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DOI: 10.2174/1874447801711010011

RESEARCH ARTICLE

Vehicle-Pedestrian crashes at Intersections in Dhaka city

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Received: November 06, 2016 Revised: December 24, 2016 Accepted: February 02, 2017

Abstract:

Background:

Pedestrians are some of the most vulnerable road users, especially in large congested cities in developing countries. In order to develop appropriate countermeasures to improve safety, research has to be conducted to understand the factors contributing to vehicle-pedestrian collisions.

Objective:

This study aims to identify the factors contributing to intersection crashes in a developing country context.

Method:

A Poisson regression model was applied to police reported crash data from the capital of Bangladesh, Dhaka.

Results:

This study finds that an increase in vehicle traffic and the presence of police officer, footbridge, bus stop, solar panel and waste deposit facility were associated with an increase in the number of vehicle-pedestrian crashes, whereas an increase in pedestrian volume, roads with the same number of inbound and outbound lanes, roads with greater number of lanes, and the presence of traffic signal, commercial area or offices, speed breaker and rail crossing were associated with a reduction in the number of vehicle-pedestrian crashes.

Conclusion:

While the results of most traffic and engineering factors are consistent with those obtained in previous studies in developed countries, some of the results on human related factors and unusual road furniture are atypical and require more locally targeted countermeasures.

Keywords: Pedestrian crashes, Intersection crashes, Developing country, Poisson regression.

INTRODUCTION

Background and Rationale

Around the world, more than 1.2 million people are killed on the roads every year and as many as 50 million others are injured, and over 90% of the deaths occur in the low and middle income countries [1]. Low and middle income countries also have a higher road traffic fatality rate (20.2 deaths per 100,000 population) than high income countries

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1874-4478/17 2017 Bentham Open

(12.6 deaths per 100,000 population). Moreover, the total number of road traffic deaths and injuries is forecasted to rise by 80% in low-income and middle-income countries between 2000 and 2020 compared to 65% worldwide. Also, the majority of traffic deaths in developing countries are vulnerable road users (pedestrians, cyclists and motorcyclists). Therefore, it is imperative that more effort be devoted to understanding the challenges and reducing the traffic injuries in developing countries, especially among the vulnerable road users.

Vehicle-pedestrian crash is a major road safety problem in many developing countries, including Bangladesh [2]. Dhaka, the capital of Bangladesh, is one of the most densely populated cities in the world and the state of pedestrian safety can be considered as alarming [3]. In one study, it is observed that pedestrians represent up to 72 percent of road traffic fatalities in the Dhaka Metropolitan area [4]. In Dhaka, pedestrians at intersections are more likely to be involved in these fatal crashes since a significant share of the total crashes occurred near the intersections [5 - 7]. It is observed that intersection crashes account for around 40 percent of total accidents occurring in the Metropolitan City of Dhaka [8]. Therefore, it is important to explore the factors affecting vehicle-pedestrian crashes to provide evidence based recommendations for improving the safety of these vulnerable road users.

Objective and Scope of Study

The objective of this study is to identify the factors contributing to the number of vehicle-pedestrian crashes at intersections in a developing country. This study will also contribute to advancing knowledge in the field because relatively few studies have been conducted in the developing country context, compared to developed countries [9]. Since the road environment and user behavior are very different, some of the risks factors identified in developed countries may have different effects in a developing country context.

In addition, this study will also explore many factors that have thus far received relatively little attention in the literature, including manual traffic controls and the presence of waste disposal facilities, speed breakers, solar panels, *etc.* Many of these features are quite unique to developing countries and are not found in most developed countries.

