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A TYPOLOGICAL ANALYSIS ON THE STRATEGIES OF BUS PRIORITY LANES ON CITY STREETS: A RECOMMENDATION FOR BANGLADESH

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ABSTRACT

Recently public transport is not regarded as well reputed in consequence of poor service quality, traffic congestion, and impoverished vehicle condition. On the other hand, traffic congestion has turned into one of the significant problems in Dhaka, capital city of Bangladesh because of the increased number of private vehicles. “Bus priority lane” is a term which is an association of different approaches to enhance service and minimize delay for public transport. It could be introduced in a roadway in order to develope the transportation system as well as to reinforce the acceptance of public transport. Bus priority lane concepts began to become eminent in 20th century in Europe (UK and Paris). Traffic signal priority (TSP) is a technique to modernize the bus priority lanes to increase its effectiveness. The objective of this research is to carry out a typological analysis on the bus priority lane techniques which are being used in the various cities around the world, as well as to recommend the suitable and effective strategis for our country. In this study, a typological analysis was carried out on different types of bus priority lane system based on priority and alignment. In addition, a comprehensive review analysis of different cities’ case study was also accomplished in order to have the better understanding about the various types of bus priority lane treatment available in those cities. Based on the scope of this study, this paper has concluded that before applying any of these bus priority lane techniques in Bangladesh, two points need to be confirmed beforehand: enough road width should be ensured to implement a bus priority lane, and the traffic volume should be within the roadway capacity.

Keywords: *Bus Priority Lane, Traffic Management, Public Transport, Congestion and Traffic Signal.*

1. INTRODUCTION

Dhaka is one of the major cities of South Asia with an area of 1383 square kilometres (BBS Report, 2008). It has a population of 8,906,039 and the population density is 29,392 per square kilometre (BBS Report, 2012b) in the city area. Everyday this vast population deals with many problems and the most common problem they have to face is the traffic congestion. Nevertheless, Dhaka is one of the least motorized cities in the world with a figure of only 2630 vehicles per 100,000 people. Among them 2195 are non-motorized vehicles (Islam & Hossain, 2001). As Dhaka is the capital of Bangladesh, it is containing the maximum facilities than the other cities of this country. Thus people are willing to come in this city for a better life and their livelihood. For this situation it becomes a huge problem to meet the basic needs of people. In this present time congestion becomes higher day by day because of the increase of private vehicles in the city streets. Eventually, people are losing their interest on public transport. Comparing with the population it can be said that the numbers of public transports are very few and the existing public transports are unable to provide people with enough comfort, rather consume their travelling time. It occurs due to poor traffic management and scarcity of adequate public transports. Nowadays, middle class people are also using private vehicle for consuming their valuable time and comfort as well. Consequently, it makes the congestion more, whereas, a bus carries twenty times as many passengers as a car, while it only adds three times to congestion (Bayen et al., 2015). However, it becomes a significant issue to promote people interested so that they would prefer public transport more than private vehicle.

Any arrangement which provides buses privileged treatment upon other traffic is termed as bus priority. Main aim motivating the application of bus priority lanes being to improve bus attraction and increase its attractiveness compared to other modes. The widespread bus preferential treatments are establishment of preserved bus lanes, exclusive median bus way, queue jump lanes, bus individual street, with flow interior bus lane, and exclusive bus lanes on main urban streets in order to ease quicker running of buses to render the mode more enviable (Vedagiri and Jain, 2012). Recently bus priority lanes are exercised wide-reaching in cities like London, UK; Paris, France; Sydney, Australia; Shizuoka, Japan, and Texas, USA.

Though several researches have been accomplished by many researchers in many countries across the world, but these studies were performed based on the situation of those respective countries. This research work was an attempt to carry out a comprehensive review analysis of different cities' case study as well as to conduct a survey in a metropolitan city street of Dhaka. A typological analysis on the different bus priority lane systems which are being used in different countries was also conducted to have a better insight about the bus priority lane treatment and thus the practicing transportation engineers can address the unexpected traffic problems and contribute to the sustainable development in our country. Even though, the authors have figured out some effective features of bus priority lane as a countermeasure for traffic congestion in our country, they also experienced some unusual features while carrying out the study as this research was only based on review analysis of different cities' case study. Consequently, it is imperative to carry out furthermore analysis in this regard.

