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Full Length Research Paper

Accident severity analysis on national highways in Bangladesh using ordered probit model

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National Highways of Bangladesh, where majority of fatal accident takes place, are considered as the accident-prone location. Statistics revealed that despite some major initiatives undertaken to improve road safety, death rate at National Highways of Bangladesh is quite high compared to other developed as well as developing nations. To understand the relationship between injury severity and accident factors, investigation concentrate on different influential factors are responsible for injury severity. Micro Computer Accident Analysis Packages (MAAP5), data of Bangladesh Police from 2004-2015, is used in this investigation to identify the probability of fatal and grievous injury. Preliminary analysis revealed that almost 80% accident recorded as fatal accident and majority of the accidents occurred in fair-weather condition, at straight portion of the road, in non-rush hour and in broad daylight. Conversely, three level of injury severity (dependent variables) was considered in the econometric analysis namely, fatal, grievous and simple injury. Ordered Probit Model examined the dependent variables based on several explanatory variables such as time factors, road geometry, environmental conditions, vehicle categories, driver attitudes, passenger and pedestrian behavior. Considering different level of independent variables, it is found that under the heading of "collision type", "hit Pedestrian" is the statistically significant variable that creates severe injury. Considering vehicle characteristics, non-motorized vehicle, bus and motorcycle was found to be the most vulnerable group of road users in Bangladesh and the probability of fatal injury is much higher for vehicle with multiple defects. This investigation also pointed on some remedial measures that will help the decision maker to set up long as well as short term strategies. For instance, installation of physical barrier at the accident-prone location will minimize the pedestrian fatalities and isolation of non-motorized vehicle and motorcyclist from main carriageway, which would dramatically reduce injury severity on highways. Finally, this investigation also provides some specific guideline for future steps on injury severity analysis in Highways of Bangladesh.

Key words: National Highway, Fatal Accident, Ordered Probit Model, Variables

INTRODUCTION

Worldwide Road Traffic Accident (RTA) is accepted as the leading cause of death. It is estimated that every year, approximately 1.25 million people are cut short due to road crash. Road Traffic Injuries (RTI) is also

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responsible for death of young people aged between 15 to 29 years (World Health Organization, WHO, 2017). Also, 54% of vehicle and about 90% of road fatalities occur in the streets of low and middle-income countries. In addition, halve of those population are the most vulnerable road users including pedestrian, cyclist and motorcyclist who die on the world street. Despite low motorization, Bangladesh has the worst fatalities in the region with 85.6 fatalities per 1000 vehicles followed by Nepal, India, Pakistan and Sri Lanka (The World Bank, 2015). Every year, around 4000 people lose their lives and almost 5000 people critically injured due to road accident; and the estimated cost of road crash is about £5.0 million per year. It is expected that without having effective remedial measures, expansion of road network and traffic growth will amplify road fatalities (National Road Safety Council, 2011-2013). Accident pattern in Highways of Bangladesh is the most complicated and injury severity influenced by several contributing factors such as human, vehicle, and roadway factors etc. Various government agencies hardly work on road safety management program. This study analyzes the highway accident data of Bangladesh and concentrates on the most significant factors which include road factors, vehicle factors, driver factors, environment factors etc.; that are vulnerable for injury severity and such findings will help the decision maker to set up appropriate strategies to mitigate road related irregularities. This investigation also focuses on setting the long and short-term targets so that states can use its limited resources in an optimal way. Chronological arrangement of this study is:

(i) Extract the accident data from MAAP5 (Micro Computer Accident Analysis Package) database of BRTA/ARI (Accident Research Institute), Bangladesh.
(ii) Identify the most significant factors on accident severity including road geometry, vehicle and traffic characteristics and environmental factors etc.
(iii) Preparation of graphical representation on several contributing factors which will help to correlate the different factors.
(iv) Introduce appropriate econometric model to identify the probability of severe injury based on different independent variables.
(v) Consider statistical model result, and the recommendation provided for potential safety measures/ strategies to prevent accident hazards on highways.

