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SAFETY OF PASSENGERS AT CURBSIDE BUS STOPS IN A DEVELOPING COUNTRY

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ABSTRACT

In this study, the improper stopping of buses near curbside bus stops was analyzed by collecting traffic data from two urban arterial sections in New Delhi, India. Several reasons for improper stopping, such as passengers stepping out from a bus stop platform onto the road prior to the arrival of a bus, standing vehicles, the presence of an already stopped bus and erratic driver behavior, were identified. Improper stopping resulted in vehicles queuing behind stopped buses and vehicles overtaking buses between the bus stop and the stopped bus. Such vehicles pose serious safety concerns to the boarding and alighting passengers. Multiple linear regression was carried out and various reasons were found to affect the number of overtaking vehicles. The results from this study will be useful to policy makers and practitioners, especially from developing countries, as it will allow them to consider the effects of improper stopping on bus stop design, and thus improve the safety of passengers.

Keywords: curbside bus stops, improper stopping, safety, passengers

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In this study, the improper stopping of buses near curbside bus stops was analyzed by collecting traffic data from two urban arterial sections in New Delhi, India. Several reasons for improper stopping, such as passengers stepping out from a bus stop platform onto the road prior to the arrival of a bus, standing vehicles, the presence of an already stopped bus and erratic driver behavior, were identified. Improper stopping resulted in vehicles queuing behind stopped buses and vehicles overtaking buses between the bus stop and the stopped bus. Such vehicles pose serious safety concerns to the boarding and alighting passengers. Multiple linear regression was carried out and various reasons were found to affect the number of overtaking vehicles. The results from this study will be useful to policy makers and practitioners, especially from developing countries, as it will allow them to consider the effects of improper stopping on bus stop design, and thus improve the safety of passengers.

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1. INTRODUCTION

Two types of bus stops, namely curbside stops and bus bays, are predominant in most cities across the world. At bus bays, buses pull out of the traffic flow to pick up and drop off passengers. They do not block the traffic flow when the bus is stopped, but might need more space for construction (Government of Ontario 2013). On the other hand, curbside bus stops are constructed near urban roads where sufficient land is not available for the construction of bus bays. They are easy to design, provide easy access to bus drivers and minimize delays to the bus to re-enter the traffic stream. Nevertheless, they reduce the available road width for through traffic, creating a temporary bottleneck, and force vehicles to queue behind or make unsafe maneuvers (Transit Cooperative Research Program 1996).

Due to space constraints, most midblock bus stops on urban roads in developing countries are curbside. Various reasons such as overcrowding, standing/parked vehicles, insufficient bus handling capacity of bus stops and erratic driver behavior as shown in Figure 1 force bus drivers to stop buses away from the designated locations. These typical bus stop conditions in developing countries are analyzed in few recent studies (Bian et al. 2015, Chand and Chandra 2015). The improper stopping of buses forces some vehicles to queue behind the bus, and some vehicles, especially auto rickshaws and motorcycles, to overtake the bus through the gap between the bus stop and the stopped bus as shown in Figure 2. Although these vehicles reduce their speed significantly while overtaking through the gap, they still pose serious safety concerns to motorists and passengers. The behavior of such vehicles needs to be studied to better understand real life situations, which will eventually help to improve the safety performance of infrastructure design. In this paper, we identify the reasons forcing bus drivers to stop improperly and then analyze the after effects of these improper stopping scenarios.

The remainder of the paper is organized in the following manner. Firstly, the few studies done to date to assess the safety issues involving buses will be discussed. The data collection process and the analysis of the data will be shown subsequently. Finally, the paper will conclude with a brief discussion on the results and future recommendations.