Literature Review

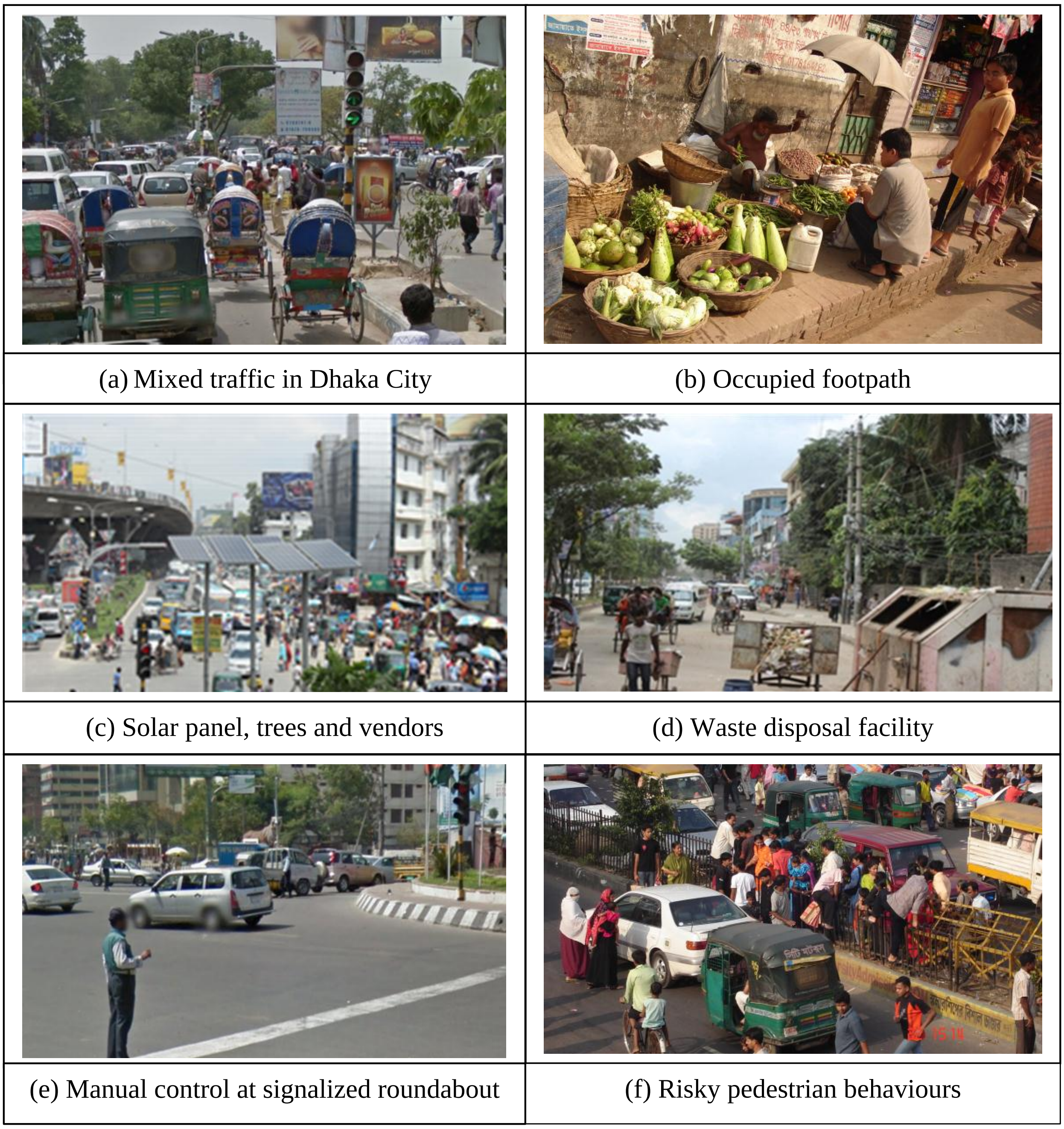
The literature on vehicle-pedestrian crashes is extensive. For example, one study collected pedestrian safety statistics at the global, regional and national levels, and studied the effect of several factors related to driver, roadway, vehicle and demography [10]. Another study examined the monthly pedestrian crashes patterns on urban roads in the American state of Connecticut [11]. Cottrill and Thakuriah [12] found that pedestrian crash frequency in the city of Chicago was related to exposure, crime rates and general population demographics. Aziz *et al.* [13] and Yasmin *et al.* [14] found road characteristics, traffic attributes and land use to be statistically significant in determining the severity of pedestrian crashes in New York City.

Several studies have specifically examined vehicle-pedestrian crashes at intersections. For example, Schneider *et al.* [15] examined the association between roadway characteristics and pedestrian crash risk in Alameda County in California while Pulugurtha and Sambhara [16] examined the influences of demographic, socioeconomic and land use characteristics on the frequency of pedestrian crashes at intersections in the American city of Charlotte. Femandes *et al.* [17] and Miranda-Moreno *et al.* [18] examined the frequency of vehicle-pedestrian crashes at intersections in the city of Montreal while Lyon and Persaud [19] examined the pedestrian crashes in the city of Toronto. Kim *et al.* [20] examined the factors determining pedestrian injury severity in the American state of North Carolina while Lee and Abdel-Aty [21] examined the severity of pedestrian crashes in Florida.

