Assessing Safety Level of Bus Stops in the Absence of Crash Data

Submission Date: 15th November, 2015
Words in Abstract: 216
Words in Text: 4918
Number of Tables: 02
Number of Figures: 08
Total word count (including Tables and Figures): 7634

Munavar Fairooz Cheranchery
Department of Civil Engineering,
Indian Institute of Technology Kharagpur,
Kharagpur - 721302, India,
Phone: +91 – 75578 18784; Email: fairoozmunavarc@gmail.com

Kinjal Bhattacharyya
Department of Civil Engineering,
Indian Institute of Technology Kharagpur,
Kharagpur - 721302, India,
Phone: +91 -98300 92700; Email: kinjalb.ce@gmail.com

*Bhargab Maitra
Department of Civil Engineering,
Indian Institute of Technology Kharagpur,
Kharagpur - 721302, India,
Phone: +91 - 94340 40738; Fax: Email: bhargab@civil.iitkgp.ernet.in

Manfred Boltze
Department of Civil and Environmental Engineering,
Technische Universität Darmstadt,
64287 Darmstadt, Germany,
Phone: +49 – 6151 16 – 2025 Email: boltze@verkehr.tu-darmstadt.de

(*Corresponding Author)

Abstract
Road safety is a major concern in emerging countries such as India and bus stops are the major points of concern as they act as interfaces where the pedestrians interact with transit vehicles. However, it is a challenge to evaluate bus stop safety in the context of emerging nations as reliable crash data near bus stops are generally unavailable. This paper presents a four-step methodology to assess the safety level of bus stops by analyzing the existing bus stop facilities in the absence of crash data. The methodology has been applied to evaluate the safety level of 45 existing bus stops located along a typical urban corridor in the Kolkata metropolitan city, India. The unsafe acts were identified and causal factors were classified in terms of design and management deficiencies, safety levels of bus stops along the corridor were assessed, prioritization of the bus stops was carried out and appropriate recommendations were made to improve the safety levels. While the methodology developed in this study is expected to be of interest to the researchers in the field of public transport safety, the application of the methodology as demonstrated in this paper is likely to encourage the practitioners to apply a similar approach to identify safety lacunas at bus stops and take appropriate measures for improvement.

*Keywords***:** safety level, bus stop, prioritization, design deficiency, management deficiency, emerging countries

INTRODUCTION

Bus system is the predominant public transport mode in majority of Indian cities, as it offers an extensive and low cost service *(1)*. While in many countries bus is serving only the mobility needs of the economically weaker segments of the society, or captive riders, it also has the potential to act as a demand management instrument by attracting private vehicle users, or the choice riders *(2), (3).* This shift in focus is necessary to address the growing imbalance between demand and supply of transport and the resulting negative externalities such as congestion and pollution *(4), (5).* In order to improve the bus system, it is necessary to focus on two major aspects: service quality (e.g., service headway, fare, schedule adherence, in-vehicle comfort, etc.) and safety standards. Road safety is a major concern in urban India as the country has witnessed an alarming increase in the number of road accidents. The total number of fatalities increased at an average rate of about 4% per year during 1997-2003 and the rate has increased to 8% per year beyond 2003 *(6)*. In order to improve the safety standards of the bus system, it is necessary to address the passenger safety on-board, as well as at the transfer points or the bus stops. Bus stops are the interface where bus users initiate/terminate their journey by bus and, hence, are potential locations for vehicle-pedestrian interaction. This demands the need of a safe bus stop facility *(7)*. Safety in and around bus stop is a crucial yet neglected aspect in Indian cities. Many of the bus stops do not have proper facilities which include passenger waiting area, loading area, sidewalk facility, and crosswalk facility *(8)*. Design deficiencies, such as inadequate capacity of the facilities, inappropriate location of crosswalk, and improper management (i.e. maintenance and enforcement) which results in physical obstructions along sidewalk, on street parking etc. (Figure 1) are the major issues of concern. It is observed that these deficiencies in and around bus stops lead to violations, such as encroachment of bus user into the roadway while accessing and waiting for the bus, crossing the road at undesirable locations, loading/unloading of passengers at multiple points on the roadway, etc. Further, it leads to the vehicle-pedestrian conflicts and ultimately to accidents of different severity levels. Hence, there is a dire need to improve the safety standards at the bus stops. However, in the case of emerging countries, such as India, owing to the serious constraints in financial resources, institutional constraints etc. massive safety improvement works may not be possible to execute within a short time span *(9)*. Therefore, it is essential to develop a methodology to prioritize the bus stop, which requires immediate attention, on the basis of safety level which will ensure the safety improvement works to be carried out in different phases based on priority rankings for the measures.

The assessment of safety level and accident potential of bus stops has been investigated by several researchers. Pulugartha et al. *(10)* developed a methodology to identify the hazardous bus stop locations by using crash data. A similar risk based approach was proposed by Hazaymeh, K. *(11)* to identify the unsafe bus stops. Subsequently, Truong et al. *(12)* developed a methodology to rank unsafe bus stops by using crash data. Amadori et al. *(7)* developed a methodology to correlate the accident occurrence to the absence of a particular bus stop facility. It may be observed that the methodologies developed by researchers use crash data for evaluation of safety performance of bus stops. However, in the case of emerging countries, either the accident data is not available or it is not reliable *(13)*. Therefore, this paper attempts to develop a methodology to assess the safety level and to prioritize bus stops regarding their need for safety improvements in the absence of accident data.

The paper is organized in four sections. Section 2 describes a four stage methodology to assess the safety level of bus stops and to prioritize them accordingly. The methodology has been demonstrated with reference to a case study in the Kolkata city and the results have been summarized in Section 3. The paper is concluded in Section 4 by summarizing the significance and applicability of the methodology in the context of emerging countries and its potential contribution in assessing the safety level of bus stops in the absence of crash data.

(a) (b)

(c) (d)

FIGURE 1 (a) Absence of passenger waiting area; (b) On-street parking in front of waiting area; (c) Physical obstruction on sidewalk; (d) Shops obstructing side walk facility.

METHODOLOGY

A four step methodology to assess the safety level of the bus stops is discussed in this section and is illustrated in Figure 2. It includes identification of unsafe acts in and around the bus stops and its causal factors, classification of the causal factors under design and management deficiencies of bus stop facilities, development of a model to assess the safety level of the bus stops, and the prioritization of bus stops based on safety level.