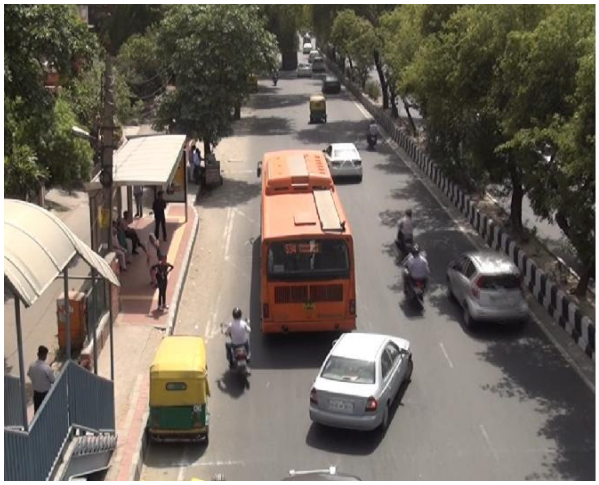
(a) Crowding
(passengers waiting on the roadway)

(b) Standing vehicles near the bus stop
(for picking-up or dropping-off the passengers)

(c) Presence of an already stopped bus

(d) Erratic bus driver behavior
(when there is no other obvious reason)

Figure 1. Reasons for the improper stopping of buses



(a) Forced lane changes

(b) Accident at the bus stop

Figure 2. Unsafe maneuvers at bus stop

2. BACKGROUND

Cities in developing countries are characterized by rapid urbanization, increasing vehicle ownership, traffic growth and, subsequently, congestion and loose enforcement of traffic rules. People in these countries depend mainly on public transport for accessibility and therefore safe, efficient and effective public transport services are essential. Surprisingly, the regulation of public transport in these countries is gradually decreasing, which is concerning (Pearce and Maunder 2000).

Generally, public transport is considered as a way to promote road safety. However, in India, the situation is different with the involvement of buses in 10% of total road crashes in the year 2009 (Ponnaluri 2012). Based on interviews of transit users in Maharashtra, India, it was observed that the prime causes for accidents involving buses are driver behavior, vehicle and road conditions. Driver error was found to be the main reason for 50% of such accidents (Pearce and Maunder 2000). Researchers in Korea found that the behavior of bus drivers changes as driving time increases and may result in a higher number of accidents (Kim and Lee 2013). Furthermore, tight work schedules and irregular working hours were found to be major inconveniences for many city bus drivers (Kompier and Di Martino 1995). All these studies were focused on bus accidents as a whole and not particularly near bus stops.

About 6% to 7% of fatal crashes involving a bus occurred near bus stops in India in 2009. This was mainly due to congested conditions at the bus stops, unsafe vehicle maneuvering operations and unregulated pedestrian activities (Ponnaluri 2012). More recently, safety issues at curbside tram stops in Melbourne were identified by researchers and they proposed more investment in platform stop infrastructure, greater separation of passengers at stops (Currie, Tivendale, and Scott 2011).

Crowding near bus stops is common in most developing countries because of high population densities, unreliable public transport systems, poor bus stop design, lower bus frequencies, etc. While in-vehicle crowding has received much of the attention in previous studies (Tirachini, Hensher, and Rose 2013, Katz and Rahman 2010), the implications of bus stop crowding, especially on safety aspects have not been given much focus. Bus crowding can be addressed somewhat by increasing bus sizes and/or bus frequencies. On the other hand, addressing bus stop crowding requires expansion of the existing infrastructure which obviously needs more funds to be invested (Duduta and Subedi 2015).

A study on the interactions between buses, passengers and through traffic on bus delays at bus stops found that a bus stop with inadequate bus handling capacity will not be able to deliver an accessible interface between buses and passengers (Fernandez and Tyler 2005). There are many other studies dealing with the bus handling capacity of bus stops (Gu et al. 2011) and the effect of bus stops on traffic flow (Tang, Li, and Huang 2009), roadway capacity (Yang et al. 2009) and speed (Chand and Chandra 2015). However, the safety issues arising due to the interactions between passengers and motorists at bus stops are continually ignored by researchers, even in developing countries. These safety issues arise mainly because of the activities shown in Figure 1, the resulting improper stopping of buses and the tendency of motorists to drive through the gap between the bus and the bus stop.

