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ROAD SAFETY PROBLEM OF ELDERLY PEOPLE IN BANGLADESH: COMPARATIVE CRASH CHARACTERISTICS ANALYSIS USING LOGISTIC REGRESSION MODEL

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ABSTRACT

Elderly people are one of the most fragile and vulnerable road users in terms of safety risk particularly in the developing countries due to the absence of their special needs in the road environment to cope with the complex traffic system. However, there are very few studies that have focused on the safety problem of elderly people in Bangladesh. This paper aims to investigate the road safety problem characteristics of elderly people in Bangladesh. Due to the special requirements and needs for elderly people, there would have differences in crash characteristics and risk factors of crashes involving elderly people than that of the other crashes. Considering this hypothesis, this study has made a comparative analysis between crashes involving elderly people fatalities and other crashes where there are no elderly fatalities using the logistic regression technique. This analysis also shades light upon the key risk factors and their interaction effects between each other. The analysis has considered 82 independent variables under different categories and finally, 21 variables are found significant with different levels of impact. The model estimations show that daytime, autumn season, October month, major, moderate and single fatal crashes, hit pedestrian, bus and 3-wheelers motorized vehicle including CNG, baby taxi, easy bike crash, pedestrian hit by a motorcycle, jeep, pickup, Pajero, microbus and ambulance are positively correlated i.e., increase the likelihood of elderly people fatal crashes. On the other hand, metropolitan area, lost control type, motorcycle crashes with bus, truck, bus-truck, a motorcycle hit by light motorized 4 wheelers, single-vehicle crashes involving, Jeep, pickup, Pajero, and a pedestrian hit by motorized 3 wheelers are negatively correlated i.e., the variable decreases the likelihood of elderly person fatalities in a crash. At the very outset, the paper highlighted a few striking characteristics of elderly people road traffic fatalities and crashes. Finally, safety improvement strategies and special requirements have been highlighted to improve the safety of elderly people in traffic.

Keywords: *Elderly people, safety, characteristics, fatality, crash factors, logistic model,*

1. INTRODUCTION

Elderly people are one of the most vulnerable road users on account of their characteristic and special requirements. Due to their physical condition, they are fragile in nature, and they need special attention and facilities in traffic to ensure safety, particularly as a pedestrian. Various studies show that the walking and crossing behaviour of elderly road users are different from the of young people.

Langlois et al. (1997) examined the sociodemographic, health characteristic and problems of elderly pedestrians in the context of road safety. This study estimated about 11% of residents reported difficulty with road crossing. Elderly pedestrian was addressing the slowest walking speed nearly about 3 times as likely as others to the purpose of the road crossing. Elderly pedestrians aged 72 or older estimated 1.22 m/s walking speed at the signalized intersection. Naveteur, Delzenne, Sockeel, Watelain, and Dupuy (2013) provided a comparison between the disabled older participants and their counterparts without disabilities expressed an estimation of crossing time at about actual and imagination road crossings. Gates, Noyce, Bill, Van Ee, and Gates (2006) presented that pedestrian walking pace was affected by age and disability, traffic control conditions, and the size of the group. The slowest pedestrians were those over the age of 65, with walking speeds of 3.81 and 3.02 feet per second, respectively. Crossing speeds of children and physically challenged people helped by adults were comparable to those of those over 65. Furthermore, walkers in groups of two or more crossed at a rate of 0.4 to 0.6 feet per second slower than single crossers.

Some studies have been focused on the factors of elderly people collision and their special needs. A study conducted by Oxley, Corben, Fildes, and Charlton (2004) on safety and mobility needs for elderly pedestrians identified some certain contributing factors to older pedestrians' greater collision and injury risk. The dominance of vehicles, high speed of vehicles at intersections and lack of traffic control on many roads used by pedestrians place high risk on an older pedestrian. As a result, older persons have numerous challenges when using public transportation, owing to a lack of accommodations for their unique needs and skills. Boenke and Schreck (2014) proved that in the road design process, the demands of the elderly, as well as the disabled, must be taken into account. Dropped kerbs are preferred by people in wheelchairs and pedestrians who want to cross the road safely and comfortably. Higher kerbs are preferred by blind and visually impaired people because they prevent them from stepping onto the road. Furthermore, visually impaired people require a discernible difference in the ground surface to determine where the sidewalk ends, and the traffic begins.