2. LITERATURE REVIEW

The overall methodology of the study has been organized in three ways. In the first section, a preliminary follow-up case study analysis of several distinct significant cities including Sydney, London and Paris has been worked out. These cities have been chosen only because of having well-established bus priority lane networks running through congested, mixed-use urban districts as well as inter-cities. Thereafter, a typological analysis on the strategies of bus priority lane system has carried out, and finally types of bus priority lane which are suitable for Bangladesh have been proposed.

2.1 Review Analysis of Different Cities' Case Study

2.1.1 Review Analysis of Sydney Case Study

Bus lanes are the well-known strategies noticed in Sydney, Australia. Those lanes give priority for buses during particular periods. These lanes are in effect even during the hours, and they only permit constrained use by specific type of vehicles, for instance taxis or vehicles taking turn. Bus lanes only turn up in small portions of the city (i.e. at key intersections queue-jump lanes are observed). In the United States transit lanes are as analogous to high occupancy vehicle lanes. After meeting specified occupancy, a vehicle is eligible to make use of the lane. This kind of lanes are usually located beyond the Central Business District on the area’s premeditated bus passageways, and able to offer a fewer constricting ways for easing bus service compared to other options. The section has some transit way or “T-way” strips that give bus with fast transit facilities. These lanes are more restraining compared to usual bus lanes and prohibit private vehicles to use those lanes. Those lanes comprise both selected lanes on street or highway amenities, or dedicated bus routes which do not flow together with diverse traffic. Nonetheless, this case study was mainly involved with bus lanes on Sydney Inner Region city streets. Bus priority lanes functioned on local streets is termed as bus lanes in this case study (Viegas & Lu, 2001).

Table 1: Metropolitan Profile of Sydney. (Sakamoto et al., 2007)

City population	1.5 million	Sydney Inner Region
Metropolitan population	4.6 million	Sydney Statistical Division
Annual unlinked urban transit trips	326.3 million	
Heavy/commuter rail (City Rail)	111.9 million	34% of urban transit trips
Light rail, monorail	8.0 million	2% of urban transit trips
Bus (Sydney Buses only)	191.9 million	59% of urban transit trips
Ferry	14.5 million	4% of urban transit trips
Ratios calculated from data above		
a) Urban transit trips per city resident	a) 225 annual trips per capita	
b) Urban bus trips per city resident	b) 132 annual trips per capita	
c) Urban transit trips per metro resident	c) 71 annual trips per capita	
d) Urban bus trips per metro resident	d) 42 annual trips per capita	

2.1.2 Review Analysis of London Case Study

London has established one of the best far reaching frameworks of effectively oversaw transport need paths across the world. Though its bus route-network has been existed over period of 40 years, London has significantly promoted and reinforced it during the past ten years, as part of a comprehensive redesign of its surface transport system. London's way to deal with the assignment and requirement of transport paths accentuates focal authority over a system of key arterials, yet nearby power over transport paths off this system.

In spite of London’s varied public transport facilities which incorporates underpasses, commuter train, light rail etc., buses persist its utmost extensively employed travel pattern. Approximately 8,000 buses run alongside 700 bus lanes. This overall treatment fulfilled more than 2.2 billion commuter trips in 2010 (Table 2). Public transport use has enhanced since the city has undertaken a number of attempts to move private car users by implementation of cordon pricing scheme for motor vehicles incoming the city center. Passenger trip routes by bus have climbed about 62% between 1998 and 2008, while the population of London has risen by only 7.8% over the same decade (Sakamoto et al., 2007).

Table 2: Metropolitan Profile of London.

City population **Metropolitan population**	7.8 million 11.9 million	Greater London London Larger Urban Zone
Annual unlinked urban transit trips Heavy rail Light rail (Docklands & Tram ink) Bus Ferry	3,944 million 1545 million 106.2 million 2289 million 4.1 million	 39% of urban transit trips 3% of urban transit trips 58% of urban transit trips 0% of urban transit trips
Ratios calculated from data above Urban transit trips per city resident Urban bus trips per city resident Urban transit trips per metro resident Urban bus trips per metro resident	 504 annual trips per capita 293 annual trips per capita 331 annual trips per capita 192 annual trips per capita	 504 annual trips per capita 293 annual trips per capita 331 annual trips per capita 192 annual trips per capita