Unsafe acts and causal factors

Unsafe acts may be defined as those practices performed by bus users or drivers, which may result in vehicle-pedestrian conflicts. For instance, encroachment of bus users to the roadway is an unsafe act which exposes the bus user to the traffic flow and leads to vehicle-pedestrian conflicts. Absence of waiting area, absence of sidewalk facility, presence of street vendors along the sidewalk etc. are some of the factors contributing to this unsafe act. Thus, the role of unsafe acts is crucial in assessing the safety level of the bus stops, and hence, it is necessary to identify the potential unsafe acts and its causal factors to quantify the safety level of the bus stops. Therefore, this stage of the methodology is focused on identifying various unsafe acts and its causal factors based on literature and field study.

Classification of causal factors

It was observed from the field that causal factors are the result of deficiencies in either design or management of bus stop facilities. Also, in emerging countries such as India, management deficiencies, in general, are more dominant and a major source of concern for the majority of bus stops. Even if the bus stop design is as per requirements in several cases, the management deficiency makes the bus stop unsafe. Therefore, in this stage, causal factors which are due to the deficiencies in capacity, location and supporting elements (lighting and drainage) of the bus stop facilities are classified under design deficiencies, and those which are due to the deficiencies in maintenance and enforcement are classified under management deficiencies. Further, the fundamental relationship between causal factors and unsafe acts, which forms the basis for the safety assessment model, were also demonstrated in a tabular form.

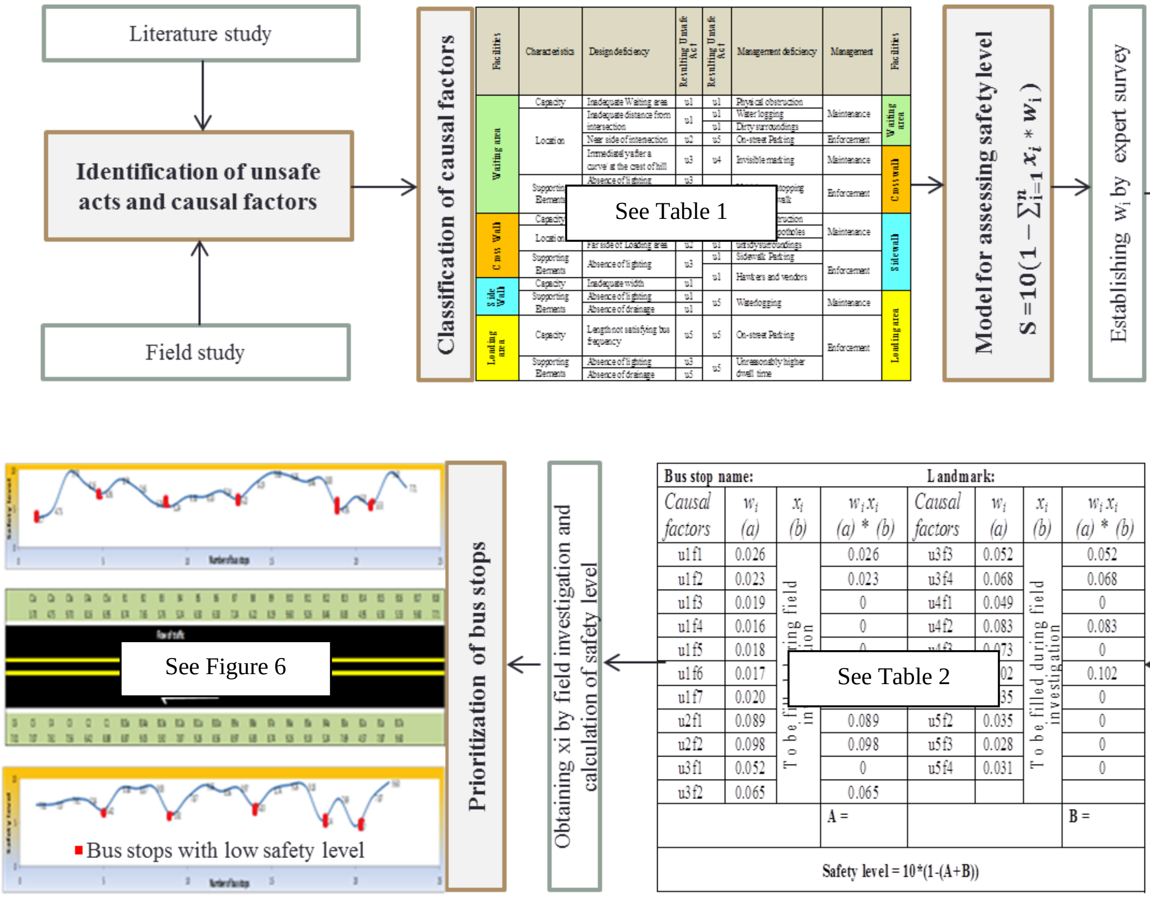

FIGURE 2 Flow chart showing methodology to assess safety level of bus stops.

Model for assessing safety level

In this stage, an attempt has been made to relate the safety level of bus stops to the unsafe acts and its causal factors. Accordingly, the independent variable being a categorical variable, a linear model is adopted *(13)*. The model developed to assess the safety level of the bus stops may be expressed as:

$$S = 10(1 - \sum_{i=1}^{n} x_i * w_i) \quad (1)$$

Where,

S : safety level of a bus stop,

x_i : a dummy variable representing the presence (x_i=1) or absence (x_i=0) of a causal factor in a bus stop,

w_i : weightage of the causal factor.

Further, weightage of the causal factor can be expressed mathematically as:

$$w_i = c_{ip} * d_p \quad (2)$$

Where,

c_{ip} : contribution index, which indicates the relative contribution of i^{th} causal factor to the p^{th} unsafe act,

d_p : degree of danger associated with the p^{th} unsafe act.

There may be more than one causal factor for the same unsafe act; as a result, the relative contribution of each causal factor to the respective unsafe act will be different, and it has been denoted as contribution index (c_{ip}). The c_{ip} values of the causal factors with respect to an unsafe act are normalized to 1.
Similarly, different unsafe acts will have different degrees of danger. For example, crossing road at any undesirable point may be more hazardous than loading/unloading passengers at multiple locations other than designated bus stops. Therefore, d_p indicates the degree of danger associated with p^{th} unsafe act.