3. DATA COLLECTION

Two midblock sections of six-lane divided arterial road sections (3 lanes in one direction) in New Delhi, India were selected for the current study. Both road sections were located on Outer Ring Road, a busy arterial. These sections have curbside bus stops, with an average bus frequency of 52 and 40 buses and traffic flow of 5800 and 5600 vehicles per hour at sections I and II respectively. Traffic video data was collected on a typical weekday during 8:00 AM to 11:00 AM at section-I and 4:00 PM to 6:00 PM at section-II. A longitudinal trap of 60 m was made on the road sections (which cover the bus stop) for measurement of the speed. Table 1 shows the traffic volume data at the study locations.

Table 1. Traffic Composition at Study Sections

Vehicle Category	Section-I	Section-II
Small Car	42	46
Big Car	8	6
Bus/Truck	4	3
3-Wheeler	13	16
2-Wheeler	33	29

In New Delhi, most buses are operated by Delhi Transport Corporation (DTC). The fleet mainly consists of modern low floor buses with superior operating capabilities and also a few old buses with lesser capabilities. Private sector operators also manage some buses in New Delhi, which are mainly old buses and a few mini buses. The combined percentage share of these buses at the study locations is shown in Table 2.

Table 2. Types of Buses at the Study Locations

S.No.	Bus Type	Percentage
1	Modern buses (low floor) operated by DTC	65%
2	Old buses operated by DTC	18%
3	Old buses operated by the private sector	12%
4	Old small buses operated by the private sector	5%
	Total buses	*262*

4. DATA ANALYSIS

4.1 Improper Stopping of Buses

At most of the curbside bus stops in India, a rectangle with width 3.3 to 4 m (nearly equal to the outer lane width) and length of around 15 to 20 m (1.5 to 2 times bus length) is marked to designate the bus stopping region. When buses stop within a single lane width (the designated region), it can be considered as a proper stop. The road width at both sections in this study was 9.9 m with each lane being 3.3 m wide. Therefore, the width of the curb lane, which is 3.3m, was considered as the proper stopping position of the buses.

To quantify the improper stopping of buses, a reference line was drawn at the outermost edge (start of the curb lane) of the roadway. The total road width of 9.9 m was divided into 9 strips along the road section starting from the reference line. The position/co-ordinates of the outermost corner of each bus was noted when they stopped to serve passengers. The stopping of buses was classified into five categories (Type 1 to 5) based on the position of the stopped bus. This is clearly explained in Table 3. Type 1 bus stopping took place only in 28 and 39 percent of the bus arrivals at Sections I and II respectively. This indicates that for most of the time, bus drivers could not stop their buses exactly inside the designated area.

Table 3. Types of Bus Stopping at the Bus Stops

Type of bus stopping	Position of the stopped bus (m)	Observed percentage	
		Section-I	Section-II
1	< 3.30	28	39
2	3.31-4.40	37	35
3	4.41-5.50	26	20
4	5.51-6.70	9	6
5	> 6.70	0	0

Data at both the sections was pooled and then a multiple linear regression model was developed to determine the reasons for the improper stopping at the bus stops. Table 4 shows the results of the regression analysis. The stopping position was considered as a dependent variable. Although the data

obtained for stopping position was in categories, the stopping position was treated as a continuous variable in this model. It can be observed that all the variables, except the type of bus, are statistically significant at the 99% confidence level. However, the R^2 value of the model is low which can be explained by the fact that driver behavior was not considered in the model development, as it is hard to capture. The bus drivers had a tendency to stop the buses away from the bus stop so as to easily merge back into the traffic stream. Sometimes, passengers inside the bus suddenly realized that they had approached their destination bus stop and requested the drivers to stop the bus. In those situations, most bus drivers found it difficult to stop closer to the designated stopping region. As the traffic videos in this study were captured from outside the buses, driver behavior could not be identified.

