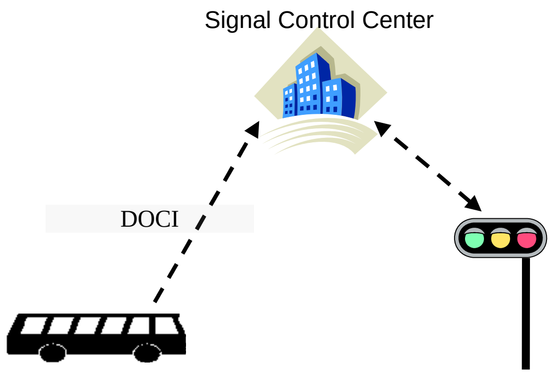


Figure 1 – Concept of A BSPS applying DOCI

2.2 The Proposed Methodology

In this paper, instead mere position data, door closure information is appreciated as the bus approaching information for the proposed BSPS. After receiving door closure information from a near side bus stop, the control center will appreciate that all passenger service of the bus is finished and it is departing from the bus stop to enter the intersection. Four strategies may be chose by the control center to arrange the signal display of the intersection.

1. When left green interval < assumed bus arriving time, green extension.
2. When left green interval >= assumed bus arriving time, do nothing.
3. When left red interval > assumed bus arriving time, early green
4. When left red interval <= assumed bus arriving time, do nothing

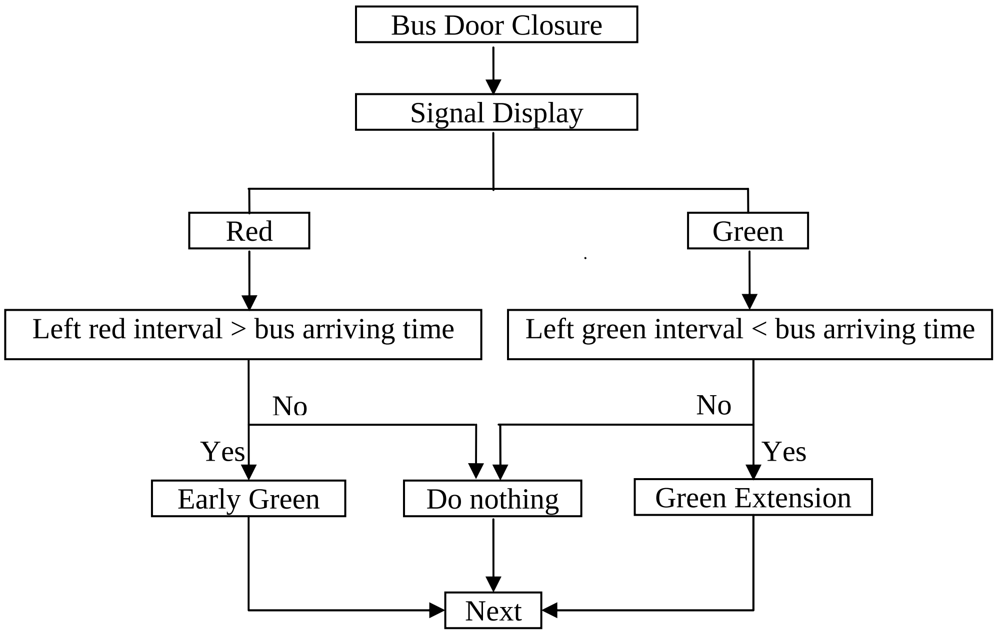


Figure 2 – Methodology of BSPS applying DOCI

2.2.1 Minimum green interval

Here the minimum green interval (sec), G_{min}, is firstly calculated by the method suggested in the Highway Capacity Manual (HCM, 2000), before checked whether it is sufficiently long enough for pedestrian crossing.

$$G_{\min} = 3.2 + \frac{L}{v_p} + \left(0.81\frac{n_p}{w_e}\right) \quad (1)$$

Where L is the width of the intersection (m), v_p is the average walking speed (m/s), w_e is the width of the crosswalk (m), and n_p is the number of pedestrians.

