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Proactive pedestrian safety evaluation at unprotected mid-block crosswalk locations under mixed traffic conditions

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ABSTRACT

The pedestrian safety can be evaluated by proactive methods (conflict techniques). Proactive method is a cost-effective technique as compared to the historic crash data analysis. Pedestrian safety studies at mid-block crosswalks based on proactive methods are required due to the growing number of pedestrian crossing facilities in developing countries. Hence, the present study evaluated the pedestrian safety at unprotected mid-block crosswalks by considering the proactive safety measure as a pedestrian safety margin (PSM). PSM is the time difference between accepted vehicular time gap with reference to the pedestrian crossing path and pedestrian actual crossing time (based on the field conditions). To fulfill this objective eight unprotected mid-block crosswalks were selected which have different roadway characteristics. Video graphic survey has been conducted for data collection at these locations. PSM values were extracted corresponding to the pedestrian behavioural, vehicular and traffic characteristics at all the eight crosswalks. Further, stepwise regression and binary logit models (the probability of pedestrian-vehicle non-conflict) have been developed in order to find out the factors contributing to the PSM values as well as predicting the probability of avoiding conflict with an approaching vehicle at unprotected mid-block crosswalks. From the study, it is observed that pedestrian behavioural characteristics such as rolling behaviour and speed change conditions significantly reduce the PSM values, and it influences the probability of avoiding conflict with an approaching vehicle at unprotected mid-block crosswalks. These findings may be useful for evaluation of the existing unprotected mid-block crosswalk locations and for increasing the pedestrian safety at these crosswalks by considering suitable control measurements on pedestrian behaviour under mixed traffic conditions.

1. Introduction

Crosswalks are the most essential and frequently used transport facility by pedestrians. The pedestrian exhibits higher risk-taking behaviour while crossing the road than walking on sidewalks. Crosswalks, which do not have crossing treatments (active or passive controllers like road markings, sign board, and signal) are designated as unprotected or un-controlled mid-block crosswalks, which are more common in developing countries. Several research studies have shown that the number of pedestrian collisions are more in developing countries as compared to the developed countries (Asiamah et al., 2002; Peden et al., 2004). In developing countries like India, many pedestrians cross the road at unprotected mid-block crosswalk locations and pedestrians are one of the most vulnerable road users at mid-block crosswalk locations. Studies have shown that 60% fatalities in urban areas are related to pedestrians and among that 85% fatalities occur at unprotected mid-block crosswalks (Mohan et al., 2009). Some other existing studies have shown that metropolitan cities have a major contribution towards pedestrian fatalities as compared to the non-metropolitan cities (MOUD, 2008). Further, pedestrian facilities are overlooked while improving transportation facilities such as flyovers and widening of roads, for motorized vehicle users.

The pedestrian gap acceptance mechanism is the process of selecting suitable vehicle gap after arriving at the curb or median during the road crossing process at uncontrolled crossings. In this process, the pedestrian may be successful or unsuccessful and it depends on the available approaching vehicular gaps, behaviour of a pedestrian (rolling as well as speed change behaviour) and driver behaviour (yielding to pedestrians). Pedestrians are rolling over (moving on with anticipation of an adequate gap in the next lane) the small vehicular gaps in each lane to accept the vehicular gaps in order to reduce overall waiting time, which is characterized as rolling behaviour (Brewer et al., 2006; Kadali and Vedagiri,

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2013). The pedestrian safety can be assessed by means of pedestrian gap acceptance behaviour and vehicular gaps with effect of different pedestrian behavioural characteristics (rolling behaviour, increase in speed, etc.). The evaluation of pedestrian safety under mixed traffic conditions (the mix of slow moving vehicles such as auto rickshaw, two-wheeler as well as fast moving vehicles together) is important, which can be done by either using historical crash data or proactive (non-crash) measurements. Many researchers have focused on proactive safety measurement studies because of the drawbacks of historical crash data, such as insufficient, lower quality and higher cost of the crash based data.

A proactive safety technique involves identifying near-miss events (narrowly escaped collisions) and seeks the actual information about the events with driver as well as pedestrian behaviour under site conditions. In a traffic stream, some of the conflicts results in collisions, and these collisions may vary from non-severe to severe collisions. The proactive safety measurement is a useful technique to identify the severity of pedestrian-vehicle conflicts during the road crossing process. In this context, the safety margin method is one of the proactive techniques to evaluate pedestrian safety at crosswalk locations. Safety margin value is the marginal safety value (time gap) maintained by pedestrian while accepting an approaching vehicle gap to cross the road. The pedestrian safety margin (PSM) can be defined as, the time difference between the accepted vehicular time gap (from pedestrian crossing path) and pedestrian actual crossing time (based on the field condition and pedestrian behaviour) (Oxley et al., 1997, 2005; Lobjois and Cavallo, 2007). The decrease in PSM will result in an increase in pedestrian-vehicle interaction and further increases the conflict with vehicles. This increase in the pedestrian-vehicle conflict motivated authors to study the pedestrian safety at unprotected mid-block crosswalks under mixed traffic conditions. The objective of the study is to evaluate pedestrian safety at uncontrolled mid-block crosswalks under mix traffic conditions, based on the proactive safety margin concept.