In general, the safety level of the bus stop is a function of three important parameters: causal factor (x_i), contribution index (c_{ip}), and degree of danger (d_p).Therefore, by considering all three parameters, the safety level equation can be modified as follows:

$$S = 10(1 - \sum_{i=1}^{n}\sum_{p=1}^{j} x_i * c_{ip} * d_p) \quad (3)$$

where, n and j are the total number of causal factors and unsafe acts respectively. In the present work, an expert scoring method was adopted to obtain the contribution of various causal factors to the respective unsafe acts, and an Analytical Hierarchy Process (AHP) was performed to obtain the degree of danger associated with various unsafe acts.

Prioritization of Bus stops

As discussed in the previous section, the safety level of the bus stops is calculated from the values of c_{ip}, d_p and x_i (obtained through field investigation of the bus stop) by using equation 3. Accordingly, the prioritization of the bus stops is performed based on the fact that 'the lower the safety level the higher is the priority for improvement'.

APPLICATION

This section briefly explains the application of the aforementioned methodology to assess the safety level of the bus stops in a traffic corridor in the Kolkata metro city, India. A corridor of 8.2 km starting from K.C. Das intersection to Tollygunge tram depot, via Shyamaprasad Mukherjee road and Deshapran Sashmal road, in Kolkata metropolitan city, India, was selected for the study (Figure 3). It includes 45 bus stops by considering both sides of the corridor. The corridor serves high pedestrian and traffic volumes, consisting of 4 lanes separated by a median. It allows two-way traffic except for the section between Exide junction and Tata center junction. The traffic from KC Das junction to Exide junction travels through the Jawaharlal Nehru road and the opposite direction traffic travels through Cathedral road, for this particular one way section. This one way section of length 1.7 km ends at the Tata center junction and again follows two-way traffic for the rest of the corridor.

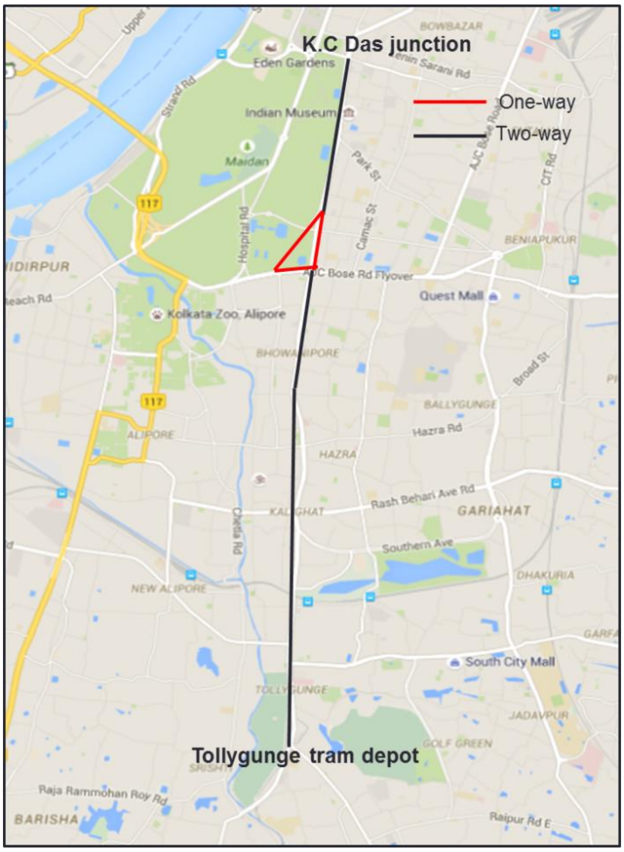

FIGURE 3 Study Corridor in the Kolkata metro city.

Unsafe acts and causal factors

Based on field observations and review of literature, five important unsafe acts in and around bus stops were identified. These are (a) encroachment of bus users to the roadway (u1) *(14)*, (b) crossing road in front of a stopped bus (u2) *(15)*, *(16)*, (c) crossing road at locations where sight distance with bus is inadequate (u3) *(16)*, *(17)*, (d) crossing road at undesignated locations (u4) *(18)*, *(19)* and (e) loading/unloading of passengers at multiple locations other than the designated bus stop locations (u5) *(20)*. The unsafe acts are further discussed below.

Encroachment of the bus users to the roadway (u1)

Bus users may encroach the roadway when they walk by using carriageway instead of using sidewalk or wait for the bus on the carriageway rather than at the waiting area (Figure 4a). The factors which predominantly contribute to this unsafe act include: Absence of/ inadequate waiting area (u1f1), absence of/inadequate sidewalk facility (u1f2), lack of lighting facility along the sidewalk (u1f3), lack of drainage facility (u1f4), untidy surrounding (u1f5), encroachment of sidewalk by parked vehicles (u1f6) and presence of street vendors along the sidewalk (u1f7).

Crossing road in front of a stopped bus (u2)

Field observations revealed that, in several cases, pedestrians attempt to cross road in front of a stopped bus immediately after alighting from the bus (Figure 4b). As a result, pedestrians were unable to see the vehicle approaching in the same direction as that of the stopped bus. Locating crosswalk at far-side of the loading area (u2f1) and locating bus stop at nearside of the intersection (u2f2) are the potential factors contributing to this unsafe act.

Crossing road at locations where sight distance with bus is inadequate (u3)

In several cases, sight distance may become inadequate for the bus drivers to stop the bus at a safe distance from the pedestrians who are either waiting for the bus in the travel way or are crossing the road in front of the bus stop (Figure 4c). Factors which may contribute to such unsafe acts include: On street parking (u3f1), locating the waiting area immediately after a curve or at the crest of a hill (u3f2), lack of lighting facility at bus stop (u3f3), and physical obstruction (u3f4).

Crossing road at undesignated locations (u4)

The following factors may force bus user to cross road at undesirable locations by not using the provided crosswalk facility, while accessing/departing the bus stop (Figure 4d): inadequate width of the crosswalk (u4f1), locating crosswalk far away from the bus stop (u4f2), invisible crosswalk marking (u4f3), and vehicle not stopping at a safe distance from the crosswalk (u4f4).