2.1.3 Review Analysis of Paris Case Study

The city of Paris has established one of the most inclusive networks of bus lanes. Presently, development of new bus lanes is considered as a fragment of an extensive local agenda for improving bus service, which is known as "Mobilien" (Bayen et al. 2015). The City, Paris has a 190 km of bus lanes network as per 2008. Around 102 km of this total route are simultaneous movement for bus lanes entitled only by means of signs and markings, while 18 km are contra flow lanes and 69 km are secured lanes isolated from other lanes through obstacles varying from small curbs to wide-ranging planted medians. Significant characteristics of the existing Paris bus lane project have incorporated the allocation of a small curb barrier to insulate the bus lanes from conventional traffic lanes, along with the city's strategy to permit taxis and bicycles to share the lane with buses.

2.1.4 Corresponding Study for Bangladesh

As per authors concern any significant study was not done before on Bus Priority Lane in Bangladesh. Though some preliminary researches (Hoque, 1991 & Ahsan, 1991) had been done in Bangladesh for the issue of reducing congestion in the metro city Dhaka, those researches have only showed different aspects from different point of view. In this study, however, we made an attempt to conduct a survey along the route from Shahbag to Farmgate (around 5 km) in order to get understand the existing situation preciously, and also whether the feasibility of bus priority lane is applicable in this roadway or not.

3. TYPOLOGICAL ANALYSIS

There are several methods to give priority to the buses on a roadway. Besides accommodating the safe and efficient operation of buses, they are at variance in maintaining of traffic flow, the necessity for curbside access, the pedestrian- safety, cyclists and so on. Often specific conditions are provided when buses are given priority in a lane to fit the situation as well.

According to priority, there are four types of bus priority lane (Eichler and Daganzo, 2006), such as:

- Type A: Dedicated (or exclusive) bus priority lane (DBL)
- Type B: Intermittent bus priority lane (IBL)
- Type C: Bus lane with intermittent priority (BLIP)
- Type D: Multiple combinations of bus lane.

Type A which is "Dedicated bus priority lane" provides maximum bus frequency, Type B is "Intermittent bus priority lane" which operation system is relatively easier, where Type C (Bus lane with intermittent priority) is suitable for high traffic volume and the Type D is “multiple combinations of bus lane” which has comparatively little adverse effects on overall traffic for continuous traffic lane. According to alignment, bus priority lanes are of three different types (Eichler and Daganzo, 2006): Type A is “Curb-side alignment” which is at the side of the curb, Type B is “Offset bus lane” which is parted from the curb by a single lane and Type C is “Median bus lane” that is near the median of the roadway.

3.1.1 Dedicated (or Exclusive) Bus Priority Lane (DBL)

It’s a type of bus lane to be used by bus exclusively. No other types of vehicle are allowed in the same lane. When DBL is applied, it is expected that both bus and other modes of vehicles’ speed will significantly increase as they will not further conflict with each other. Alternatively, as it takes up a lane completely for this purpose, it results in reducing vehicle capacity in the street. However, for controlling or reducing congestion, dedicated bus lane is proved to be a better policy rather than transit subsidization or congestion pricing.

By providing DBL, a major change in bus frequency (about 70%) is noticed. Moreover, in order to decrease total travel time, some buses should leave off at only main stopages and avoid certain less -essential ones. Furthermore, less bus stops might be constructed to enhance bus manoeuvres if the situation considers (Zhang, 2015). Eventually, DBL brings considerable changes in service levels,

though something subjected to mixed traffic conditions do not happen. These conditions may lead to higher demand of public bus transport under mixed traffic conditions (Leonardo & Basso, 2010).

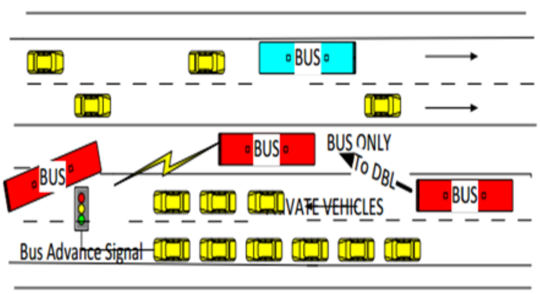


Figure 1: Single Dedicated Bus Lane (Type A) Scenario in the Middle of the Road only