Most of the studies related to elderly person crash risk problem mainly concentrated on the elderly people safety problem as pedestrians and suggested their requirements as a pedestrian. There is no doubt that elderly people are most vulnerable as a pedestrian. However, more than 40 percent of fatal crashes involving elderly people fatalities are other than hit pedestrian crashes. In terms of the number of fatalities, this is 42 percent, 369 out of 886 fatalities are 60 and over aged from 2018 to 2020 are not pedestrian (ARI database, 2021). Therefore, there is a need to conduct a comprehensive study to evaluate the overall risk factors of elderly people fatalities in crashes comprising all types of crashes. Apart from this, all of the studies are mainly related to economically high-income countries, whereas traffic environment, characteristics, facilities, human behaviour and capacities are completely different in low- and middle-income countries like Bangladesh (Mahmud, Ferreira, Hoque, & Tavassoli, 2019). But there is no study concentrated on the elderly people traffic safety problem characteristics and crash risk factors using the crash data of these countries. In this study, an attempt has been made to evaluate the safety problem characteristics and crash risk factors through a comparative analysis between crashes resulted elderly fatalities and no elderly fatalities using logistic regression model using the latest three years crash data in Bangladesh. This study used 3 years of crash data from 2018 to 2020 developed by ARI, BUET based on media reported secondary information.

The rest of the paper has been organized as follows: The following section briefly outlines the striking characteristics of elderly people crash fatalities (Section 2). The next section presents the empirical model development which includes modelling methodology and data with descriptive analysis (Section 3). Empirical analysis including results and discussions are provided in the subsequent section (Section 4). Finally, the paper has been concluded with main findings, limitations, recommendations and future research direction.

2. SOME STRIKING CHARACTERISTICS OF ELDERLY PEOPLE CRASH FATALITIES

- Out of 10504 reported crashes in three years, from 2018 to 2020, there are at least 863 crashes where at least one person died who is 60 or above. Total elderly people fatalities among the reported age are 886, accounting for 11% of all road traffic known age fatalities (Table 1).

Table 1: Magnitude of the problem

Year	Total no. of Crashes	No. of Crashes with elderly people fatalities (%)	Total Fatalities	Fatalities Known Age	Elderly fatalities (%)
2018	3498	254 (7)	4005	2571	262 (10)
2019	3943	360 (9)	4365	3068	370 (12)
2020	3063	249 (8)	3561	2369	254 (11)
Total	10504	863 (8)	11931	8008	886 (11)

- In case of month, involvement of elderly people in August, September, and October is relatively higher in compared to the rest of the crash.
- Fatality rate per day in percent on the weekend holiday is more than the weekday, 1.27 vs 1.14, with particular prevalence on Friday. The percent number of elder and rest fatalities on Friday are 17 and 14 respectively.
- Hit pedestrian is the most dominant type of elderly fatality crash, accounting for around 60% of all such crashes, followed by rear-end (12%), head-on (9%) and lost control (8%) (Figure 1).