LITERATURE REVIEW

Diverse statistical approach has been employed by the researcher to identify correlation among the contributing factors as well as the severity of accident. Frequently used techniques are: 1) logistic regression, 2) multinomial logit or nested logit model also known as unordered response model and 3) ordered response model widely known as ordered probit or logit model.

Xi et al. (2014) studied the influence of road geometric element (at curve segment) on road crash severit, using logistic regression model. The investigation analyses the accident data based on 15 evaluation indicator including driver, driving conditions and traffic factors. Binary logistic regression model considered dependent variable in the binary form that is 1 for death and 0 for otherwise. Crash severity used evaluation categories (independent variables) which are: driver attributes (gender, age, household register, driving knowledge, etc.); driving environment (weather conditions, terrain, visibility, road surface condition, lighting condition); and road environment (traffic signal, roadside protection, physical separation, pavement structure and surface conditions). Weather is considered as the main contributing factors in the accident severity, as bad weather conditions reduce the visibility and co-efficient of friction between tyre and road surface. Moreover, severity will be greater when the vehicle crosses over the median, roll over or rear end collision under foggy, snow or ice weather condition. In addition, providing speed limit and road side protection facilities greatly reduce crash severity, especially in the mountain regions. Pavement surface condition also put positive impact on accident severity. For instance, compare cement concrete or gravel pavement; asphalt pavement offer smooth riding facilities to the driver which induced speed and due to temperature sensitivity, asphalt pavement loses its structural strength in adverse weather condition and create severe accident.

While analyzing the contributing factors that affect the injury severity in the Erzurum and Kars Provinces of Turkey, Çelik and Oktay (2014) categories three level of injury severity namely fatal, injury and no injury. In this study, risk factors are divided into seven different characteristics such as driver factors, accident categories, vehicle types, temporal, environmental conditions, road geometry, and traffic control. Independent variables such as driver characteristics which describe the demographic features of driver including age, gender and education level; accident characteristics which includes speed violation and collision type; vehicle characteristics which concentrate on type and number of vehicle accountable for accident; temporal characteristics which describes the time and day of the week; environmental characteristics that illustrates seasonal variation, weather condition, natural lighting and road surface; geometric characteristics including road type and road class; and control characteristics describes the pedestrian cross walk and traffic lights that accumulate to analyze crash severity. Model output implies that drivers aged 65 or older, having primary education, state route with single vehicle accident and highways. Having pedestrian crossing facilities increases the probability of severe injury. Conversely, car or private vehicles operating on cities streets at the evening peak with clear weather conditions decrease the probability of severe injury.

To analyses and quantify the impact of crashes on driver injury severities, Wu et al. (2016) employed NLM and mixed logit model; where driver injury severity categories as no injury, probable injury, noticeable injury, incapacitating injury and fatality. The conceptual idea of choosing the nested logit model is that individual preferences (perception time, driving experience, vehicle category, etc.) influence driver's injury severity, involving similar crash type under the same situation. Model output of mixed logit model represents the impacts of single vehicle crashes on driver's injury severity in rural areas, whereas nested logit model represents the crashes in urban areas.

Abegaz et al. (2014) analyzed the impact of vehicle crash on Injury severity. The study investigates one of the main two-way two-lane busiest highways of Ethiopia, 61 km long. Generalized ordered logit (partial proportional odds model) analyzed the data from June 2012 to July 2013 to assess the contributory issues that influence the crash severity. Ordered logit calculated four level of injury severity: no injury, minor injury, serious injury, and death. Explanatory variables categories as driver's attributes (age, alcohol, speed, fatigue etc) crash type, road features (alignment, traffic sign, speed limit etc), vehicle category and environment (light/weather). Investigating driver's risky behavior, estimated co-efficient measures that sleep/fatigue and alcohol impaired driver are liable for severe injury; whereas speed has diverse effect on injury severity, ranging from no injury to death. Considering environmental attributes, driving in the rain is a significant cause of injury severity compared to clear weather conditions. Similarly, driving in the dark likely produces severe injury. In addition, minibus, vans, two wheeled as well as three wheeled vehicles increase the probability of sever accident.