Although many studies have been conducted to understand the factors influencing vehicle-pedestrian crashes at intersections, most of these studies are conducted in developed countries where the roads are better designed, the traffic is better separated and controlled, and traffic rules are generally obeyed. On the contrary, road environment and user behaviors are very different in many cities in the developing countries [22 - 28].

Road Environment and User behavior in Dhaka City

Like many large cities in the developing world, the roadway and traffic conditions in Dhaka city are significantly different from many cities in the developed world. For example, there is a much higher share of non-motorized traffic (pedal bicycles, rickshaws, pushcarts, animals, *etc.*) on many roads (Fig. **1a**) and restrictions on non-motorized traffic have to be imposed on some of the intersections. Most of the pedestrian footpaths are occupied by vendors and extension of roadside shops (Fig. **1b**), illegally parked vehicles, refuse, other roadside furniture and motorcycles. Thus, pedestrians are often forced to use the road instead of the allotted pedestrian pathways, which will increase the chances of conflict with vehicles. Pedestrian crossing facilities (*e.g.*, zebra crossing, underpass and overpass) are inadequate, and when available, rarely used due to inconvenience and poor law enforcement.



(a) Mixed traffic in Dhaka City
(b) Occupied footpath
(c) Solar panel, trees and vendors
(d) Waste disposal facility
(e) Manual control at signalized roundabout
(f) Risky pedestrian behaviours

Fig. (1). Road and traffic conditions in Dhaka city.

Also, the sight distance at the approach roads are often restricted by sculptures, advertisement billboards, solar panels (Fig. **1c**) and waste disposal facilities (Fig. **1d**). Moreover, side roads and gas stations are often present close to intersections, and many of them carry heavy traffic, which contribute to significant traffic jams and congestion. Since traffic congestion is a common phenomenon in Dhaka, drivers often have to take more risks due to insufficient clearance time at intersections. Interestingly, the traffic flow in many intersections at Dhaka city, even signalized intersections, is manually controlled by traffic police (Fig. **1e**). It should also be noted that many of the drivers are not educated, not properly trained and are often ignorant about the road rules and regulations [29]. Similarly, many pedestrians often ignore safety rules and exhibit risky walking and crossing behaviors (Fig. **1f**).

MATERIALS AND METHODS

Statistical Method

The aim of this study is to explore the factors contributing to the frequency of crashes at intersections in a developing country. Researchers have used various statistical techniques to model accident frequencies (Lord and Mannering [30] for a review of the various techniques). Since the number of crashes is a count variable, the Poisson regression model is an appropriate technique to use [31 - 37]. However, the Poisson model, assumes that the mean is equal to its variance and this assumption is often violated in practice. Hence, a more general model, namely the negative binomial model, has been employed by many researchers to account for over-dispersion in the data [18, 38 - 41] while some researchers have used the Sichel model [42]. In this study, the Poisson regression model was used because the dependent variable was a count variable. The Poisson model was selected over the negative binomial model because over-dispersion was found to be statistically insignificant (p=0.500) in the data.

Let 'y' be the number of crashes at an intersection, then the Poisson regression model is given by:

$$P(Y = y) = \frac{e^{-\lambda}\lambda^{y}}{y!} \qquad y = 0,1,2,3... \tag{1}$$

$$\ln(\lambda) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k \tag{2}$$

where P is the probability of observing y crashes at an intersection

λ is the mean of the distribution

$\beta_0, \beta_1, ..., \beta_k$ are parameters to be estimated

$x_1, ..., x_k$ are explanatory variables

The above model was estimated using the maximum likelihood method. It should be noted that several mixed-Poisson and random parameters Poisson models have recently been applied to account for heterogeneity [42 - 46]. The random parameters model assumed that some or all of the parameters may be random because of unobserved variations or unobserved heterogeneity [43, 44]. However, preliminary analyses found no significant unobserved heterogeneity (no statistically significant scale parameter or variance for all coefficients). Hence, the fixed parameters Poisson regression model was used to estimate the final model.

Data

Vehicle-pedestrian crash data from 2011 to 2013 at 45 intersections in Dhaka city were provided by the Accident Research Institute at the Bangladesh University of Engineering and Technology. These intersections have been termed as the hazardous intersections by traffic police in Dhaka city corporation road network. In this study, an intersection crash included all crashes within 20m of an intersection. In order to collect relevant information on geometric features, roadside environment, traffic operations and neighborhood land use, a thorough *in-situ* investigation was performed by the research team at every intersection.