Loading/unloading of passengers at multiple locations other than the designated bus stop locations (u5)

Passengers, in some cases, are forced to board/alight the bus at multiple locations along the roadway which expose them to the traffic at different locations along the roadway as they are unable to access the pedestrian facilities immediately (Figure 4e). Inadequate capacity of the loading area (u5f1), bus not stopping at the designated loading area (u5f2), unreasonably high dwell time (u5f3), and lack of drainage facility (u5f4) are the potential factors which may contribute to such unsafe act.

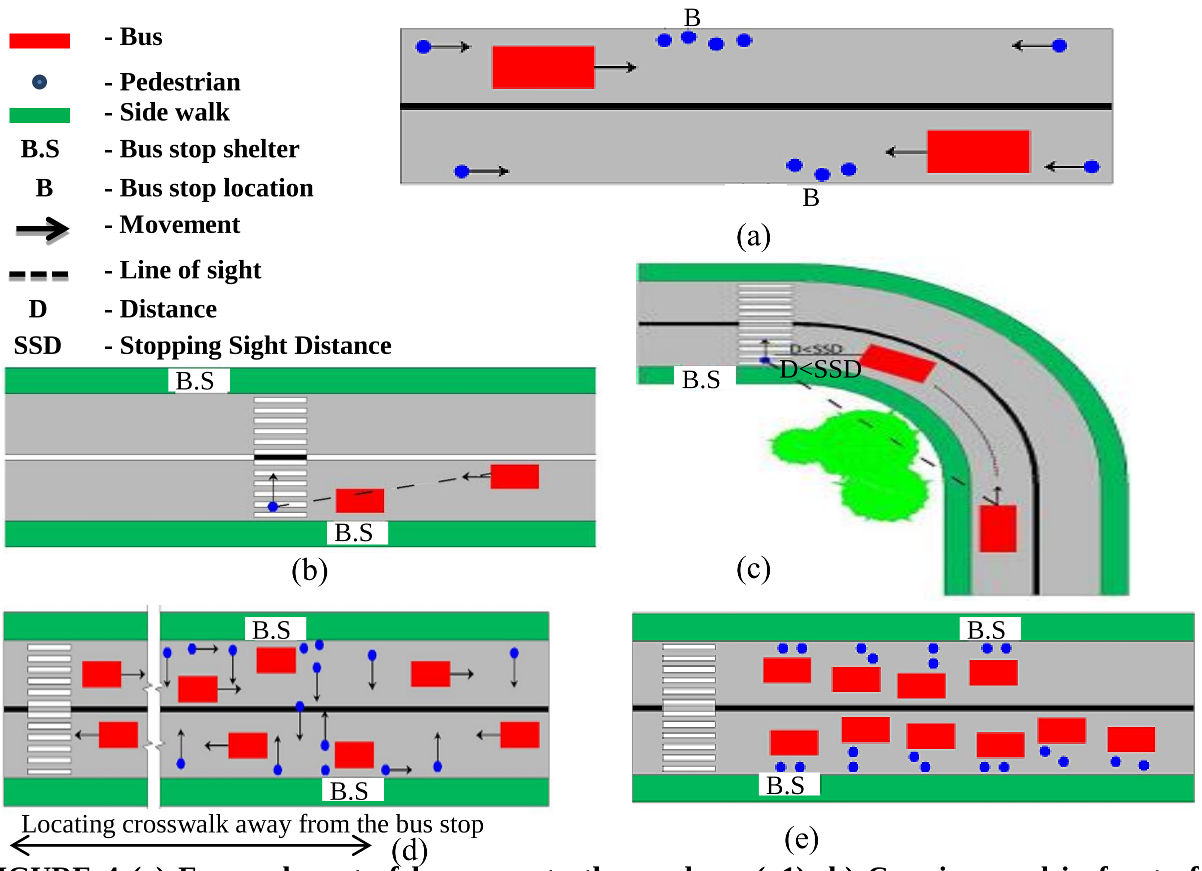

FIGURE 4 (a) Encroachment of bus users to the roadway (u1); b) Crossing road in front of a stopped bus (u2); c) Crossing road at locations where sight distance with bus is inadequate (u3); d) Crossing road at undesignated locations (u4); e) Loading/unloading of passengers at multiple locations other than the designated bus stop locations (u5)

Classification of causal factors

The identified causal factors were classified under design and management deficiencies of bus stop facilities, and the relation between causal factors and the unsafe acts are also demonstrated in Table 1. For this purpose, a bus stop facility was broadly divided into four segments, viz., passenger waiting area, loading area, sidewalk facility and crosswalk facility *(15)*, *(21)*. While the left side of the table is showing the unsafe design characteristics for each segment, the right side deals with the management issues. The middle portion of the table describes the resulting unsafe acts due to deficiencies in design and management.

TABLE 1 Classification of causal factor under design and management deficiencies of bus stop facilities[1]

Facilities	Characteristics	Design deficiency	Resulting Unsafe Act	Resulting Unsafe Act	Management deficiency	Management	Facilities
Waiting area	Capacity	Inadequate Waiting area	u1	u1	Physical obstruction	Maintenance	Waiting area
	Location	Inadequate distance from intersection	u1	u1	Water logging		
				u1	Dirty surroundings		
		Near side of intersection	u2	u5	On-street Parking	Enforcement	
		Immediately after a curve/ at the crest of hill	u3	u4	Invisible marking	Maintenance	Crosswalk
	Supporting Elements	Absence of lighting	u3	u4	Vehicle not stopping before crosswalk	Enforcement	
		Absence of drainage	u1				
Cross Walk	Capacity	Inadequate width	u4	u1	Physical obstruction	Maintenance	Sidewalk
	Location	Too far from bus stop	u4	u1	Patches and potholes		
		Far side of Loading area	u2	u1	untidy surroundings		
	Supporting Elements	Absence of lighting	u3	u1	Sidewalk Parking	Enforcement	
				u1	Hawkers and vendors		
Side Walk	Capacity	Inadequate width	u1				
	Supporting Elements	Absence of lighting	u1	u5	Waterlogging	Maintenance	Loading area
		Absence of drainage	u1				
Loading area	Capacity	Length not satisfying bus frequency	u5	u5	On-street Parking	Enforcement	
	Supporting Elements	Absence of lighting	u3	u5	Unreasonably higher dwell time		
		Absence of drainage	u5				

Capacity, location, and supporting elements (lighting and drainage facility) are the design related characteristics of the waiting area. For example, inadequate waiting area is an unsafe design related to the 'capacity' characteristic of the waiting area, which may result in unsafe act u1. Similarly, locating the bus stop immediately after a curve or at the crest of a hill is an unsafe design related to the 'location' characteristic of the waiting area, which may result in unsafe act u2. Moreover, lighting and drainage facilities are considered as the supporting elements of the bus stop, and their absence is also considered as an unsafe design practice. Likewise, unsafe design related to the characteristics of other segments like sidewalk facility, crosswalk facility and loading area may also result in unsafe acts around the bus stop, and all the factors which may cause potential unsafe acts are comprehensively shown in Table 1.

