STUDY ON OPERATION AND PERFORMANCE OF BUS PRIORITY POLICY CONSIDERING INTENDED PLATOONING OF BUS ARRIVALS *

by Pradeep Kumar SHRESTHA** Fumihiko NAKAMURA*** Toshiyuki OKAMURA****

1. Introduction

The quality of bus service has been concerns for all policy makers, operators and users. Transportation experts are exploring different alternatives ranging from space priority such as exclusive bus lane to the application of advanced Intelligent Transport System (ITS) technologies such as bus signal priority, automated scheduling and dispatch systems etc[6–8] for improvement of bus service. The preferential treatment to buses has been increasingly considered in transportation system for improving bus movements and operational efficiency. Exclusive bus lane is one of the approaches that avoid traffic congestion and the conflict of buses with other traffic, there by increasing average speed and decreasing delay of buses. Thus, buses running in the exclusive bus lane are expected to be highly reliable in schedule. The installation of BRT exclusive lane can effectively bring benefits the operation efficiency of BRT and improve the passenger carrying capacity of the road up to 40% [5].

However, the deviation from bus schedule is still exists as buses has to stop at bus stop while picking up passengers and stop at traffic signals in red time which affect bus operational efficiency. In case of high demand bus routes, if bus is delayed for small amount of time, there is increased numbers of passenger at next stop. Thus, the number of passengers to be picked up at the next stop increases quickly from average passenger which causes further delays. Also, when passenger demand is higher, it takes longer time to board and alight passenger from the crowded bus than uncrowded buses. As a result, the bus continues falling further behind schedule. On the other hand, the following bus would have fewer passengers than average numbers of passenger to pick up and lower dwell times, allowing it to catch up with the preceding. Furthermore, when buses have to stop at traffic signal, there is a natural tendency of buses bunching up into platoon[4].

Most researches recommended the bus platooning is an undesirable because it tends to increase the variation in scheduled headways, demand and increase waiting times for passenger. Also, when two bus comes together, passenger might be in confusion that where bus will stop. It will some time create crowding and increase boarding time. Therefore, the most of researcher recommended that the potential control strategies should be focused on reducing bus platooning problem. Though, the natural tendency of the bus platooning is undesirable, the intended bus operation in platoon can maximize the capacity of the exclusive lanes, reduce dwell time at stop, and less disbenefit to other traffic. The capacity increment depends on how many buses are used for platoon. This will help to reduce peak hour overcrowding of passenger in the buses. One of the analyses in TCRP- RRD- 38[9] suggested that one of the reasons for the Bogotá busway is being able to move high passenger flows is due to the buses moving in platoons along the busway. Each platoon consists of 12 to 16 buses with average 96 sec headways. Buses on the high demand routes are articulated to increase the passenger carrying capacity. These buses not only require more than one loading area, they also have higher dwell times because of large crowd formation at their busiest boarding door [3]. In such situation also, bus operation in platoon will be helpful to accommodate high demand. The modern technologies and information system for passenger movement, fare payment, bus scheduling etc. can help further.

Thus, this paper tries to figure out the potential benefit of operating bus in platoon intentionally. The bus priority bus lane while operating with bus platoon can maximize capacity and reduce cost of operation. However, when bus comes at bus stop together, the boarding of passenger should be regulated and directed into proper channel to avoid confusion among passengers. The exclusive curb bus lane which extended through intersection has been considered along with the operation of platoon of buses for the study purpose. At present, operation of two and three buses in platoon were studied and compared with the normal bus operation. Two cases, one with average dwell time assumptions and other with high dwell time have been considered. In the first case, bus platoon was considered for the purpose of increasing headway between bus arrivals. Since bus dwell time in second case is large, the purpose of considering bus platoon is to distribute bus dwell time thereby sharing demand among bus platoon. It was observed that the capacity of the bus lane was increased with reduction in delay. In spite of potential benefits of operating buses in platoon, it is