Rifaat and Chin (2010) employed Ordered Probit Model to connect injury severity with risk factors. To identify the contributing factors behind crash severity, the study analyzes driving attitude, road factors, vehicle characteristics and pedestrian behavior. Regarding driver characteristics, roadway features, vehicle types, pedestrian characteristics, the study concentrates on the contributing factors behind crash severity. Ordered probit model considered three level of injury severity: fatal injury (dies within 30 days of accident); serious injury (if a person suffered fracture, concussion, etc or other forms of bodily pain and have to take medical leave for 7days); and slight injury (if victims suffer from slight injury and have to take medical leave for 3 days) as dependent variables. Several independent variables have been tested for their statistical significance and correlation before running the final model. For instance, roadway factors and speed are strongly correlated, and it was found that road factors are better indicator for predicting accident severity. Likewise, some factors like day of the week, gender, security camera etc are statistically insignificant and excluded from the final model. For two and single vehicle crashes, independent variables classified in 5 groups: general characteristics including time of the day; vehicle characteristics (types of vehicle related to car etc); road characteristics (types of location related to straight road etc); driver characteristics (offending party related to non-offending etc); and crash categories including collision types. Conversely, pedestrian accident variables such as location of accident and pedestrian activities have been included in the final model.

Model output (estimate coefficient β) for time factors indicates that night time crashes are the severest for all three model which may be the effect of low vehicle frequency that push speed, reduce visibility and late reaction time that increase the severity of accident. In addition, crash involves in two-vehicles, when heavy truck colloid with motor cycle it creates severe accident. Moreover, road classification and accident area significantly influence crash severity; particularly, expressway and curve generate worst severe accident. However, apart from turning at curve, narrow road width with moist surface negatively influenced the accident severity. Analyzing the single and two vehicle crashes, age distribution of the drivers indicates that older driver intensifies the injury severity. The younger driver, especially, motorcycle rider increases the severity in single vehicle crashes. Conversely, considering other forms of collision which includes colloid with parked vehicle, lamp post, guard rail or sign post, and hitting trees shows the greatest fatality risk. Finally, older pedestrian shows higher injury risk compared to younger ones and night time crashes are more vulnerable compared to day time.

Earlier works concentrate on some specific issue including human, environmental and road factors. However, Pattern of accident is quite complex for developing countries like Bangladesh and no significant investigation has been carried out for developing econometric model that correlate the injury severity with contributing factors. The objectives of this study are to analyze highway characteristics (roadway features, traffic control, speed limit etc), vehicle factors (e.g., collision type, maneuver), environment condition (e.g., rain, fog), driver attributes (e.g., seat belt worn, alcohol), pedestrian characteristics and passenger characteristics (position, activities) that connect different influential variables. The statistical analysis including econometric model provide the significance of different attributes on crash severity and pointed on the specific issue which would require more attention and suggests some ways to improve highway safety.

METHODOLOGY

The investigation focuses on the estimation of accident severity at national highways in Bangladesh and how to appropriate statistical model will be employed that will help to develop specific strategies for highway safety improvement in the country. Accident database of National Highways from 2004 to 2015 was extracted from Accident Research Institute (ARI) database and stored in the MAAP5 (Microcomputer accident analysis package) database system.

In Bangladesh, highway police (rank of police inspector) is responsible for accident reporting. After having information on road accident, the data recorded as the First Information Report (FIR) or in the form of General Diary (GD), then the police officer fill up the Accident Report Form (ARF) which contains 67 different field of information, ARF accumulate wide range of variables including time factors (time and date of incident), roadway factors (junction type, location, road class, surface type, quality and conditions, road geometry), crash characteristics (head-on, rear-end, angle, hit pedestrian etc), environmental factors (weather, light), controlling factors (traffic control, movement, divider), vehicle factors (type, maneuver and loading of vehicle, fitness certificate, defects, damage etc), driver attributes (sex, age, driver injury, alcohol, seat belt worn), passenger attributes (age, sex, position, activities) and Pedestrian attributes (age, sex, position, action). After extracting accident database from MAAP-5, econometric model has been employed to quantify the Dependent Variable (Fatal/Grievous/ simple) based on independent variable.