It was also observed that, lack of proper enforcement and maintenance, collectively called as management deficiency can also result in unsafe acts around the bus stop. For instance, waterlogging in

[1] The used symbols for the unsafe acts are explained in the text above.

front of the bus stop may force the bus users to move away from the bus stop and wait for the bus by encroaching the roadway. Similarly, on-street parking in front of the waiting area may force the bus users from the dedicated waiting area to encroach the roadway. While waterlogging in front of the waiting area is a result of improper maintenance, on-street parking is a result of improper enforcement, yet both contribute to the same unsafe act u1. Likewise, improper management related to each segment may result in unsafe acts around the bus stop and they are again comprehensively demonstrated in Table 1.

Model for assessing the safety level

As discussed in the methodology section, a linear model for assessing the safety level of the bus stop is suggested in Equation (1). Weightage of any causal factor is the product of its relative contribution to the unsafe act c_{ip} and the degree of danger associated with the unsafe act d_p. In order to establish the c_{ip} and d_p values, an analytical approach has been adopted. Expert scoring method was used to estimate c_{ip}. For estimating d_p values, expert's pairwise comparison on each unsafe act was obtained, followed by AHP to transform it into a normalized matrix. A panel of 15 experts (same experts for both scoring and AHP method) including traffic engineers, safety engineers and researchers of transportation engineering were approached for conducting the survey.

Determination of c_{ip}

An expert scoring survey was conducted to determine the relative contribution of each causal factor to the corresponding unsafe acts. The questionnaire was given to the experts and they were asked to give their score (out of 10) on the contribution of each factor to the unsafe act. The normalized score of the factors was taken as the contribution index of the causal factors.

Determination of d_p

An AHP survey questionnaire was developed to facilitate a pairwise comparison on the degree of danger among the five unsafe acts. SAATY's 9 point scale *(22)* was used to compare them. After conducting the pairwise comparison survey, the response from each expert was transformed into a standardized matrix. The responses obtained from the experts were checked for consistency and those responses with a consistency ratio of less than 0.1 were accepted (12 responses) *(22).* After checking the consistency, normalized matrix was formed by performing AHP computations on standardized matrix. Finally, d_p values of unsafe acts were obtained by taking the arithmetic mean of rows of the normalized matrix. 'Crossing at undesignated locations (u4)', 'crossing road at locations where sight distance with bus is inadequate (u3)' and crossing road in front of a stopped bus (u2) were found to be the most dangerous with d_p values 0.3, 0.24, 0.19 respectively, whereas 'loading/unloading of passengers at multiple locations other than the designated bus stop locations (u5)' and 'encroachment of bus users to the roadway (u1)' were found to be least dangerous with d_p values 0.13 and 0.14 respectively.

Weightage of the causal factors

As mentioned earlier, weightages (w_i) of the causal factors were obtained by taking the product of contribution index the (c_{ip}) and degree of danger values (d_p). Initially, weightages given by the individual experts were calculated, and then the arithmetic means of these individual weightages were reported as the weightages of causal factors (Figure 5). It was found that, 'vehicle not stopping before crosswalk (u4f4)' got maximum weightage (10.2%), followed by 'Locating crosswalks at the nearside of the intersection (u2f2)' (9.8%) and 'locating the cross walk at far side of the loading area (u2f1)' (8.9%). On the other hand, 'lack of drainage facility (u1f4)' (1.6%), 'encroachment of sidewalk by parked vehicles (u1f6)' (1.7%) and 'physical obstruction and untidy surroundings (u1f5)' (1.8%) were found to be the causal factors with least weightages.

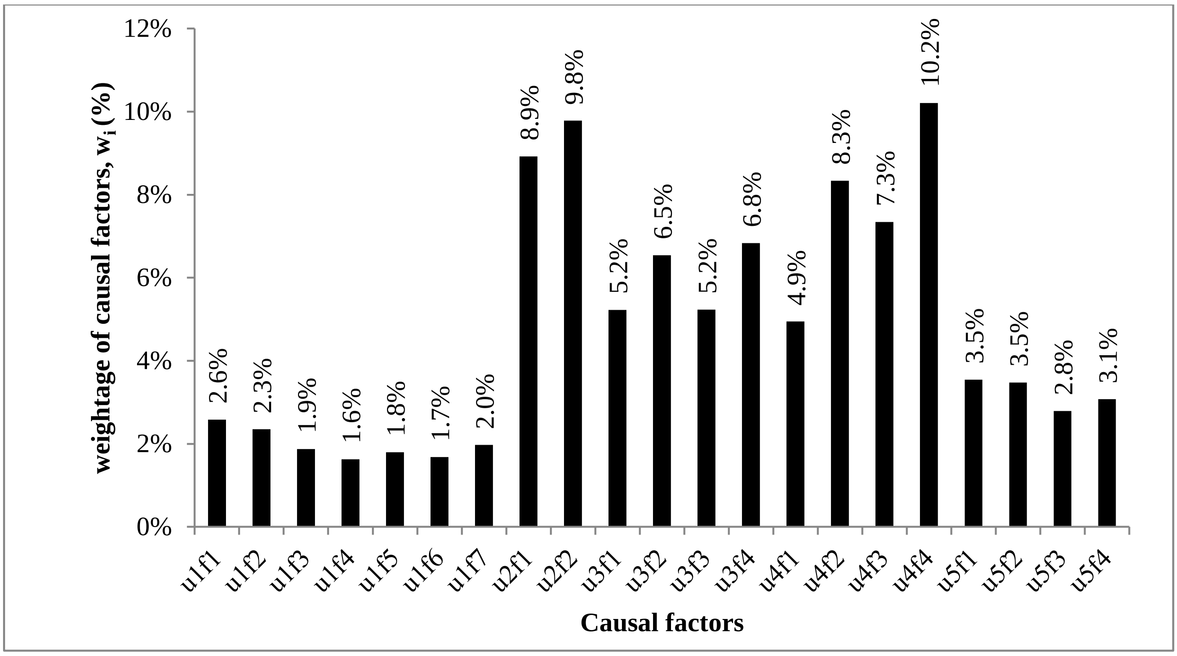

FIGURE 5 Variation of weightage among causal factors

Calculation of the safety level of bus stops

After obtaining the weightage of the causal factors, the presence/absence of the causal factors (whether xi is 1 or 0) in each bus stop were checked by visiting aforesaid traffic corridor. Finally, the safety level of each bus stop was calculated as shown in Table 2. Safety levels of the bus stops were found to be varying in the range 3.7 to 9.7. Nearly 40% of the bus stops were having a safety level less than 7.5.