2.2.2 Green Extension

As described in Fig.2, when left green interval is less than the bus arriving time, green extension will be carried on if the extended green time will be less than the maximum green interval that can be calculated according to Equation (2).

$$G_{\max} = C - G_1 - \left\{ \sum_{i=2}^{n} G_{\min}, i + \sum_{i=1}^{n} (Y_i + A_i) \right\} \quad (2)$$

Where, G_{max} is the maximum green interval (sec), C is the cycle length (sec), G is green interval (sec), Y is yellow interval (sec), and A is the all red interval (sec).

The calculation result for our case study is shown in Fig.3.

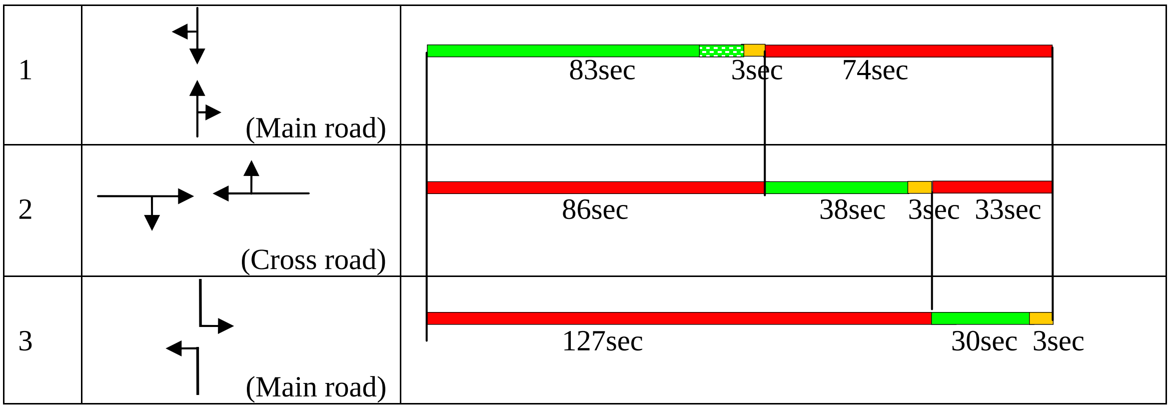


Figure 3 – Calculation Results for Green Extension

2.2.3 Early Green

When left red interval is larger than the assumed bus arriving time, early green will be carried on if the minimum green interval of the cross road can be guaranteed.

$$G_{early} = C - \left[(G_1 + I_1) + \left\{ \max(G_{\min,2}, t_2) + I_2 \right\} + (G_3 + I_3) \right] \quad (3)$$

The calculation results for the case study are shown in Fig.4.