Econometric model for ordered discrete data

MAAP5 considered four level of accident severity: Fatal, Grievous, Simple Injury and Motor collision. Due to similar nature and having very few data, motor collision merged with simple injury and in the final model 3, level of injury severity were considered for investigation. The dependent variable in this study is more than two categories; this means accident analysis is multivariate rather than the descriptive or univariate/bivariate. Appropriate approach for ordered response discrete choice is either logit or probit model; considering ordinal nature data, ordered probit model was recognized as suitable for this analysis.The equation for ordered probit model can be expressed as:

$$y^* = x_i\beta + \varepsilon_i \quad (1)$$

where y_i^* is the predicted injury severity of the ith victim in accident; β is a row vector of unknown parameter; xi is a vector of explanatory variables; ε_i is the random error term (Lee & Abdel-Aty, 2005).

Equation of the observed ordinal variable can be defined as:

$$y_i = j \text{ if } \mu_{j-1} < y_i^* \le \mu_j \quad (2)$$

where j can take any values from 1 to m and μ is the cut point which can be represented as $\mu_0 = -\infty$ and $\mu_m = +\infty$

From the above equation, predicted injury severity (observed and coded discrete injury severity), y_i can be calculated in the following order:

$$y_i = \{1 \text{ if } -\infty \le y_i^* \le \mu_1 \text{ (Simple injury) } 2 \text{ if } \mu_1 \le y_i^* \le \mu_2 \text{ (Grievous injury) } 3 \text{ if } \mu_2 \le y_i^* \le +\infty \text{ (fatal injury)} \quad (3)$$

Where the μ1 and μ2 (threshold values) are the unknown parameters estimated in the model.

Changes in explanatory variables significantly change the probability of dependent variables in ordinal nature. To identify the impact on dependent variables as ordinal outcomes, equation can be expressed as:

$P(y_i = 1) = P(\mu_0 < y_i^* \le \mu_1)$, [here the lowest severity level considered as Equation 1]

Using the threshold value $\mu_0 = -\infty$ and $y^* = x_i\beta + \varepsilon_i$ equation can be re-write as

$= P(\varepsilon_i \le \mu_1 - x_i\beta)$

$P(y_i = 1) = F(\mu_1 - x_i\beta)$

For the 2nd value in ordinal ranked

$P(y_i = 2) = P(\mu_1 < y_i^* \le \mu_2)$ and by substituting $y^* = x_i\beta + \varepsilon_i$

$P(y_i = 2) = F(\mu_2 - x_i\beta) - F(\mu_1 - x_i\beta)$

Similarly the highest rank of severity value yi =3

$P(y_i = 3) = F(\mu_3 - x_i\beta) - F(\mu_2 - x_i\beta)$

Generalized form of probability can be expressed as:

$$P(y_i = j) = F(\mu_j - x_i\beta) - F(\mu_{j-1} - x_i\beta) \quad (4)$$

When j=m, probability equation can be rewrite as

$P(y_i = m) = F(\mu_m - x_i\beta) - F(\mu_{m-1} - x_i\beta)$

$$= 1 - F(\mu_{m-1} - x_i\beta) \; [F(\mu_m - x_i\beta) = F(\infty - x_i\beta) = 1] \quad (5)$$

For this study three level of estimated co-efficient was observed in the model, y_i takes the value of 1 for simple/motor collision, grievous injury is considered 2 for y_i and finally, for the fatal injury y_i takes the maximum order of 3, here $y_i = m = 3$ for fatal injury and the probability can be measured with the following equation:

$$\text{For simple injury} = P(y_i = 1) = F(\mu_1 - x_i\beta) \quad (6)$$

$$\text{For Grievous injury} = P(y_i = 2) = F(\mu_2 - x_i\beta) - F(\mu_1 - x_i\beta) \quad (7)$$

$$\text{For Fatal injury} = P(y_i = 3) = 1 - F(\mu_2 - x_i\beta) \quad (8)$$

Estimated parameters based on variation of explanatory variables, the probability of injury severity were calculated. For instance, some independent variables are positively associated with the probability of injury severity; whereas some factors reduce the probability of fatalities.