TABLE 2 Calculation of safety level of Charu market Bus stop

Bus stop name: Charu market bus stop **Landmark:** SBI							
Causal factors	w_i *(a)*	x_i *(b)*	$w_i\, x_i$ *(a) * (b)*	*Causal factors*	w_i *(a)*	x_i *(b)*	$w_i\, x_i$ *(a) * (b)*
u1f1	0.026	1	0.026	u3f3	0.052	1	0.052
u1f2	0.023	1	0.023	u3f4	0.068	1	0.068
u1f3	0.019	0	0	u4f1	0.049	0	0
u1f4	0.016	0	0	u4f2	0.083	1	0.083
u1f5	0.018	0	0	u4f3	0.073	0	0
u1f6	0.017	0	0	u4f4	0.102	1	0.102
u1f7	0.020	1	0.020	u5f1	0.035	0	0
u2f1	0.089	1	0.089	u5f2	0.035	0	0
u2f2	0.098	1	0.098	u5f3	0.028	0	0
u3f1	0.052	0	0	u5f4	0.031	0	0
u3f2	0.065	1	0.065				
			A = 0.321				**B = 0.305**
Safety level = 10*(1-(A+B)) = 10*(1-(0.321+0.305))= 3.74							

Prioritization of bus stops

In this stage, based on the safety level obtained for various bus stops, prioritization of the bus stops was carried out for the fact that lower the safety level higher the priority for improvement. It was found that, Jeevan Deep (Safety Level = 9.7), Hazra junction (Safety Level = 9.6) and Rashbehari (Safety Level =

9.6) bus stops respectively were at the bottom three positions in terms of the priority, and on the other hand, Charu market (Safety Level = 3.7), Park street (Safety Level = 4.3), and Dharmatala (Safety Level = 5.1) bus stops were at top three positions respectively. In addition, the variation of the safety level of the bus stops along the corridor is plotted (Figure 6), so that it helps in identifying segments of the corridor with low safety levels.

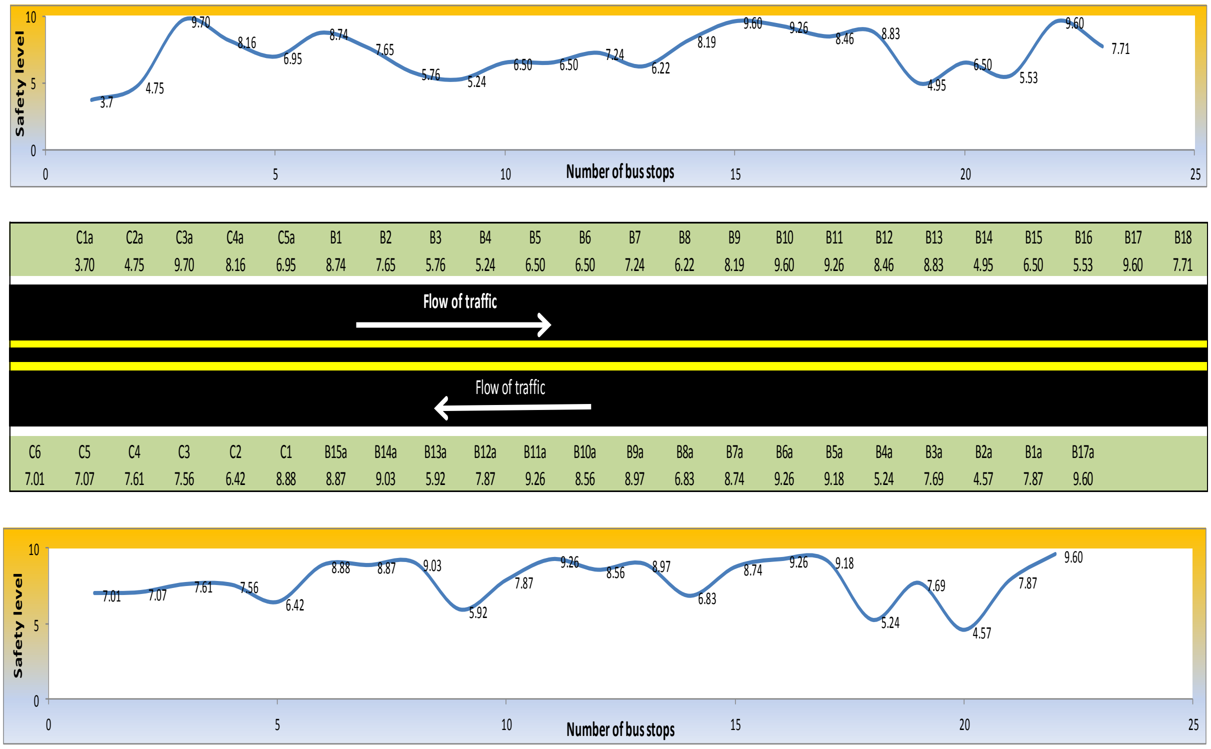

FIGURE 6 Variation of the safety level of bus stops along the study corridor

Discussion and Recommendations

After determining the safety levels of 45 bus stops, it was observed that the safety level is varying from 3.7 to 9.7 (10 being best and 0 being worst in terms of safety) and about 40 % of the bus stops have safety levels less than 7.5. The frequency of occurrence of the safety deficiencies at the bus stops which were investigated is illustrated in Figure 7. Vehicle not stopping at a safe distance from crosswalk (u4f4), presence of street vendors along the sidewalk (u1f7), on street parking (u3f1), and absence of waiting area (u1f1) were the most common deficiencies associated with the bus stops that were investigated. Also, it is evident from the figure that management deficiencies are dominant over design deficiencies at the bus stops along the study corridor. Although the study included a safety level assessment (as illustrated for Charu market bus stop in Table 2) and recommendations to improve the safety level for all 45 bus stops along the corridor, in the present paper, safety levels and recommendations based on the observed deficiencies are reported only for the three worst and best cases, as examples.