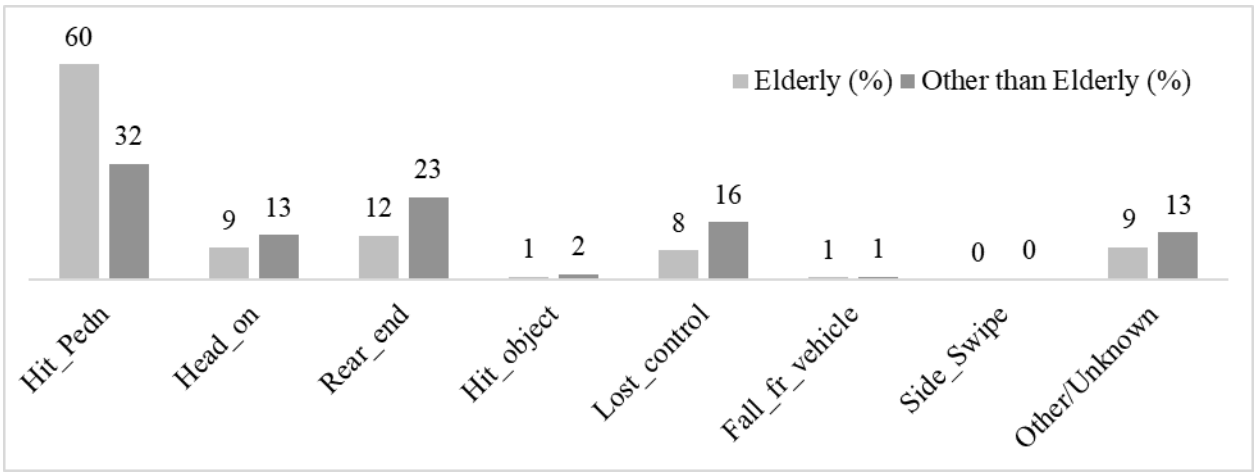


Figure 1: Crashes by crash type: Elderly fatality crashes and other crashes

- In case of vehicular involvement, bus is the prime most contributor in elderly fatalities in single vehicle crash (26%) which is followed by truck and motorcycle, both are equally contributed, 23%. Whereas, for the rest of the crashes, truck is the main contributor (29%), next to that is bus and motorcycle (Figure 2). In case of pedestrian vehicle crash, this share is almost equal for bus, truck and motorcycle (26%, 25% and 24% respectively) crash involving elderly fatality. In

contrary, pedestrian hit by truck is disproportionately higher in case of rest of the crashes, 37 % of all other hit pedestrian crashes (Figure 3).