Modelling with Ordered Probit Model based on general and vehicle characteristics information

Total 7721nos data has been extracted from the MAAP5 software for this investigation, after extracting, it was found that some of the explanatory variables are small and some of the independent variables are strongly correlate to each other, also ARF also bear some empty cell in the database for some attributes. Due to ordinal in nature, fatal accident considered as the highest level of injury severity and Simple/Motor Collision in the lowest scale of severity (Table 1).

Based on preliminary analysis, some of the variables such as accident date, month, year, road features and road class are not included in the modeling as these types of variables is statistically insignificant and provides indistinct effect on injury severity. Moreover, some of the independent variables like morning peak, evening peak merged as peak hour. Similarly, small truck, medium truck, heavy truck etc. are considered for goods, which has impact on these attributes and are very close to each other. Considering all the explanatory variables, it was noticed that Collision Type, Light effect, Vehicle Type, Vehicle Defects and Vehicle Damage provide the statistically significant output. So, in the final model the independent variables provide statistically significant outputs that are considered in the final model. From Table 2, it is obvious that based on angle collision, hit pedestrian (estimated co-efficient, β=0.921) accident type provide highest positive impact on fatal injury. However, head-on (β=0.458) and overturned collision (β=0.444) is also positively associated with injury severity for pedestrians. In addition, statistical analysis also specifies that in collision type has the highest number of accidents, recorded as “hit pedestrian”.

Table 1. Explanatory variables considering general and vehicle characteristics for single vehicle.

Description	Categorization	Description	Categorization
Injury	= 1; if Simple/Motor Collision = 2; if Grievous = 3; if Fatal	Junction Type	= 1; if Not in Junction = 2; if Not Defined = 3; if Cross/Tee/Roundabout
Collision Category	= 1; if Head-on = 2; if Rear-end = 3; if Hit Pedestrian = 4; if Hit Object/Vehicle = 5; if Overturned Vehicle = 6; if Angle Collision	Time of Accident	= 1; if Peak Hour (0700 to 1000 and 1600 to 1800) = 2; if Midnight to Early Morning (0000 to 0700) = 3; if Evening to Midnight (1800 to 0000) = 4; if Non-Rush Hour (1000 to 1600)
Light	= 1; if Night (lit) = 2; if Dawn/Dusk = 3; if Night (unlit) = 4; if Daylight	Traffic Control	= 1; if No Control = 2; if Signal Control = 3; if Police Control
Vehicle type	= 1; if Non-Motorized Vehicle = 2; if Motorcycle = 3; if Bus = 4; if Goods Vehicle = 5; if Car/jeep	Surface Type	= 1; if Earth = 2; if Brick = 3; if Sealed
Vehicle Defects	= 1; if Multiple = 2; if Lights/Brakes/Steering = 3; if None	Surface Quality	= 1; if Good = 2; if Rough/Under Repair
Vehicle Damage	= 1; if None = 2; if Multiple = 3; if Front/Rear/Roof	Surface Condition	= 1; if Dry = 2; if Wet
Movement	= 1; if One Way = 2; if Two Way	Road Geometry	= 1; if Curve/Slope = 2; if Straight/Flat
Divider	= 1; if No = 2; if Yes	Vehicle Maneuver	= 1; if Crossing/Overtaking = 2; if Going Ahead = 3; if Turning/Stopping
Weather	= 1; if Rain/Wind/Fog = 2; if Fair	Vehicle loading	= 1; if Legal = 2; if Illegal/Unsafe
		Alcohol	= 1; if Alcohol Suspects = 2; if Not Suspect