The descriptive statistics of the 13 variables used in the final model were summarized and presented in Table **1**. Correlations between variables have been tested and no significant relationship was observed between the independent variables. In this study, any variable with a 90% confidence level was considered to be marginally significant and retained in the models.

Table 1. Descriptive statistics.

Variables	Mean	SD	Min	Max
Number of pedestrian crashes	1.600	2.168	0	10
Traffic volume per hour				
Vehicle volume	1451.111	777.128	180.9	3540
Pedestrian volume	374.207	202.439	27	894
Traffic control				
Signal	0.800	0.405	0	1

(Table 1) contd.....

Variables	Mean	SD	Min	Max
Police	0.867	0.344	0	1
Number of lanes				
Maximum number	3.222	0.735	2	5
Same inbound-outbound	0.311	0.468	0	1
Nearby land use				
Office area	0.444	0.503	0	1
Presence of infrastructure and furniture				
Foot over bridge	0.511	0.506	0	1
No bus stop	0.622	0.490	0	1
Speed breaker	0.222	0.420	0	1
Rail crossing	0.111	0.318	0	1
Solar power	0.489	0.506	0	1
Waste deposit facility	0.267	0.447	0	1

RESULTS

The estimation results from the final model were summarized and are reported in Table **2**. In general, the model fitted the data fairly well, with large chi-square statistics for goodness of fit, fairly high McFadden pseudo R-square and very small p-values.

Table 2. Estimation results of final model.

Number of Observations = 45 **Log likelihood function = -60.28** **P-value < 0.001** **Chi-squared statistic = 63.66** **McFadden Pseudo R-squared = 0.35**				
Variables	**Coefficient**	**Std. Err.**	**t-statistic**	**p-value**
Traffic volume				
Vehicle volume *	0.000786	0.000281	2.79	0.005
Pedestrian volume	-0.001537	0.000845	-1.82	0.069
Traffic control				
Signal *	-2.180	0.579	-3.77	0.000
Police *	2.038	0.777	2.62	0.009
Number of lanes				
Maximum number of lanes	-0.451	0.254	-1.78	0.075
Same inbound-outbound *	-1.053	0.386	-2.73	0.006
Nearby land use				
Office area	-0.683	0.393	-1.74	0.082
Presence of road infrastructure in or near intersection				
Foot over bridge *	1.227	0.432	2.84	0.004
No bus stop *	-0.609	0.296	-2.06	0.039
Speed breaker	-0.655	0.408	-1.60	0.109
Rail crossing *	-1.087	0.484	-2.25	0.025
Solar power *	1.125	0.343	3.28	0.001
Waste deposit facility *	0.887	0.2895	3.07	0.002

* denotes statistically significant at $\alpha = 0.05$ level.

DISCUSSION

Consistent with previous studies [15 - 19], an increase in the vehicle traffic was found to be associated with an increase in crashes. However, in contrast to previous studies [15 - 18], an increase in pedestrian volume was found to be associated with a reduction in crashes. The difference in our result might be due to the safety in number effect [47] and the difference in behaviors between pedestrians in developed and developing countries, with higher prevalence of pedestrian jaywalking. Drivers might be induced to drive more carefully in areas with high pedestrian volume.

As expected, this study found that signalization was negatively associated with the number of vehicle-pedestrian crashes. This result was consistent with Garder [48] who found that the installation of traffic signals was associated with a reduction in vehicle-pedestrian conflicts at 115 urban intersections in Sweden, and Lee and Abdel-Aty [21] who found that signal control was associated with a reduction in vehicle-pedestrian crashes in Florida.

Interestingly, we found that intersections controlled by police were associated with an increase in crashes. One possible reason might be police presence would be more likely at intersections with high crash risks. Another possible reason might be the poor signal timings in developing counties, including those in Dhaka city, which would result in traffic police officers controlling traffic at intersections, including signalized intersections and roundabouts (Fig. **1e**). This multiple controls at the same intersection might lead to an increase in congestion as well as confusion and risk-taking behaviors by both drivers and pedestrians [49, 50].

Our results showed that having the same number of in-bound and out-bound lanes was associated with fewer crashes. Similarities of approach roads would have beneficial effects from a pedestrian safety perspective. With the same number of lanes for both the inbound and outbound traffic at an intersection, drivers might have a less need to change lanes. This reduction in weaving activities near the intersection would reduce the potential for both vehicle-vehicle and vehicle-pedestrian conflicts.