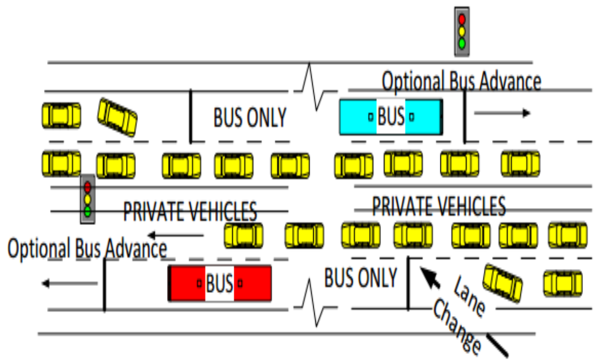


Figure 2: Two Dedicated Bus Lanes (Type B): one bus at each side of the Road

However, when a Dedicated or Exclusive bus priority lane is introduced, buses are still subject to traffic signal regulations, which are often governed by the overall traffic conditions, including buses and other private vehicles as well (Wang & Misook, 2013). DBL can be combined with traffic signal priority (TSP) to make the system more effective. Nevertheless, it has some drawbacks like dealing with pedestrian interference. In addition, an exclusive lane can be followed by a special lane of about 150m before intersection to facilitate left turning vehicles. Exclusive bus lanes implemented in the city of Dallas, Texas, USA was studied by (Cox, 1975) and he established that the additional special lane does not affect other vehicular traffic but helps increasing in speed of buses as well as reduces traffic time. Exclusive lanes are sometimes called with flow lanes and also accommodating bicycles and other emergency vehicles, such as ambulence, fire-services or even high occupancy vehicles can be allowed in it (National Capital Region Transportation Planning Board, 2011).

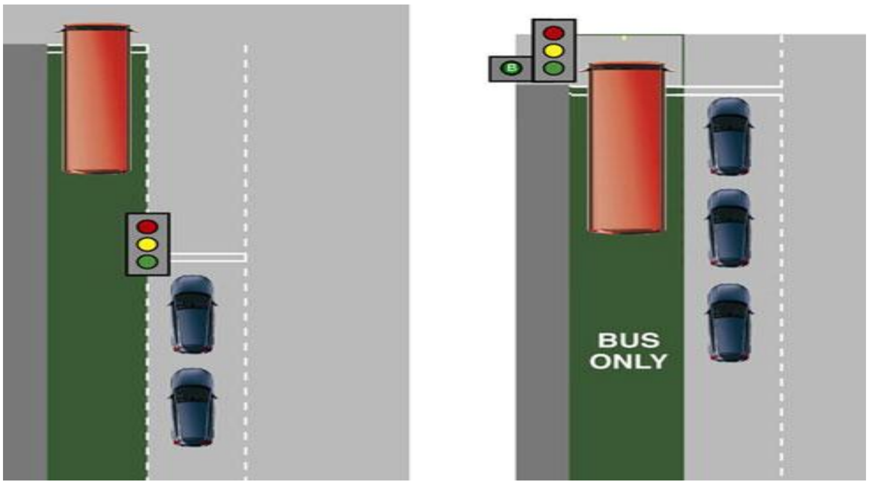


Figure 3: Exclusive bus lane (Type A) followed by special lane for left turning bus.

3.1.2 Intermittent Bus Priority Lane (IBL)

In this system, when a bus lane is not used by bus, it allows private vehicle to use the lane. It also never requests traffic to leave the lane to accommodate the bus. (Vegas, 2001 and 2004) first suggested the theory of IBL. Although, IBL restricts traffic from coming into the bus lane when it is occupied by bus, it does not interrupt in traffic as dedicated lane. Sometimes, traffic signal priority (TSP) is used in intermittent lane. Hence, IBL is much more efficient than dedicated bus lane. Structure of Intermittent Bus Lanes has been shown in Figure 4 below.