Table 4. Model Results for Stopping Position of the Bus

Variable	Coefficient	Standard Error
Number of standing passengers on the road	0.1036**	0.0195
Presence of a previous bus	0.6580**	0.1059
Number of standing vehicles near the bus stop	0.3343**	0.0466
Type of bus 1. Modern buses (low floor) operated by DTC 2. Modern buses (low floor) operated by DTC 3. Old buses operated by the private sector 4. Old small buses operated by the private sector	 base -0.1852 0.1570 -0.7612*	 0.1142 0.1669 0.2940
Intercept	1.4645**	0.0597
R^2	0.3548	
Adj. R^2	0.3397	
F-test	23.37**	

Significance levels: *p < 0.05 **p < 0.01

4.2 Vehicles through the Gap between the Bus and the Bus Stop

It was observed from the traffic videos that many vehicles were overtaking the stopped bus through the gap between the bus and the bus stop. When buses stop farther from the bus stop for more dwell time, it is generally expected that a greater number of vehicles overtake through the gap. A multiple linear regression model was developed to identify various reasons for such overtaking maneuvers. The results, as shown in Table 6, indicated that old buses by the private sector were associated with a greater number of vehicles overtaking through the gap. Furthermore, the presence of standing vehicles near the bus stop motivated a few vehicles to overtake through the gap. The decrease in the speed of the vehicles on the right side of the stopped bus indicated the lower throughput at the bus stop section, and also indicated congestion. Even these cases resulted in an increase of the overtaking through gap maneuvers. The intercept term is statistically insignificant.

Table 6. Model Parameters for Number of Vehicles Overtaking through the Gap

Variable	Coefficients	Standard Error
Type of bus		
1. Modern buses (low floor) operated by DTC	base	
2. Old buses operated by DTC	0.133	0.172
3. Old buses operated by the private sector	0.792**	0.265
4. Old small buses operated by the private sector	0.815	0.463
Position of the bus from the edge of the curblane		
3.3 m	Base	
4.4 m	0.573**	0.140
5.5 m	1.322**	0.234
6.7 m	1.835**	0.368
Number of standing passengers on the road	0.029	0.034
Presence of a previous bus	0.134	0.169
Number of standing vehicles near the bus stop	0.275**	0.078
Number of passengers boarding using the front door	0.034	0.079
Number of passengers boarding using the rear door	0.046	0.027
Number of passengers alighting from the front door	-0.009	0.023
Number of passengers alighting from the front door	0.001	0.030
Dwell time	0.028**	0.011
Number of queued vehicles behind the bus	0.066	0.045
Speed of the through traffic (vehicles overtaking the stopped bus from right side of the bus)	-0.021*	0.010
Intercept	0.430	0.424
Adjusted R^2	0.492	
F-statistic	14.815**	

Significance levels: *p < 0.05 **p < 0.01

As shown in Table 6, the number of overtaking vehicles through the gap can be influenced by various factors. With the increase in the number of such vehicles, the safety of boarding and alighting passengers will be severely compromised.

5. CONCLUSIONS AND FUTURE WORK

The real situations at bus stops should not be undervalued and need to be studied elaborately to understand the safety concerns of the people. In this study, we identified various reasons for the improper stopping of buses near curbside bus stops on an arterial road in New Delhi, India. Furthermore, we developed a multiple linear regression model to study the factors influencing the number of vehicles that overtake the stopped bus through the gap between the bus and the bus stop. Various reasons like private buses, standing vehicles, dwell time and position of the bus were found to be statistically significant. The results from this study will be useful to policy makers and practitioners, especially from developing countries, to design infrastructure so as to ameliorate the events of improper stopping. Thus eventually, they will be able to improve the safety of passengers.

Generally, the degree of privatization of public transport is found to be positively correlated with the severity of accidents. In many developing countries, public transport is owned and operated by the private sector, which focuses on maximizing profits by minimizing costs instead of increasing

efficiency (Pearce and Maunder 2000). Additionally, bus drivers should also be taught technical, social and psychological skills to be safe and responsible professional drivers.
Our work in progress includes developing discrete choice models to understand the bus stopping operations and its implications in developing countries. To better understand the safety issues of passengers, our future study will try to identify the relationship between the speeds of vehicles through the gap and other variables of interest. An observation from this study was that boarding passengers wait for the vehicles to pass through the gap before boarding the bus, and alighting passengers stand near the bus door to ensure that they are safe before walking towards the bus stop. This waiting time of passengers further increases the dwell time of buses, which subsequently leads to more vehicles passing through the gap. This aspect needs to be explored by researchers.

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