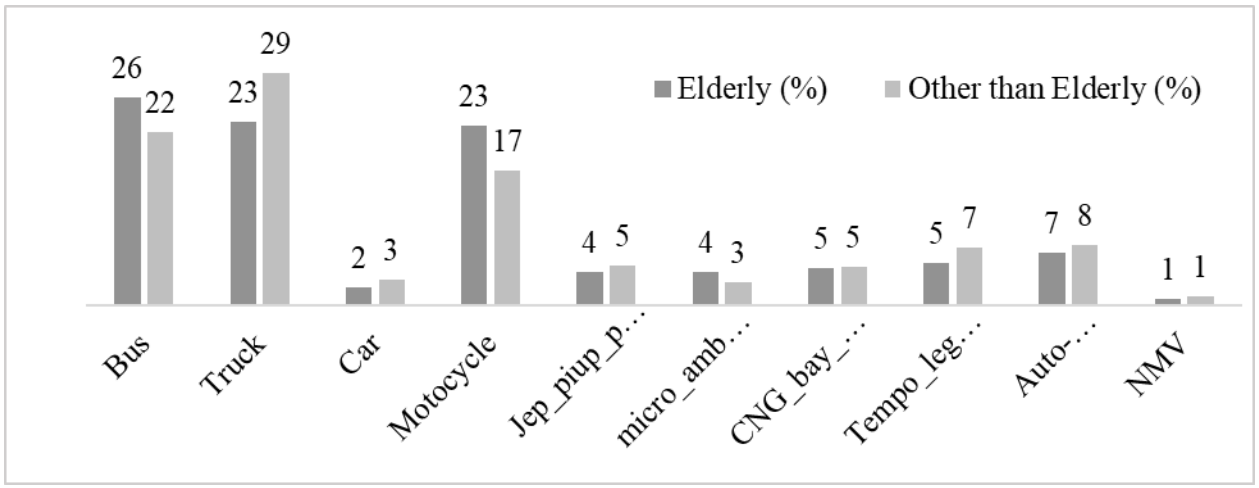


Figure 2: Vehicular involvement: Elderly fatality crashes and other crashes

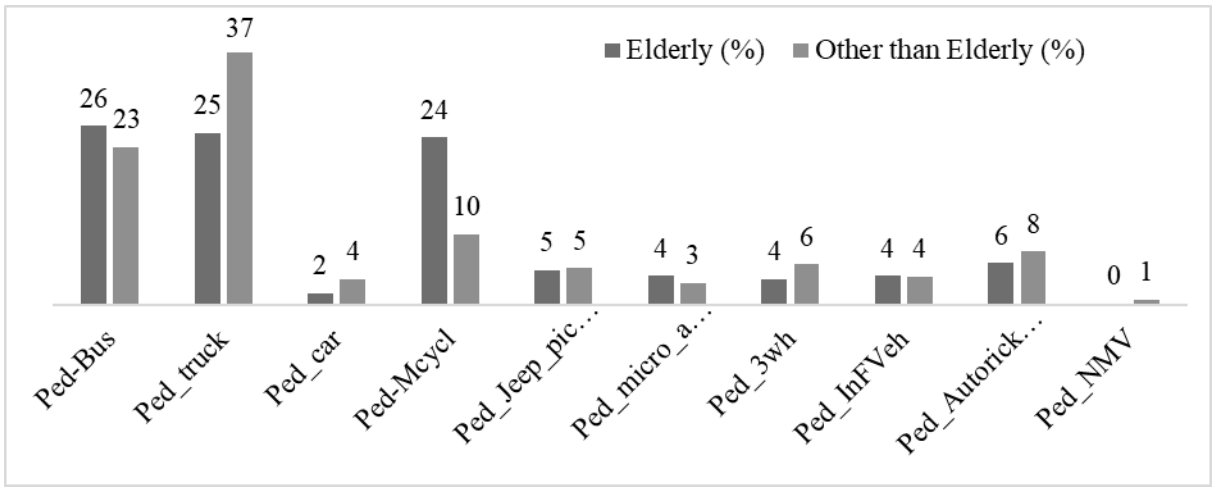


Figure 3: Vehicular involvement in hit pedestrian crash only: Elderly fatality crashes and other crashes

3. EMPIRICAL MODEL

3.1 Methodology

The binary nature of the dependent variable (crash involving elder people or otherwise) makes logistic regression suitable for the analysis. Mathematically, the logistic regression model is flexible and intuitive which results in meaningful interpretations (reference please).

Consider a dependent variable Y with two possible values coded as 0 or 1, and let x denote a value of the independent variable. The logistic function which defines Y is shown below (equation, i) (Manski & McFadden, 1981),

$$f(x) = \frac{1}{1+e^{-x}} \quad \text{(i)}$$

The range of the logistic function is 0 to 1, with x ranging from $-\infty \; to + \infty$. Assume the conditional mean or expectation of Y is specified as E to derive the particular logistic regression form from the logistic function $E(Y|x)$. To associate independent variables $x_1, x_2, \ldots, x_k$ this mean can be stated in a linear manner (equation, ii).

$$E(Y|x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k \quad \text{(ii)}$$

where $\beta_0, \beta_1, \ldots \beta_k$ are constant terms representing unknown parameters.
In order to simplify, the quantity $\pi(x) = E(Y|x)$ is used to represent the conditional mean of Y (crash type). The logistic regression model's particular form is as follows (equation, iii).:

$$\pi(x) = \frac{e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k}}{1 + e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k}} \quad \text{(iii)}$$

Where π is the probability of a response, β_0 denote the intercept and $\beta_1, \beta_2, \ldots, \beta_k$ denote the regression coefficients.

3.2 Data

The study used data obtained from Accident Research Institute (ARI), BUET. It is worth mentioning that ARI, BUET has developed an independent crash database based on print media crash report.

The preliminary analysis contained 82 independent variables under different categories including time, geographic area, crash severity, crash type, vehicular involvement, hit pedestrian accident by vehicle type etc. Most of the variables are converted to binary variable. Finally, 21 variables are found significant with 95% significance level. The descriptive statistics in terms of frequency and percent value of total number of the variables that have been found significant and included in the final model are presented in Table 2.