* Keywords: Bus Priority, Bus lane, Bus Platooning, CORSIM

** Student Member of JSCE, M.Eng, Graduate School of Engineering, Yokohama National University
(79-5 Tokiwadai, Hodogaya-ku, Yokohama, 240-8501 Japan, Fax: +81-45-339-4031, email: d06sc194@ynu.ac.jp)
*** Member of JSCE, Dr. Eng., Graduate School of Engineering, Yokohama National University
(79-5 Tokiwadai, Hodogaya-ku, Yokohama, 240-8501 Japan, Fax: +81-45-339-4032, email: f-naka@ynu.ac.jp)
**** Member of JSCE, Dr. Eng., Graduate School of Engineering, Yokohama National University
(79-5 Tokiwadai, Hodogaya-ku, Yokohama, 240-8501 Japan, Fax: +81-45-339-4033, email: tokamura@ynu.ac.jp)

required to be managed and controlled properly so that it would not give negative impact. Also, for the further study bus operation in platoon can be considered with different bus signal priority[7]. As the number of priorities to be activated is lowered while considering buses in platoon, the increased delay impact to non-priority vehicles would be reduced.

2. Existing Problem

During peak hour buses on the high demand routes are demanded with heavy flow of passengers. The understanding of passenger demand, the passenger behavior at bus stop and control system through Intelligent Transportation System (ITS) can have potential to improve efficiency of the bus system. The priority treatment of bus by providing exclusive bus lane has been widely considered. Thus, buses running in the exclusive bus lane are expected to be highly reliable on schedule. It is to be noted that the inclusion of other bus priority method along with bus exclusive lane can provide the high capacity bus system. One of the approaches can be operation of buses in the platoon. But, most research describe platoon of buses as negative impact factor since it reduces the efficiency of the network. Well planned operation of platoon of buses and their potential benefit has rarely been focused. The platoon of bus movement will increase capacity of the system through less impact to other traffic than while running individually. Thus, this study aimed to study the bus priority policy with intentional formation of platoon of buses.

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3. Objectives of Study

The objectives of study are (1) to study on the impact of considering bus platoon on the capacity of the bus priority lane policy, and (2) to study the performance of the bus priority policy while considering bus platoon in terms of delay and speed.

4. Literature Review

For bus routes with frequent service (headways less than 10 minutes), most passengers tend to pay less attention to printed timetables and generally arrive at bus stops at random, expecting small waiting times there. Therefore, for bus routes with service headways less than 10 minutes, the ability for buses to maintain a constant headway is important. Otherwise, service reliability is likely to deteriorate quickly, and bus bunching (i.e., a bus catching up to a bus in front) is likely to occur. Chavala,T. *et al*[1] studied the compromised operation of one station has effects on the downstream stations as illustrated in Figure 1. Suppose a bus arrives ‘on time’ at station A and experiences peak hour passenger crowding at the station. The increased passenger crowd decreases the space available per passenger for walking, reducing their walking speed. In such cases the bus driver has to wait until all passengers reach the bus door and board. The bus needs to spend more time at the station and hence increases its dwell time and reduces the time gap allotted between the two bus arrivals causing a decrease in their headway. Further, when this bus reaches the next station (station B) and experiences the similar situation, the headway between the two bus arrivals reduces further. At some point in time this headway will be very small forcing buses to run one behind other forming ‘bus bunching’. This situation is not attractive from the point of view of passenger as it may create uncertainty (Figure 1).