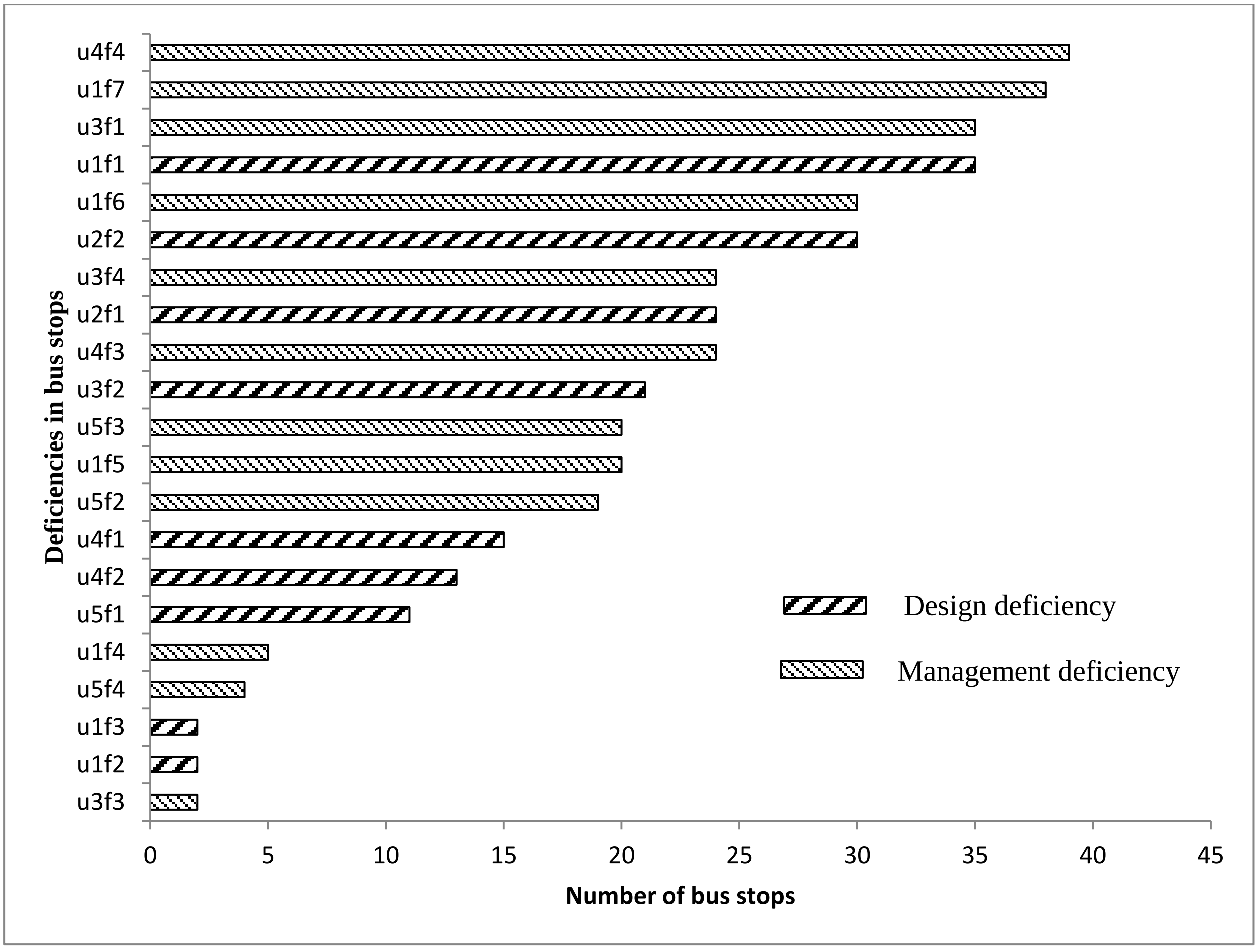

FIGURE 7 Frequency of safety deficiencies along the study corridor[2].

Analysis of the worst three Bus Stops

Charu market (Figure 8a) (Safety Level = 3.7), Park street (Figure 8b) (Safety Level = 4.3), and Dharmatala (Figure 8c) (Safety Level = 5.1) bus stops were found to be the worst three among 45 bus stops in terms of safety level.

Measures for improving the safety deficiencies of the bus stops are classified under design and management measures. Based on the safety deficiencies observed in the design, it is recommended to (i) increase the waiting area capacity (ii) provide adequate sidewalk and lighting facilities to improve the safety level of these bus stops. In case of Charu market and Park Street bus stops, it is recommended to provide a crosswalk facility near the bus stop.

Based on the safety deficiencies observed in the management, it is recommended to carry out regular maintenance works to remove physical obstructions, and to strengthen the enforcement measures to avoid vehicle-pedestrian conflicts at the crosswalks. It is observed that the street vendors and parked vehicles encroach into the designated side walk facility, thereby significantly reducing the pedestrian walking space along these bus-stops. While a control on the encroachment of vendors into the walking space of pedestrians is necessary, it is important to provide a designated space for these vendors. Therefore, it is recommended to segment the available footpath space into pedestrian zone (as per the standards, a continuous unobstructed minimum width of 1.5 m *(23)*) and vendors' zone, and strictly enforce the use respective zones to prevent encroachment of pedestrian space by vendors or parked vehicles.

[2] Symbols (u4f4, u1f7 etc.) are explained in the subsection named unsafe acts and causal factors.

In principle, while designing the urban road network, it is important to consider the requirements of all users especially pedestrians; so that pedestrians do not feel the need to encroach the right of way of cars in an unsafe manner, which will improve safety, mobility, and efficiency around the bus stops*(8)*.

Analysis of Best Three bus stops

Jeevan Deep (Figure 8d) (Safety Level = 9.7), Hazra junction (Figure 8e) (Safety Level = 9.6), Rashbehari (Figure 8f) (Safety Level = 9.6) bus stops were found to be the best in terms of safety level. All three bus stops were devoid of any deficiencies related to passenger waiting area and crosswalk facility. In order to further improve the safety level, it is recommended to discourage the buses at Jeevan deep from stopping for unreasonably long durations to pick up more passengers and to remove physical obstructions along the sidewalks in Hazra and Rashbehari.