2. Literature review

There are several studies, which have been carried out to evaluate the pedestrian safety either by crash based methods such as historical crash data, user opinion surveys or proactive (non-crash) based methods, which includes conflict as well as traffic maneuvers studies (Evans and Norman, 1998; Retting et al., 2003; Holland and Hill, 2007; Ukkusuri et al., 2012). One of the most often studied aspect in the pedestrian safety analysis is identifying the significant factors affecting the safety of pedestrians, either by historic crash based method (Sinha and Sengupta, 1989; Zegeer et al., 1993) or conflict method (Oxley et al., 1997; Svensson and Hydén, 2006; Lobjois and Cavallo, 2007). Studies have shown the effect of pedestrian age and gender on pedestrian safety analysis at the intersection and mid-block crosswalk locations (Oxley et al., 1997, 2005; Lobjois and Cavallo, 2007, 2009). Studies have shown that the type of approaching vehicle also has a significant effect on pedestrian safety (Zajac and Ivan, 2003; Liu and Li, 2009). However, some studies have stated that approaching vehicle distance is more important as compared to the pedestrian individual characteristics in decision-making process of road crossing (Connelly et al., 1998).

Further, the driver yield behaviour is also one of the important factors contributing to pedestrian safety at mid-block crosswalk location. Some studies identified that there is no significant effect of static sign boards, traffic calming devices, and markings on the driver yield behaviour at crosswalks (Huang and Cynecki, 2000; Knoblauch et al., 2001). Some studies also considered the effect of pedestrian gestures on driver yield behaviour and the results concluded that L-bent-level gesture increases the driver yield behaviour at unprotected mid-block crosswalks (Zhuang and Wu, 2014). Research studies have shown that with an increase in the driving speed, there is a decrease in driver yield to pedestrians (Salamati et al., 2013). Further, research studies have been done with different modeling techniques in order to identify the factors contributing to the driver yield behaviour at un-signalized crosswalks and the results show that the behaviour of pedestrians has a strong correlation with the driver yield behaviour (Schroeder and Rouphail, 2011; Kadali and Vedagiri, 2013). Harrell investigated that the increase in pedestrian platoon size has low risk than individual pedestrian during road crossing (Harrell, 1991). Moreover, studies have shown that there is an increase in the risk taking behaviour with an increase in pedestrian waiting time at signalized intersections (Hamed, 2001).

There are several studies which have explored pedestrian safety in laboratory investigations (a virtual field) by safety margin evaluation to find out the effect of pedestrian, traffic and vehicular characteristics (Oxley et al., 2005; Lobjois and Cavallo, 2007). Researchers found that the increase in gap size increases the safety margin value (van der Molen, 1981). Studies have also been conducted to understand the effect of pedestrian looking behaviour on the PSM while crossing the road (Schoon, 2006; Zhuang and Wu, 2012). Most often studies have not considered the pedestrian behavioural characteristics such as pedestrian rolling behaviour, speed and path change conditions with inadequate vehicle gap acceptance. Such pedestrian behaviour reflects the tradeoff between the pedestrian waiting time and vehicular driver yield behaviour, which further contributes towards pedestrian-vehicle collisions. Hence, pedestrian behavioural characteristics are important in pedestrian safety analysis. Most of the above studies are related to well-designed crosswalks present in developed countries, where in the pedestrian-vehicle interaction might be less. In contrast, the mixed traffic conditions in developing countries, where the traffic is highly heterogeneous, non-lane based and with a wide variety of pedestrian behaviour as well as vehicle characteristics, results in higher pedestrian-vehicle interaction. As a result, the outcome of these earlier studies cannot be considered and used in developing countries like India. In this context, the present study evaluates the pedestrian safety by using proactive safety measurements at eight different unprotected mid-block crosswalks under mixed traffic conditions. Further, a stepwise regression model and binary logit model have been developed in order to find out the factors contributing towards PSM as well as quantification of the probability of pedestrian-vehicle non-conflict.

3. Study method

3.1. Site selection

In this study, eight unprotected mid-block crosswalk locations having different roadway characteristics such as number of lanes (roadway width), median width and the median open width are selected in Mumbai city, as shown in Fig. 1. These selected locations provide a good set of data for the current study due to a significant interaction between pedestrian and vehicle drivers. The selected crosswalk locations are representative of unprotected mid-block crosswalks prevailing in Indian cities. Also, the selected survey locations consist of varied traffic volumes, motor vehicle speeds and pedestrian behavioural characteristics with a wide range of the available gaps. This variability of roadway geometry with pedestrian as well as vehicular characteristics is suitable to obtain a wide range of safety margin values and is useful to develop the generic model. The details of the selected sites are summarized in Table 1.