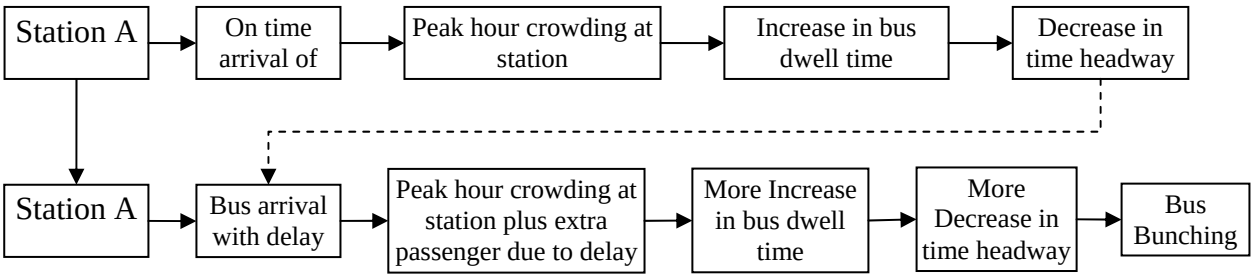

Figure 1 Peak hour crowding at station plus extra passenger due to delay

One of the factors that affect the bus capacity of an arterial street bus lane is whether or not buses move along the lane in platoons. TCRP- RRD- 38[9] report explained that if three buses could be processed each cycle, the capacity of the bus lane would be 195buses/hr, and average bus speeds would be approximately 13 mph (including dwell times). Also, the platooning of buses appears to create a higher efficiency in the bus berth use.

5. Bus Operation Modeling

Bus priority methods are a range of techniques designed to speed up buses and improve overall system efficiency. The curb bus lane and median bus lane are few of those techniques of bus priority in which physical improvements are necessary. Both curb bus lane has advantages and disadvantages. The benefit of curb side bus lane is the ease with passenger boarding and alighting activities where as such lane suffered with illegal parking, interfere with left turn

vehicles and thus their efficiency decreases. Median bus lane has advantage that it does not interfere with left turning vehicles and illegal parking activities where as such lanes are difficult to access for passenger. Passenger has to cross road to boarding buses there by risk of passenger safety against accident. Since this paper tries to examine the effects of considering bus platoon while operating on bus lane, only curb bus lane has been considered. The extended type curb bus lanes are considered along with other priority method which includes operation changes such as bus operation in intended platoon. The intended bus platoon operation is aimed to increase capacity of bus lane in the high demand corridors. The following sections explains about the assumptions made, scenario considered, model application and evaluations etc.

(1) Model Overview

Two cases are modeled as shown in Table 1. Demand is assumed to be constant for both cases for headway of 2 minutes. However, first case is for low demand with less dwell time and second case is assumed to be of high demand with high dwell time. First case (Case I) assumes that it would give system wide benefit by increased headway and impact to other traffic will be less while operating in larger headway. Thus, if we increase supply by increasing number of bus operating in platoon, it is possible to increase headway of buses. Suppose, the average heady way is 2 minutes and average dwell time is 20 sec. The demand at 4 minutes and 6 minutes headway will be twice demand for 2 minutes headway and supply should also be increased accordingly to accommodate demand. Thus, by operating 2 and 3 buses in platoon, the headway can be increase to 4 min and 6 min. operate.

In case of high passenger demand corridor, supply should also be higher by running bus at small head way to accommodate all demand. However, it is not desirable to run buses at very small headway. In such case of large volume of waiting passenger at bus stop, the crowding takes place and dwell time may be exceptionally large while processing all passengers in single bus. Thus, in second case (Case II), buses running in platoon will provide additional supply at same headway. Assumption is that total passengers will be shared between total numbers of buses in platoon there by reducing total dwell time. Suppose it takes about 60 sec per bus to process all passengers while operating single bus, then it may take only half of total dwell time if two buses are running in platoon provided that total passengers are assumed to be shared equally between two buses.

Table 1 Case for Analysis

	Average Dwell time per bus	Headway	Nos. of Bus in Platoon
CASE I	20	2 Min.	1
	20	4 Min.	2
	20	6 Min.	3
CASE II	60	2 Min.	1
	30	2 Min.	2
	20	2 Min.	3

(2) Model Application

For model application the real world case study is to be carried out to see the effect of the range of the alternative situation considered. However, a series of 2 intersections and road configuration with near side stop are developed as shown in Figure 2 and alternative cases were examined. This will allow evaluating the bus priority lane considering bus platoon for number of combinations of demand configurations. The maximum flow of intersections for main and side road are 930veh/hr and 640veh/hr, respectively. Total cycle time of main road is 130 sec. The green times are 90 sec and 44 second for Intersection 1 and 2 respectively. The extended type exclusive bus lane was considered for this study.