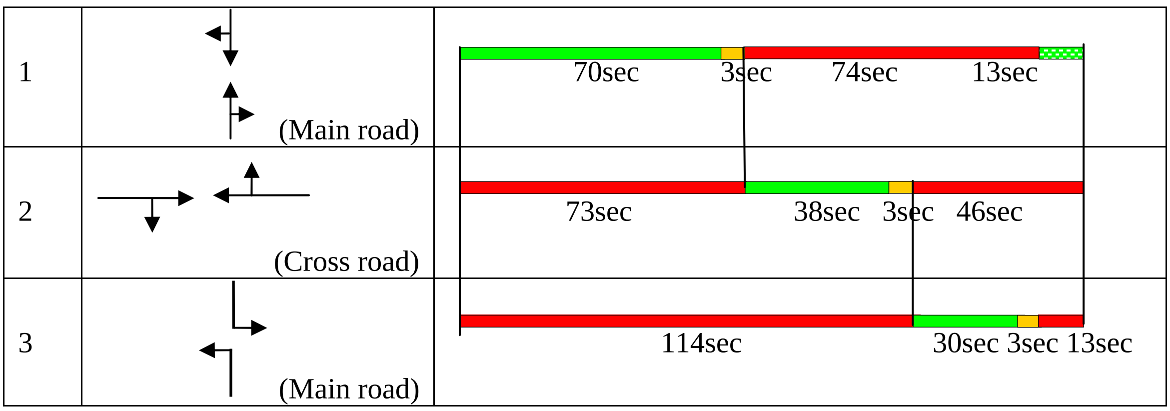


Figure 4 – Calculation Results for Early Green

3. PRACTICAL CASE STUDY BY TRAFFIC SIMULATION

Traffic simulation is an important and useful measure for evaluating BSPS methodologies (Muroi, T., et al., 2006). In this paper, through microscopic traffic simulation, a practical case study is carried on at a signalized intersection located in Seoul, South Korea.

3.1 Survey on the Case Study Intersection

Kyongbok APT intersection is chose as the case study intersection of the paper, as shown in Fig.5. The intersection is located in Gangnam-gu, Seoul, South Korea. On site video survey was carried on to collect the necessary information on traffic volumes, bus operations, and the signal settings on July 29, 2009. Buses running on the main roads only.

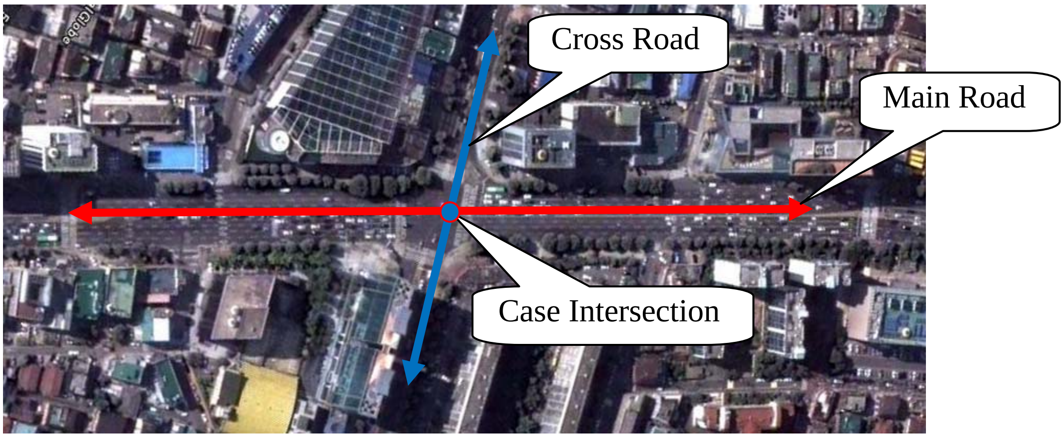


Figure 5 – Kyongbok APT intersection at Gangnam-gu, Seoul, South Korea

3.2 Microscopic Traffic Simulation

On the basis of the on-site field survey, traffic simulation research of 1-hour morning peak (8:00am – 9:00am) is carried on under the traffic simulation platform NETSIM that is developed by Federal Highway Administration (FHWA), the USA. Since NETSIM provides priority only from exclusive lanes, we design the original signal algorithm so that buses on all lanes can be included.

3.2.1 Scenarios of Traffic Simulation

Three different scenarios of signal control strategies are simulated, each with three different traffic demand patterns. The details of the scenario setting are shown in Table 1.

Scenario 1 is the ordinary signal setting that is used in the real world intersection. Scenario 2 is the proposed BSPS that applying the real time DOCI. Scenario 3 is the currently existing BSPS for the comparison purpose. Three case of traffic demands are used in the simulation analysis, the 1st is the measured traffic demand where the 2nd and the 3rd are increased traffic demands, +30% for the former and +60% for the latter. The reason is that almost no congestions were observed during the survey period, July 29, 2009.

Table I – Table legend (Use Caption Table style to insert the table legend)

Scenarios of signals	Cases	Traffic demand
Scenario 1: ordinary signal setting	1	Real demand
	2	+30% demand
	3	+60% demand
Scenario 2: Proposed BSPS setting	1	Real demand
	2	+30% demand
	3	+60% demand
Scenario 3: Existing BSPS setting	1	Real demand
	2	+30% demand
	3	+60% demand

Fig.6 shows the comparison of observed (Case 1 of Scenario 1) and simulated results (Case 1 of Scenario 2) for traffic volumes and bus travel times. Only slight difference can be found between the simulated results and the practical results. It proves that the simulation model can represent the real situation with satisfactory.