Table 2: The descriptive statistics of the significant variables

Variables	Frequency	Percent
Crash with no elderly fatalities	9641	91.8
Crash involving elderly fatalities	863	8.2
Time		
Day time	7567	72
Autumn	1723	16.4
October	826	7.9
Geographical area		
Metros_4	1612	15.3
Crash severity		
Major Fatal (>3 fatalities)	422	4.0
Moderate Fatal (at least 2 fatalities)	1029	9.8
Single Fatal ((at least 2 fatalities)	7385	70.3
Crash type		
Hit_Pedestrian	3627	34.5
Lost_control or overturn	1621	15.4
Crash involving Vehicle type		
Bus crash	1156	11.0
Motocycle crash	917	8.7
Jeep_pick-up_pajero (light vehicle)	256	2.4

CNG_baby_easy_3wheelers	256	2.4
Bus_Truck	202	1.9
Bus_M/C	383	3.6
Truck_M/C	813	7.7
M/C_4WhlLi	151	2.3
Hit Pedestrian by vehicle type		
Ped-Motorcycle	405	3.9
Ped_Jeep_pickup_pajero	174	1.7
Ped_micro_ambulance	108	1.0
Ped_3wh	184	1.8

4. EMPIRICAL ANALYSIS

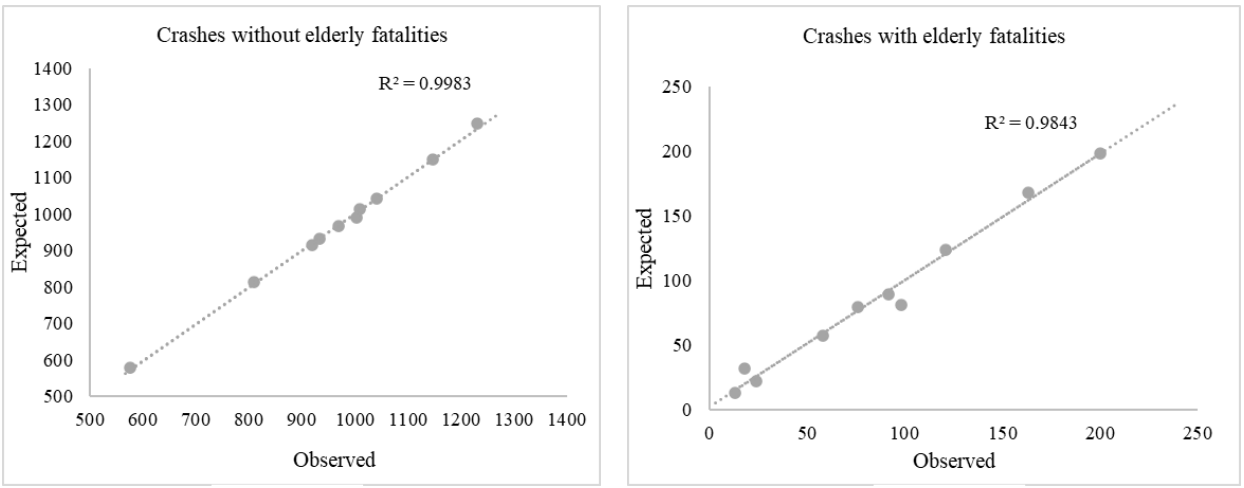
The model estimation results using logistic regression model derivatives are presented in Table 3. The table presents the model coefficient along with standard error, Wald Chi-square, significance and most importantly the odds ratio which represents the effect of a particular variable over others. It is to be noted that the positive value of the coefficient indicates that the likelihood of crash involving elderly fatalities will increase rather than other crashes and vice-versa. The total number of observations was 10,504. Among them there were 863 crashes where at least one elderly people died. The overall fitness of the model is relatively well with 91.8% correct prediction and large chi-square value (562.79). In terms of p-value, the model is significant with very small value (<000). Model performance interm of the relationship between the observed and estimated values for each categories of crash is shown in Figure 4 (a) crashes without elderly fatalities and (b) crashes with elderly fataliteis.