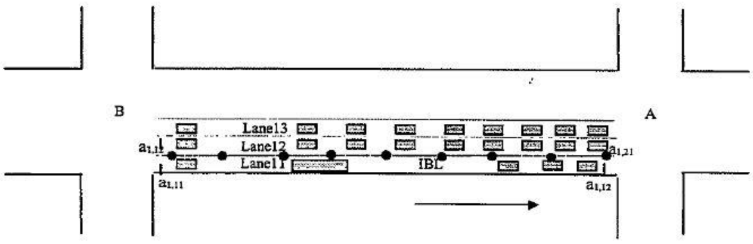


Figure 4: Structure of Intermittent Bus Priority Lane (Type B). (Eichler and Daganzo, 2006)

3.1.3 Bus Lane with Intermittent Priority (Eichler and Daganzo, 2006)

It is similar to the system of IBL except some specifics. It clears traffic out at the time when the lane to be used by bus, meaning when a bus approaches. However, it does not depend on TSP or any other kind of traffic signal. For that purpose, variable message sign (VMS) or dynamic signage is used to communicate with the users of BLIP. The evaluation and analysis to be made for establishing the system is comparatively less complex. Nevertheless, TSP is included in the system when it is highly required. BLIP can also be combined with in-pavement lights. For the reason that the lane needs to be cleared for approaching buses, it would be difficult to clear it many times a day. These types of lanes only benefits when traffic intensity is low and buses maintain a regular routine.

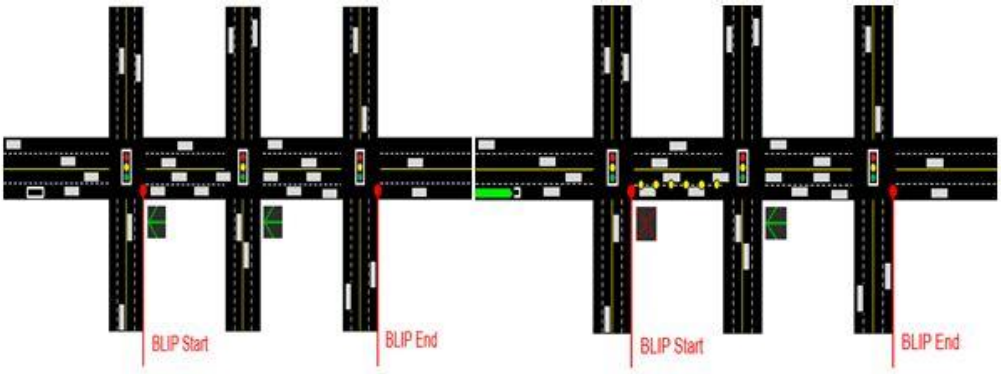
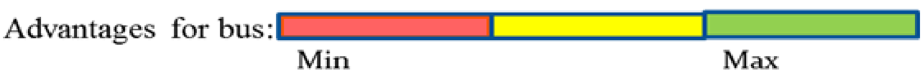


Figure 5: (a) Step 1: All Lanes Open; (b) Step 2: Bus Approaching & signals change.

Figure 6: (a) Step 3: General traffic leaving BLIP lane; (b) Step 4: Bus enters cleared BLIP lane (Eichler and Daganzo, 2006).

Table 3: Characteristics of (Type A, B, & C). (Eichler and Daganzo, 2006).

Type	**Lane**	**Priority Type**	**% of Reduced speed delay/Bus frequency**	**Advantages over other types**	**Drawbacks**
Type A	Dedicated Bus Lane (DBL)	Maximum no of Bus (no other traffic)	70% Bus frequency	Maximum bus frequency	• Interrupts traffic • Pedestrian interference
Type B	Intermittent Bus Lane (IBL)	Private vehicles allowed	Average 20-25%	Operation is easy	• Cannot force existing vehicles to move away
Type C	Bus Lane with Intermittent Priority (BLIP)	Private vehicles allowed (for a limited time)	5% reduced speed delay	High	• Disrupts traffic • Not recommended for low traffic



3.1.4 Multiple Combinations of Bus Lane

(Truong, et al., 2015) first attempted to understand the combined effect of multiple types of bus lanes through micro-simulation. Also, for observation, they considered that the bus lanes could be either continuous or discontinuous. And they figured out that series of continuous lanes have low negative impacts on general traffic rather than the identical number of intermittent bus lanes. They suggested that multiplier effects such as bus travel time advantages and ordinary traffic travel time demerits definitely exists for combined bus lanes. They also established that when upstream traffic volume outstrips the capacity of existing traffic lanes, it should never be recommended to turn the lanes into bus priority lanes as it promotes negative impacts significantly.