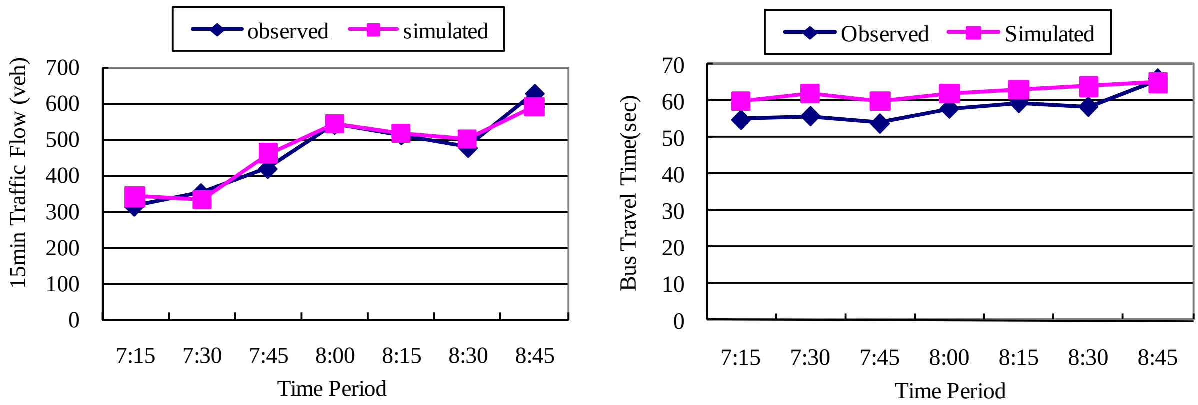
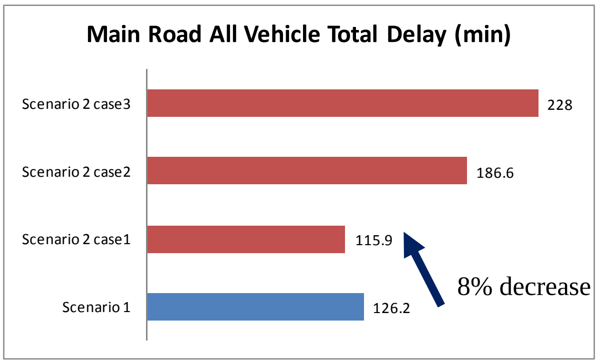


Figure 6 – Comparison of observed and simulated results

3.2.2 Evaluation of the proposed BSPS, the delay of all vehicles

As shown in Figure 7, under the proposed BSPS the all vehicle delay decreases on the main road by about 8% but increases by 7.6% on the cross road. An interesting fact is that the total delay, i.e. the sum of main and cross road delay, decreases by the proposed BSPS. A possible reason is that the cross road traffic is relatively low on the survey day.

In the targeted route at Seoul, congestion is not serious except the morning peak period, thus the proposed BSPS will be applicable to the morning peak period only. For this reason we assume full bus occupancy situation and utilize vehicle delay only for the evaluation of the proposed BSPS. And we also assume the RFID technology always works well.