An increase in the maximum number of lanes in any of the approach roads at an intersection was found to be associated with a reduction in vehicle-pedestrian crash frequency. This result was in contrast to Femandes *et al.* [17] who found that an increase in the total number of lanes was associated with an increase in the frequency of vehicle-pedestrian crashes. Although an increase in the number of lanes would increase the distance the pedestrians have to walk to cross the intersection, they might compensate for the increased risk by being more cautious about their safety and reduce their tendency to jaywalk.

With regards to nearby land use, office buildings were found to be associated with a decrease in the number of vehicle-pedestrian crashes. This result was in contrast to Schneider *et al.* [15] and Femandes *et al.* [17] who found the presence of commercial land use was associated with an increase in the frequency of vehicle-pedestrian crashes. The presence of office buildings near intersections might indicate an increase in the pedestrian traffic streams and result in a greater awareness by drivers of the presence of pedestrians. This result reinforced our previous finding that an increase in pedestrian volume was negatively associated with vehicle-pedestrian crashes.

As expected, the presence of a speed breaker (road hump) near an intersection was found to be associated with a decrease in the number of pedestrian-vehicle crashes. Theoretically, a speed breaker would reduce the speed of vehicles and thus, reduce the likelihood and frequency of crashes.

The presence of overhead bridge was found to be associated with an increase in the number of vehicle-pedestrian crashes at an intersection. This finding was in contrast to previous research from Japan that found a decrease in vehicle-pedestrian crashes [51]. However, it was consistent with Mutto *et al.* [52] who found an increase in vehicle-pedestrian crashes in Kampala, Uganda. The differences in the results between developed and developing countries might be due to the differences in pedestrian behaviors (not using the overhead bridge in developing countries) and/or differences in driver behaviors (not slowing down because of the presence of overhead bridge in developing countries).

In this study, we found that the presence of railway was associated with a decrease in pedestrian-vehicle crashes. This result was in contrast to previous studies [53, 54] that found the presence of railway crossing was a contributing factor towards vehicle-pedestrian crashes. Although railway crossings might be hazardous locations, they would also induce drivers to slow down and drive more carefully.

In contrast to most developed countries, in Dhaka city, waste disposal facilities would often be placed on the roads (Fig. **1d**) and this study found that its presence was associated with an increase in vehicle-pedestrian crashes. This result was expected because the placement of large waste bins on the outer lane of a road would pose a safety threat, especially to pedestrians who might be forced further into the roads. Also, the waste disposal facility might not be properly maintained and serviced, and the waste would often spill and scatter onto the roads. This might further narrow the effective lane width. Moreover, drivers might increase their speed to avoid this eyesore and accompanying odor, which might elevate the crash risks. In addition, the waste disposal facility and any waste collection truck servicing them would often restrict the drivers' vision and reduce their perception reaction times.

Solar panel would be another unusual on-road furniture that could be found in some developing countries (Fig. **1c**) but not in most developed countries. As expected, the presence of solar system was found to be associated with an increase in the number of pedestrian crashes at intersections. These hazards would reduce the sight distance and vision of drivers, as well impede pedestrian movements and forced pedestrians to walk around them.

The absence (presence) of bus stop near an intersection was found to be associated with a decrease (increase) in vehicle-pedestrian crashes. This result was in consistent with Diogenes and Lindau [55] who found that crossings located close to bus stops experienced higher pedestrian crash rates.

CONCLUSION

The objective of the study was to identify the factors affecting vehicle-pedestrian crashes at intersections in Dhaka city. Our study found that an increase in vehicle traffic and the presence of police officer, footbridge, bus stop, solar panel and waste deposit facility were associated with an increase in the number of vehicle-pedestrian crashes, whereas an increase in pedestrian volume, roads with the same number of inbound and outbound lanes, roads with greater number of lanes, and the presence of traffic signal, commercial area or offices, speed breaker and rail crossing were associated with a reduction in the number of vehicle-pedestrian crashes.

Some countermeasures that may be effective in reducing vehicle-pedestrian crashes at urban intersections in Dhaka and other large cities in developing countries include the installation and proper optimization of traffic signal, and relying on automated signaling rather than manual signaling controlled by traffic police officers. Other potential countermeasures include equalizing the number of in-bound and out-bound lanes, installing marked pedestrian crossings at intersections located near large commercial or office buildings, removing of waste deposit facility and solar panel from the road to safer locations, installation of speed breakers and other traffic calming devices, and on site communication or education campaigns to encourage the use of footbridges and increase the awareness of safety hazards around bus stops.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

The authors would like to thank the Accident Research Institute in Bangladesh University of Engineering and Technology for providing the intersection crash data.

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