Moreover, according to alignment, there are four types of lane (Eichler and Daganzo, 2006), as mentioned below:

- Type A: Curb-Side Alignment.
- Type B: Offset (or interior) Bus Lane.
- Type C: Median Bus Lane.
- Type D: Far curb Lane.

3.1.4.1 Curb-Side Alignment

When a bus priority lane is established alongside the curb, it does not reduce the vehicle capacity of the street, rather it can be allocated for parking or dispatching in off peak hours. This type of lane can also be used by general traffic if it permits. But there are some drawbacks of this sort of lanes as well. For example, during the time it being used as a bus priority lane, the curbside cannot be used for delivering goods, passenger pick up, drop off or parking (Agrawal & Goldman, 2012). These bus lanes are sometimes called “Queue Jump Lanes” (QJL) as they make the buses ‘jump’ the queue of the traffic and do not make them wait on signals for a long time. Queue jump needs signal controlling to provide a phase specifically for the vehicles in it. This type of bus lane has significant effect that usually brings in 38 percent mean travel time reduction 103 to 44 seconds (Vedagiri & Jain, 2012).

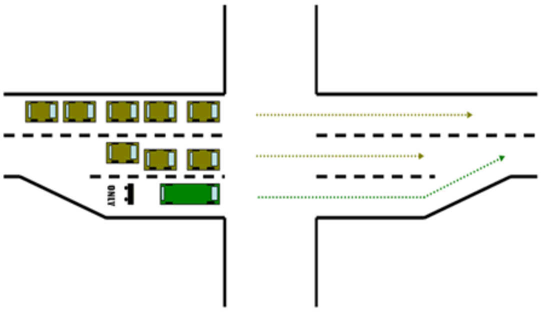


Figure 7: Queue Jump Lanes. (Bayen, et al., 2015)

3.1.4.2 Offset (or Interior) Bus Lane

Offset lane can be used as an alternative for curb-side lane. In this case, the lane is only detachted from the curb by a travel or parking lane. If not, it can be made large enough to share it with bus stops, parking spaces and other uses of the curb. These lanes are also known as “self-enforcing” for being separated from the curb and not being interrupted by the stopped vehicles.

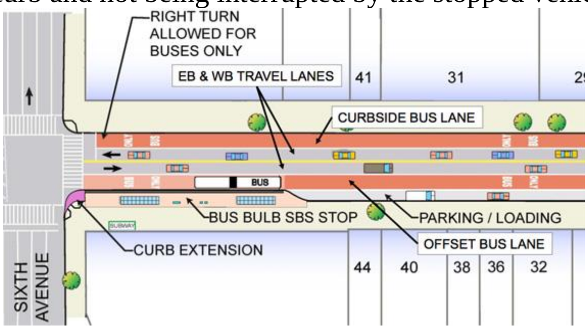


Figure 8: Offset or interior bus lane (Type B). (Bayen et al., 2015)

3.1.4.3 Median Bus Lane

Median bus lanes are provided along the median lanes in a two-way traffic. They are even further separated from the curbside and effective in long, large corridors that serve many bus routes. However, passenger platforms or loading areas will be needed in the middle of the road so that it will abate the vehicle capacity in the street and also might induce the safety issues.

3.1.4.4 Far Curb Lane (Agrawal & Goldman, 2012)

Far curb lanes have two options bus lane i.e. either concurrent with the flow or the opposite direction of traffic.

Table 4: Bus lanes according to alignment (Agrawal & Goldman, 2012)

Type	Lane	Position	Advantages	Drawbacks
Type A	Curbside Alignment	Alongside the curb	• Vehicle capacity remains same. • 38% mean travel time reduction.	• Curb cannot be used for other purposes.
Type B	Offset Bus Lane	Separated from curb by a single lane	• Curb can be used for other purposes.	No significant Drawbacks.
Type C	Median Bus lane	Along the Median	• Effective in Long, wide corridors.	• Require passenger platforms or loading areas. • Reduces vehicle capacity. • Safety Issues.

3.2 Review Analysis of Software Simulation (Tran et al., 2013)

Using “PARAMICS” simulation tool Tran et al., (2013) established a simulation-based analysis for the lane operation of bus and bus-signal priority also in city streets. PARAMICS can simulate exclusive bus lane and ordinary lane without any API (Application Programming Interface) development, but for bus priority lanes it is necessary to supersede the default core in PARAMICS by developing specific API for it. For the accuracy of the data simulated, some simple assumptions were also considered for lane changing behavior (Bayen et al, 2015).

