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Impact of grade separator on pedestrian risk taking behavior

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ABSTRACT

Pedestrians on Delhi roads are often exposed to high risks. This is because the basic needs of pedestrians are not recognized as a part of the urban transport infrastructure improvement projects in Delhi. Rather, an ever increasing number of cars and motorized two-wheelers encourage the construction of large numbers of flyovers/grade separators to facilitate signal free movement for motorized vehicles, exposing pedestrians to greater risk. This paper describes the statistical analysis of pedestrian risk taking behavior while crossing the road, before and after the construction of a grade separator at an intersection of Delhi. A significant number of pedestrians are willing to take risks in both before and after situations. The results indicate that absence of signals make pedestrians behave independently, leading to increased variability in their risk taking behavior. Variability in the speeds of all categories of vehicles has increased after the construction of grade separators. After the construction of the grade separator, the waiting time of pedestrians at the starting point of crossing has increased and the correlation between waiting times and gaps accepted by pedestrians show that after certain time of waiting, pedestrians become impatient and accepts smaller gap size to cross the road. A Logistic regression model is fitted by assuming that the probability of road crossing by pedestrians depends on the gap size (in s) between pedestrian and conflicting vehicles, sex, age, type of pedestrians (single or in a group) and type of conflicting vehicles. The results of Logistic regression explained that before the construction of the grade separator the probability of road crossing by the pedestrian depends on only the gap size parameter; however after the construction of the grade separator, other parameters become significant in determining pedestrian risk taking behavior.

1. Introduction

As per the accident data, among all road users in Delhi, the ones who are most exposed to risk are the pedestrians. Pedestrian deaths in Delhi are about 4 times the national average. Fig. 1 shows the share of pedestrian fatalities in Delhi from 2001 to 2009 (Delhi Police, 2009); it indicates that pedestrians have the largest share in total fatalities and the share remains the same over the years, which is about 50% of the total fatalities.

Pedestrians are the most vulnerable and the ongoing infrastructure improvement projects in Delhi are making them even more vulnerable (Gupta et al., 2010). It is therefore important to study pedestrian behavior in order that the risks faced by them can be minimized while the transportation facilities are improved for motorized traffic. Pedestrians are mainly exposed to risk when crossing a road in urban areas as non-crossing accidents generally represent a small proportion of pedestrian accidents (Lassarre et al., 2007; Duncan et al., 2002). A common phenomenon in Delhi is that a pedestrian has to fight for space on the road, because of a lack of safe and convenient pedestrian paths. In Delhi, a significant investment has been made for the construction of flyovers/grade separators to increase the speed of motorized vehicles, to reduce their delay, and to make arterial roads in Delhi signal free. As new grade separators are constructed the signalized crossings are converted into signal free crossings, causing more problems for pedestrians. Although a pedestrian often has the option of crossing the road using the subway/foot over bridge most often they do not use it. Rather, they prefer to cross the roads on the surface. Rasanen et al. (2007) and Tanaboriboon and Jing (1994) confirmed this by comparing signalized intersection pedestrian crossings to overpass and underpass counterparts and found that pedestrians preferred signalized at grade crossings to overpass or underpass crossings. The objective of this study is to examine whether construction of

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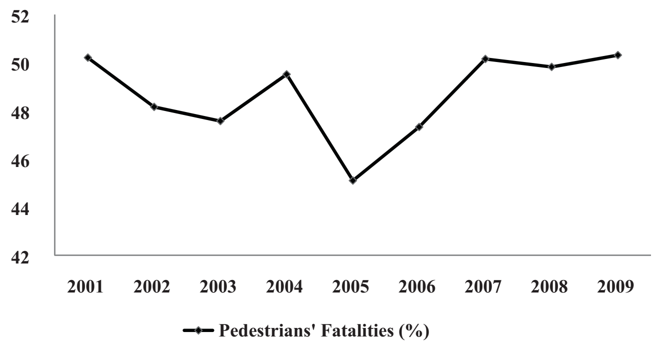

Fig. 1. Share of pedestrian fatalities in Delhi.

grade separators in place of signalized intersections has any significant effect on the risk taking behavior exhibited by different type of pedestrians. It should be noted that after the construction of grade separators, traffic signals are removed. As a consequence, there is no safe signal, rendering all crossings unsafe. Thus pedestrians who cross the road on the surface always face a risk.

1.1. Literature review

A number of studies have been conducted on the behavior and movement of pedestrians at junctions and/or at other crossing locations. These studies include the impact of the road environment, traffic environment and road safety treatments by means of before and after studies on pedestrian's behavior and safety.