Table 3: Estimation results for crashes involving elderly people fatalities of the binary logistic regression.

Variables	Coefficients	Standard Error	Wald Chi-square	Significance	Odds Ratio
Constant	-3.755	.165	516.127	.000	.023
Time					
Day time	.189	.085	4.977	.026	1.208
Autumn	.198	.096	4.245	.039	1.219
October	.284	.135	4.453	.035	1.328
Geographical area					
Metros_4	-.294	.111	7.000	.008	.745
Crash severity					
Major Fatal (>3 fatalities)	2.118	.195	118.200	.000	8.311
Moderate Fatal (at least 2 fatalities)	1.204	.182	43.898	.000	3.334
Single Fatal (at least 1 fatality)	.850	.142	35.921	.000	2.341
Crash type					
Hit_Pedestrian	.695	.103	45.989	.000	2.004
Lost_control	-.389	.147	6.978	.008	.677
Crash involving Vehicle type					
Bus crash	.488	.110	19.678	.000	1.629
Motocycle crash	-.645	.260	6.158	.013	.525

Jeep_pick-up_pajero (light vehicle)	-1.668	.891	3.509	.051	.189
CNG_baby_easy_3wheelers	1.106	.369	8.982	.003	3.021
Bus_Truck	-.843	.396	4.541	.033	.430
Bus_M/C	-1.051	.330	10.118	.001	.350
Truck_M/C	-1.491	.283	27.722	.000	.225
M/C_light 4Wheelers	-1.586	.716	4.903	.027	.205
Hit Pedestrian by vehicle type					
Pedestrian-Motorcycle	1.894	.284	44.428	.000	6.646
Pedestrian_Jeep_pickup_pajero	1.882	.900	4.375	.036	6.564
Pedestrian_micro_ambulance	.649	.259	6.276	.012	1.914
Pedestrian_3wheelers	-1.240	.445	7.754	.005	.289

Number of observations	10,504
Percentage corrects	91.8
Log likelihood at convergence	-5403.723
Chi-square (21)	562.79
P-value	<000



(a) (b)

Figure 4: Model peroformance in terms of relationship between obsersed and estimated value

4.1 Results and Discussions

In the final estimated results, altogether 21 variables are found significant with 95% significant level. The analysis shows that in case of variables related to time of crash occurrence, daytime, autumn season and October month are found significant with positive coefficient which indicates that the likelihood of crash resulting elderly people fatalities in those times is higher compared to other time. Odd ratio is almost same for all three variables. The odds of being involved in an elderly fatality in a crash for daytime crash are 1.2 times higher compared to nighttime crash when all other variables are held constant. In case of geographic area, probability of crashes resulting elderly people fatalities is significantly lower in four major old metropolitan areas.

For crash severity, among four binary variables three are found significant. However, odds ratios are different. The likelihood of elderly fatalities is four and two and half times higher than the single fatalities and two fatalities crashes respectively controlling for all other factors in the model and these findings are normally consistent with the general belief and observations that the more fatalities in a crash are more dangerous elderly people.

In case of crash type, two types are found significant but with opposite sign. Elderly people are significantly more likely to be involved in hit pedestrian crash. In loss control crash, the likelihood of crash involving elderly fatalities is less rather than other crashes.

The study considered vehicular involvement in different crash and their significance in the elderly people fatalities in greater details. In case of single vehicle crash, bus, motorcycle, light vehicle, and motorized three wheelers are found significant. Among them bus and motorized three wheelers including CNG, baby taxi, easy bike and other motorized three-wheelers are showing positive sign and other two are showing opposite direction. The probability of elderly people fatalities in a single vehicle bus and motorized three wheelers crash is significantly higher than other single vehicle crashes, odds ratios 1.6 and 3.0 respectively. In case of two vehicle crash, bus & truck, bus & motorcycle, truck & motorcycle and motorcycle & light 4 wheelers are found significant but with negative sign.