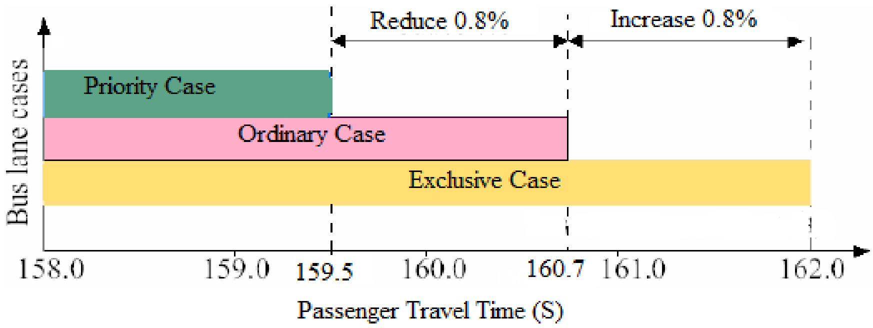


Figure 9: Comparison of passenger travel time (s). (Tran et al., 2013)

Comparative analysis of this research, however, made it evident that the bus priority lanes have had better contribution in minimizing passenger travel time in comparison between the bus priority lane and the regular lane. Accordingly, the bus priority lane system is capable to decrease travel time by 1.2 sec. (or 0.8%) per passenger compared to that in the current ordinary lane case (Figure 1), whereas, the exclusive bus lane treatment made the passenger travel time increase by 1.3 sec. (equivalent to 0.8%). Even though the exclusive bus lane can increase the bus travel time significantly, it has also the significant adverse impacts on non-bus operation in this case. Therefore, bus priority lane is the better strategy, which might enhance bus performance and decrease adverse effects on other vehicles (others than bus) concurrently.

4. DISCUSSION & RECOMMENDATION

Nowadays, it is a common scenario in our country that the metropolitan city streets are becoming less efficient with their high intensity of heterogeneous traffic. Besides, ordinary bus lane or bus priority lane is not yet a common policy to use against the congestion. In this study, on the scope of our survey (from Shahbag to Farmgate: around 5 km), it has been found that the ordinary bus lane in spite of having adequate width is not capable enough to minimize the traffic congestion. Moreover, due to the ample quantity of private vehicle, the ordinary bus lane is completely blanketed with them. Consequently, to order to reduce the pressure on the roads, increasing the demand of public transportation like bus is one of the crying needs on the city streets nowadays. However, based on the scope of the study and above discussion, the followings could be put forwarded to some extent. Among the discussed types in this study, almost each type of the bus priority lanes is applicable in the country, yet it is indispensible to analyze some more factors beforehand with a view to bring out the maximum benefit. In general, the dedicated lanes might not be the best option to consider for its significant drawbacks: it takes up a whole lane for its sole purpose and interferes with other traffic the most as well as pedestrians. The advantages that intermittent bus lane (IBL) has, makes it a better choice than DBL. BLIP also might not be a good preference all the time. Moreover, the Median bus lanes mostly require bus bulb with bus stoppage and other facilities in the middle of the road. Therefore, careful consideration is needed about the road width before choosing this type. Curbside alignment or off set lane can be a better option considering they allow the curb to be used for other purposes. Even though bus priority lane is not applicable in the roads, where traffic intensity is greater than the road capacity, nonetheless, if bus priority is given to some certain routes, it is possible that it will affect the alternate modes. Thus, the intensity of mixed heterogeneous traffic will decrease. For a bus priority lane, to be applied, the road width should be at least same as that there could be at least three lanes in each direction on the road, whilst it is not always necessary to take up a lane only to give priority to buses. Instead, it can be used by general traffic when not required by buses. Accordingly, a bus priority system should only be established in the priority lane. Moreover, it is very important to know the bus schedule or intensity at different times or days of a week. In addition, in order to maintain the bus priority lane system effectively, the TSP, VMS or other systems might be engaged as well. Moreover, traffic signal priority is highly recommended as it is inexpensive and has a great significant. To recapitulate, the bus priority lane system should be applied in a way so as to fulfill the objective of reducing congestion in an economical way and effectively as well, and thus by to promote public transport instead of private vehicle.

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