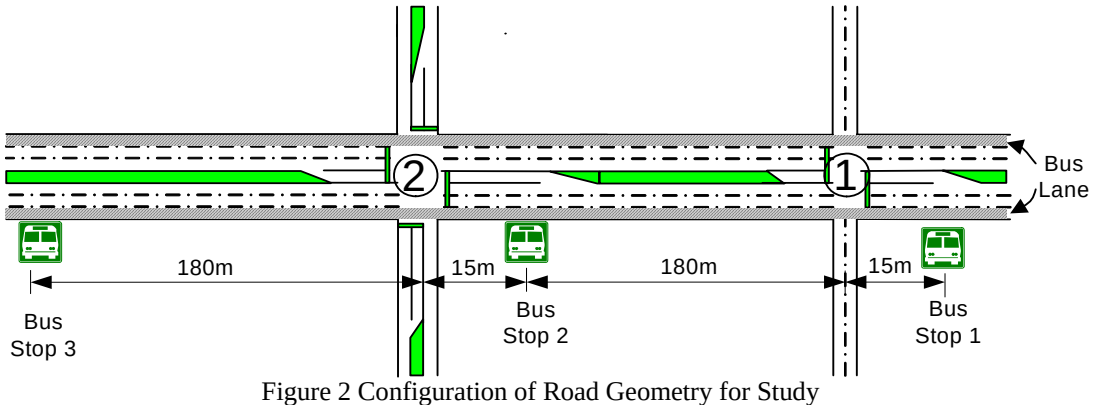

Figure 2 Configuration of Road Geometry for Study

(3) Model Evaluation

CORSIM[2)] micro-simulation package was used to model the scenario cases and study the road operations impacts of bus priority lane along with platoon arrival of buses. CORSIM simulation runs were performed for the road configuration shown in Figure 2 for given traffic volume, signal timings data, bus dwell time and bus berth capacities were assumed accordingly to model the situations considered. CORSIM[2)] passenger arrival can not be modeled. So the average dwell time was calculated for average number of passenger demand for bus stop and used in the simulation

model. Dwell time was assumed constant for this part of study. The bus platoon was created by using but route properties and bus station modeling in simulation package.

6. Results and discussion

The result for Case I (Table 2) shows that the there is very small amount of difference for performance indicators such as delay and speed while considering bus platoon with increased headway. The number of buses served remained same as demand and supply is constant. This means bus platoon can be used to increase headway. Such method would be useful if bus signal priority is considered as numbers of priority to be activated will decrease.

With exceptionally large dwell time due to large volume of passenger, it is possible to increase capacity of bus stop by operating buses in platoon. Since total passenger is assumed to be divided between numbers of buses in the platoon, the total dwell time will be reduced. The result of analysis for this case in Table 3 shows that 32% and 38% delay reduction has been observed for the case of bus operation with 2 buses and 3 buses in platoon. Similarly, 34% and 48% increase in average speed were observed for 2 buses and 3 buses in platoon, respectively, while comparing with base case. The numbers of buses served were also increased. Which means the capacity of bus lane could be reduce by bus operation in platoon.

Table 2 Result of Analysis for Case I

Platoon	% Increase in Delay	% Increase in Bus Speed	Nos. of Buses Serviced
Base	0	0	30
2	-0.001	-0.001	30
3	0.62	-0.003	30

Table 3 Result of Analysis for Case II

Platoon	% Increase in Delay	% Increase in Bus Speed	Nos. of Buses Serviced
Base	0	0	30
2	-32.1	33.9	60
3	-38.7	48.1	89

7. Conclusion

In this study two cases, of which bus operation in platoon was considered in Case I for increasing headway between bus arrivals where as increase capacity of bus stop there by decreasing bus dwell time for Case II. From the results of Case I revealed that there in small amount of the differences in performance indicators such as delay and speed for considering bus platoon when compared with base case. Thus, it can be concluded that bus operation in platoon has potential for increasing capacity and decreasing delays. Also, it was observed that the capacity of the bus lane was increased with reduction in delay and increase in speed. While considering it with other priority methods such as bus signal priority, it could help to reduce disbenefits in the system. Additional research and experimentation are needed to show how bus operation in platoon can affect bus signal priority.

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