In case of hit pedestrian by vehicle type, four variables are found significant, among them three are positive. Hit pedestrian by motorcycle and light four wheelers including jeep, Pajero and pick-up are represented as very high predictor of elderly people fatalities in a crash, recording odds ratio of over 6.5. This indicated that hit pedestrian by motorcycle and light four wheelers are over 6.5 times more likely to report elderly fatalities than the other hit pedestrian crash type, controlling for all other factors in the model. The odds ratio of 0.289 for elderly people fatalities crash is less than 1, indicating that for every hit pedestrian three wheelers crash, there are 0.29 times less likely to report having an elderly people fatality, controlling for other factors in the model.

5. CONCLUSIONS

Elderly people are one of the most vulnerable road users and are often viewed that they have special need to keep safe on road. Therefore, many jurisdictions in and around the world including developed and developing countries, have developed special policy, and invested additional resources to improve geometric design of road and vehicle, engineering features, enhance enforcement and educational campaign for the safety of elderly people. However, most of the study are concentrated on the safety problem characteristics and very little research has been conducted to examine factors associated with the elderly people safety problem, particularly in developing countries like Bangladesh. This study was performed to examine the significant factors and their impact associated with the likelihood of that crashes that resulted at least one elderly people fatality in compared to the other crashes.

At the very outset, this study highlights some striking characteristics of elderly people crash fatalities. The main contribution of this study is to develop a logistic regression model to evaluate the probability of crashes resulting child fatalities and estimated impact of different significant factors. Several relevant factors are tested, and 21 variables are found significant. In case of policy implications, the results showed that daytime, autumn season, October, major, moderate and single fatal crash, hit pedestrian, bus and 3-wheelers motorized vehicle including CNG, baby taxi, easy bike crash, pedestrian hit by motorcycle, jeep, pickup, Pajero, micro-bus and ambulance are positively correlated. On the other hand, metropolitan area, lost control type, motorcycle crashes with bus & truck, motorcycle hit by light motorized 4 wheelers, bus-truck crash, single vehicle crashes involving, Jeep, pickup, Pajero, and pedestrian hit by motorized 3 wheelers are negatively correlated i.e., the variable decreases the likelihood of elderly person fatalities in a crash. Hit pedestrian by motorcycle and jeep, pickup and Pajero are the most dominant and strongest elderly fatality risk factor with odds over 6.5. This implies that hit pedestrian crash by these categories of vehicle are over 6 times more

likely to report elderly people fatalities in a crash than hit pedestrian by other vehicles, controlling for all other factors in the model.

From the analysis, it is clear that elderly people are most vulnerable as a pedestrian. Therefore, walking and crossing facilities need to be designed considering the need of elderly persons such as proper ramp, obstruction-free continuous footpath, disabled friendly crossing facility etc. It is found that, as a pedestrian, motorcycle and jeep, pickup and Pajero are the most dominant risk factor for elder people. Special attention needs to be taken focusing on the development of awareness, education of the riders and drivers and upkeep of adequate enforcement to ensure safety-conscious behaviour on a priority basis. Bus and light vehicles particularly 3-wheelers drivers need to make more concerned about the issues of elderly people and their safety. An elderly person should be more cautious to use 3-wheelers motorized vehicle including CNG, baby taxi, easy bike etc. There is also a need for a policy guideline regarding the operation of this type of vehicle on road, especially on the city and main roads. Special guidance also should be provided particularly to reduce daytime, seasonal and monthly risk factors. Apart from this, the model results would be useful to identify potential target areas and set the right priorities for future engineering, enforcement, and educational program for improving elderly people mobility facilities and safety in Bangladesh. Moreover, the model estimation results have important implications for effective safety management to ensure mobility needs of the citizen including elderly people and safe traffic operation in developing countries.

This study is based on print media reported crash database which contains some most common types of information or attributes. Many important parameters are missing in this report. Inclusion of other variables like road geometry, driver, passenger profile etc. and/or more samples may provide better output and could be a future research direction as well. A further attempt also could be made to develop case-specific or area-specific, such as hit pedestrian crash type, urban crash or intersection crash type, micro-level crash prediction models for elderly people fatalities with the incorporation of some other attributes and/or using more advanced modelling derivatives.

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