1.1.1. Road and traffic environment

Li and Fernie (2010) studied the pedestrian behavior under different road surface conditions at a busy two-stage crossing. The results show that a significant number of pedestrians fail to comply with the delay involved in a two-stage crossing, leading to unsafe crossing behavior. Jacobs et al. (1968) also found that when there is a median refuge, non-compliance rates increase.

King et al. (2009) found that illegal crossing behavior is associated with an increased crash risk. Crossing against the lights and crossing away from the lights both exhibited a crash risk per crossing event approximately 8 times that of the legal crossing at signalized intersections.

Rasanen et al. (2007) designed a study to find out factors that influence use/non-use of pedestrian bridges. This study showed that the factors influencing pedestrian perceptions of bridge use are time saving, safety and familiarity of the area. It also suggests that generally bridge use or non-use is a habit and not coincidental behavior.

Leden (2002) calculated the risks for pedestrians as the expected number of reported pedestrian accidents per pedestrian and found that the risk decreased with increasing pedestrian flows and increased with increasing vehicle flows.

Sisiopiku and Akin (2003) findings from an observational study of pedestrian behavior at various urban crosswalks and a pedestrian user survey reported that unsignalized midblock crosswalks were the treatment of preference to pedestrians and also showed high crossing compliance rate of pedestrians. Crosswalk location, relative to the origin and destination of the pedestrian, was the most influential decision factor for pedestrians deciding to cross at a designated location.

Himanen and Kulmala (1988) used multinomial Logit model to examine pedestrian and driver reaction to "encounters" occurring at pedestrian crossings. The probabilities of a driver braking or weaving, and of a pedestrian continuing to cross in response to an encounter are identified for a variety of pedestrian, environmental, and traffic conditions. The results indicate that the most important explanatory variables included a number of vehicles in the platoon, vehicle speed, pedestrian distance from kerb, number of pedestrians simultaneously crossing and city size, whereas road width, median refuge, yield rules and most of the pedestrian variables were not found to be significant.

1.1.2. Before and after studies

Keegan and O'Mahony (2003) evaluated the impact of the pedestrian waiting countdown timers and they found that these units induced a reduction in the number of individuals who crossed during the red-man (do not walk) signal. Carsten et al. (1998) observed the effect in pedestrian behavior and their safety, before and after construction of innovative pedestrian signalized crossing and they found that there were general gains in safety and comfort for pedestrians, and these improvements were obtained without major side effects on vehicle travel. Hakkert et al. (2002) observed the impact of a new type of uncontrolled pedestrian crossing which included a system for detecting pedestrians near the crosswalk zone and for warning drivers of pedestrian presence. Their findings suggest that after the installation of the device there was a decrease of about 2–5 kmph in average vehicle speeds, an increase in the rate of giving way to pedestrians and a significant reduction in vehicle pedestrian conflicts in the crosswalk zone.

However, earlier studies have not attempted to quantify the risk faced by pedestrians after providing free flow facilities to motorized vehicles. In this study we analyzed the risk taking behavior of pedestrians when a signalized intersection is converted into a signal free intersection (grade separated). This study also examines the combined impact of influencing variables to provide a better estimate of pedestrian risk taking behavior.

2. Methodology

The aim of the study is to analyze the risk taking behavior of pedestrians before and after the construction of a grade separator. Data have been collected at an intersection when it was a four-way signalized intersection in 1998 and was changed to a signal free intersection by constructing a grade separator in 1999. Pedestrians had an option of crossing the road at the signalized crossing safely or unsafely at grade when the intersection had a signalized operation. After the construction of the grade separator at grade crossing is always unsafe; safe crossing requires using a pedestrian underpass about 50 m from the intersection. We compared pedestrians crossing the road unsafely at grade before and after the construction of the grade separator. As a first step, pedestrian risk has been defined. Afterwards, frequencies are compared for gap size accepted and rejected by pedestrians, acceptance and rejection of gaps with respect to different types of conflicting vehicles and speeds of conflicting vehicles for both before and after construction of the grade separator. Frequencies are also compared for the waiting time of pedestrians before and after construction of the grade separator.

In order to see the impact of pedestrians' waiting time on their gap acceptance behavior, the correlation co-efficient is calculated for both below and above average waiting time and accepted gaps. A model is fitted to determine the probability that a pedestrian will accept a gap size and start crossing the road. Here in this case the outcome has two categories i.e. the pedestrian will cross the road or not cross the road, hence "Binary Logistic regression model" is used for the analysis. Gap size is defined as the difference between the time when each pedestrian arrives at the crossing and each conflicting vehicle enters at the crosswalk. The length of each gap is calculated from the differences between the arrival times of two consecutive vehicles, as indicated in Fig. 2. This available gap is the gap presented to the pedestrian. If the pedestrian accepts the