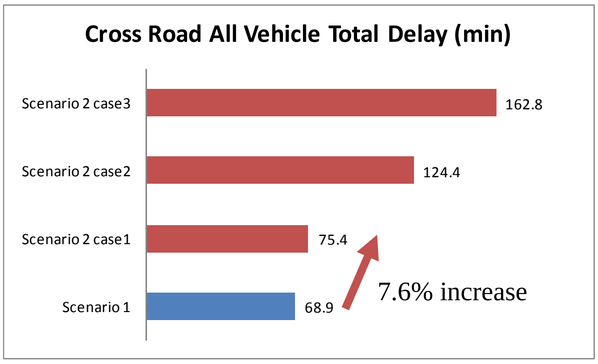


Figure 7 – All vehicle delay, the main road and the cross road

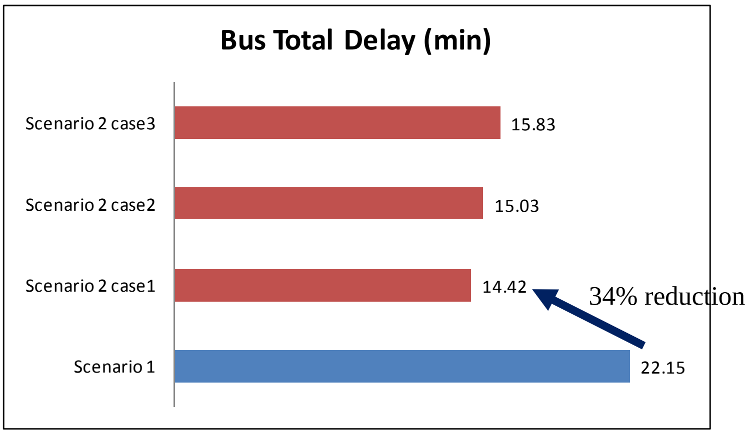


Figure 8 – Comparison of Scenario 1 and Scenario 2

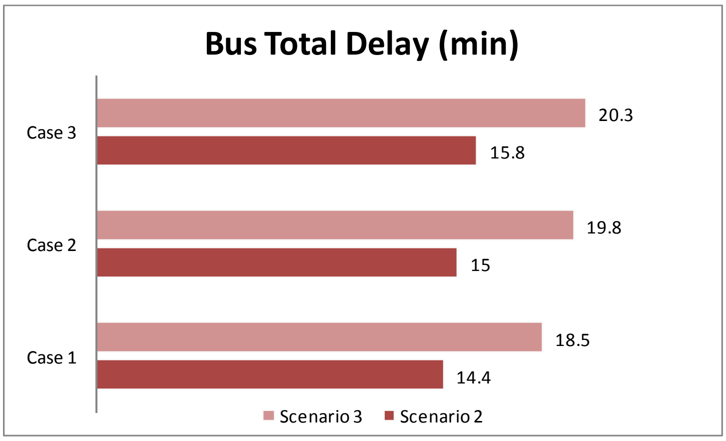


Figure 9 – Comparison of Scenario 2 and Scenario 3

3.2.3 Evaluation of the proposed BSPS, the delay of buses

The change of bus total delay is shown in Fig. 8. The total bus delay is reduced by 34% for the measured demand. Even for case 2 and 3, the bus delay is controlled to relative level without significant increase, despite the sharp increase of traffic demands. The proposed BSPS is proved to be a successful BSPS that is able to reduce bus travel time at various traffic situations.

3.2.4 Comparison with the existing BSPS (Scenario 3)

Comparison between the proposed BSPS (Scenario 2) and the existing BSPS (Scenario 3) is also carried on in this paper. By the application of DOCI, the proposed BSPS can avoid the influence of the uncertain bus dwell time on stops. Fig.9 shows and proves the better performance of the proposed BSPS under all cases of traffic demands.

CONCLUDING REMARKS

In this paper, a new practical Bus Signal Priority Strategy (BSPS) that applying bus Door Open and Closure Information (DOCI) is proposed. Different from the existing BSPS, this new BSPS can avoid the uncertainness of bus dwell time on bus stops. Therefore, bus arriving times are more correctly predicted and a more effective BSPS is achieved. Traffic simulation analysis demonstrates that the proposed BSPS can reduce 18% more bus total delay, if compared with the existing BSPS. This research proves the potential of applying DOCI in the design of BSPS on urban intersections.

In this paper, full occupancy is assumed for all passing buses. In future, a more elaborate scheme should be developed to minimize total passenger delay, rather than vehicle delay. Also the special issues of coordinated signals and area-wide should be more carefully tackled to further improve the proposed BSPS.

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