FIGURE 8 (a) Charu market bus stop; (b) Park Street bus stop; (c) Dharmatala bus stop; (d) Jeevan Deep bus stop; (e) Hazra junction bus stop; (f) Rashbehari bus stop

CONCLUSIONS

The study presents a novel methodology to assess the safety level of bus stops by analyzing the existing bus stop facilities in the absence of crash data. This methodology provides a rational basis to investigate bus stop safety at majority of the emerging countries where reliable accident records are not available. The methodology includes the identification of potential unsafe acts and its causal factors, the classification of causal factors under design and management deficiencies of bus stop facilities, establishing a model to assess the safety level of bus stops, and prioritization of the bus stops for improvements based on their safety level.

The methodology was applied successfully to evaluate the safety level of 45 existing bus stops located along a typical urban corridor in the Kolkata metropolitan city, India. The causal factors were identified in terms of design and management deficiencies, safety levels of bus stops along the corridor were assessed, prioritization of the bus stops was carried out and appropriate recommendations were made to improve the safety levels of the unsafe bus stops. Vehicle not stopping at a safe distance from crosswalk, presence of street vendors along the sidewalk, on-street parking, and absence of waiting area were the most common deficiencies associated with the bus stops investigated in the present work. It was also observed that management deficiencies were dominant over design deficiencies at these bus stops. Safety levels of the bus stops ranged between 3.7 and 9.7 (10 being the best and 0 being the worst), and nearly 40% of the bus stops have a safety level less than 7.5. The recommended measures are expected to improve the safety deficiencies of these bus stops.

Although the methodology was developed to assess bus stop safety in the context of emerging countries where exhaustive and reliable accident data for bus stops are unavailable, it would be interesting to apply the methodology in cases where crash data are available and relate the findings with the actual crash data. While the methodology developed in this study is expected to be of interest to the researchers in the field of public transport safety, the application of the methodology as demonstrated in this paper is likely to encourage the practitioners to apply a similar approach to identify safety lacunas at bus stops and take appropriate measures for improvement. Further, the methodology developed provides an insight into the safety related to design and management of the bus stops, which could be instrumental in formulating appropriate policies. Also, the findings from the present work encourage the need for identifying potential solutions for safety improvements in challenging environments prevailing in developing countries. The perception of safety may vary with respect to different classes of pedestrians based on their age, gender etc. Therefore, it may be necessary to extend the work further to account the perception of different classes of pedestrians to improve the safety level of bus stops.

REFERENCES

1. Tiwari, Geetam. "Urban transport in Indian cities." Urban age (2007): 1-4.
2. Ceder, Avishai. "New urban public transportation systems: Initiatives, effectiveness, and challenges." Journal of urban planning and development 130.1 (2004): 56-65.
3. Maitra, Bhargab, Saurabh Dandapat, and Phanikumar Chintakayala. "Differences between the Perceptions of Captive and Choice Riders toward Bus Service Attributes and the Need for Segmentation of Bus Services in Urban India." Journal of Urban Planning and Development 141.2 (2014): 04014018.
4. Pucher, John, et al. "Urban transport crisis in India." Transport Policy 12.3 (2005): 185-198.
5. Maitra, Bhargab, and Shubhajit Sadhukhan. "Urban public transportation system in the context of climate change mitigation: Emerging issues and research needs in India." Mitigating Climate Change. Springer Berlin Heidelberg, 2013. 75-91.
6. MoRTH (2013). Road Accidents in India. Ministry of Road Transport & highways transport research wing, New Delhi
7. Amadori, Marco, and Tommaso Bonino. "A methodology to define the level of safety of public transport bus stops, based on the concept of risk." Procedia-Social and Behavioral Sciences 48 (2012): 653-662.
8. 'Better streets and better cities' A guide to street design in Urban India by Institute for Transportation and Development policy, December 2011
9. Maitra, Bhargab, P. K. Sikdar, and S. L. Dhingra. "Modeling congestion on urban roads and assessing level of service." Journal of Transportation Engineering 125.6 (1999): 508-514.
10. Pulugurtha, Srinivas S., and Vinay K. Vanapalli. "Hazardous bus stops identification: An illustration using GIS." Journal of Public Transportation 11.2 (2008): 4.
11. Hazaymeh, Khaled. "GIS-Based Safety Bus Stops-Serdang and Seri Kembangan Case Study." Journal of Public Transportation 12.2 (2009): 3.
12. Truong, Long Tien, and Sekhar VC Somenahalli. "Using GIS to identify pedestrian-vehicle crash hot spots and unsafe bus stops." Journal of Public Transportation 14.1 (2011): 6.
13. Agarwal, Pradeep Kumar, Premit Kumar Patil, and Rakesh Mehar. "A methodology for ranking road safety hazardous locations using analytical hierarchy process." Procedia-Social and Behavioral Sciences 104 (2013): 1030-1037.

14. Singh, Sanjay Kumar, and Ashish Misra. "Road accident analysis: A case study of Patna City." Urban Transport Journal 2.2 (2004): 60-75.
15. Bus Stop Field Audit Reports by North Jersey Transportation Planning Authority, 2011
16. Bus Stop design guidelines by Darnell & Associates, 2006
17. Fitzpatrick, Kay, Daniel Fambro, and Angela Stoddard. "Safety effects of limited stopping sight distance on crest vertical curves." Transportation Research Record: Journal of the Transportation Research Board 1701 (2000): 17-24.
18. Sharples, J. M., and J. P. Fletcher. Pedestrian perceptions of road crossing facilities. Scottish Executive Central Research Unit, 2000.
19. Pedestrian Safety at Midblock Locations report prepared by Center for Urban Transportation Research September, 2006
20. AIURA, Nobunori, and Eiichi TANIGUCHI. "Planning on-street loading-unloading spaces considering the behaviour of pickup-delivery vehicles." Journal of the Eastern Asia Society for Transportation Studies 6 (2005): 2963-2974.
21. ADA bus stop tool kit "Assessment of bus stop accessibility and safety",2011
22. Saaty, Thomas L. "How to make a decision: the analytic hierarchy process." European journal of operational research 48.1 (1990): 9-26.
23. IRC (103-1988). Guidelines for pedestrian facilities. The Indian Road Congress.