In Bangladesh, national highways are always exposed and frequent movement of pedestrian along the road is very common in the road side market (local bazar) location. In addition, having limited knowledge on road safety, people cross the street in indefinite way which intensifies the pedestrian fatality in built-up area. While investigating 1491 crashes of 148 roundabouts in Flanders-Belgium, Daniels et al. (2010) also found that pedestrians, bicyclists, moped riders and motorcyclists are the most vulnerable group of road users and are severely affected than other groups. Considering the vehicle characteristics, most significant estimated coefficient were detected for non-motorized vehicle (β=0.409) and motorcycle (β=0.404). Non-motorized vehicle already been a part of transport system of Bangladesh. Considering availability and economy, general people depends on locally modified vehicle for short trip, without having any physical separation; non-motorized vehicle as well as motorcycle share the space on motorways which boosts the fatality on highways for these two groups. Conversely, motorized two-wheeler operators are unaware of safety measures and travel without wearing helmet that amplifies the fatality on highways. Similar study in Singapore (Quddus, et al., 2002) investigates the factors that affect the injury severity among the motorcyclist and damage level of the vehicle involved in the crash pointed to diverse factors accountable for severe injury including increasing the engine capacity, headlight not turn on during day time, collisions with pedestrian and stationary objects. Driving early morning hours and having pillion passengers also leads to severe injury for non-Singapore nationalist. Surprisingly, improving road design standard increases the probability of severe injury for motorcycle-involved accident.

Finally, multi-defective vehicles (β=0.281) hold positive estimated co-efficient compared to vehicle having no defects that is fatality is much higher for multi-defective vehicles. Strictly speaking, there are no options for issuing fitness certificate for locally modified vehicles (Non-motorized vehicles) and frequent movement of NMV on highway increase the severe injury. However, developed nations tackle diverse problems associated with vehicle defects. Abdel- Aty

Table 2. Estimated parameter considering general and vehicle characteristics.

Variable description	Category for each variable	Estimate	Std. Error	P-value
Collision types	Head-on	0.458	0.062	0.000
	Rear-end	0.316	0.067	0.000
	Hit Pedestrian	**0.921**	**0.064**	**0.000**
	Hit Object/Vehicle	0.204	0.077	0.008
	Overturned Vehicle	0.444	0.073	0.000
	Angle Collision			
Light	**Night (lit)**	**0.241**	**0.083**	**0.004**
	Dawn/Dusk	0.204	0.048	0.000
	Night (unlighted)	0.037	0.048	0.432
	Daylight			
Vehicle type	**Non-motorized Vehicle**	**0.409**	**0.057**	**0.000**
	Motorcycle	0.403	0.079	0.000
	Bus	0.272	0.050	0.000
	Goods Vehicle	0.253	0.046	0.000
	Car/jeep			
Vehicle defects	**Multiple**	**0.281**	**0.046**	**0.000**
	Lights/ Brakes/ Steering	0.072	0.081	0.374
	None			
Damage	None	0.243	0.045	0.000
	Multiple	**0.268**	**0.044**	**0.000**
	Front/Rear/Roof			
Threshold	Parameter 1	-0.372	0.111	0.001
	Parameter 2	0.467	0.111	0.000

and Abdelwahab (2004) investigate the motorways of United State and found that inappropriate geometric design of Light Truck Vehicle (LTV) such as light-duty truck, vans and utility vehicles obstruct the visibility of following passenger cars and generate rear-end collision. Among the other influential variable including drivers age, gender, traffic control device, action initiated by leading vehicle and inattention, obstructing vision plays a significant role in rear-rear end collision. Sudden application of brake on a moving vehicle also increase the probability of car-truck rear-end collision.

Modelling with Ordered Probit Model based on pedestrian characteristics

Injury severity for pedestrians is classified in three groups: Fatal, Grievous and Simple. Due to ordinal nature, sequential form of the pedestrian fatality is 3= Fatal, 2= grievous and 1= Simple. In addition, Gender, Position of the Pedestrian and Activities of the Pedestrian are considered as the prime explanatory variables that influence the injury severity for pedestrian on highways. Injury severity has been tested with 3430 number of accident data which include time of accident, junction type, collision type, vehicle type, defects and fitness as well as surface type (Tables 3 and 4).

Econometric model for pedestrian activities indicates that compared to road side or footpath, road center imposes significant (β=0.210) impact on accident severity and fatality is much higher (β=0.367) for the pedestrian who is crossing the road. In addition, compared to non-rush hour, mid night to early morning provides significant effect on pedestrian fatalities. Moreover, compared to males, fatality is higher for the female pedestrian. In the preliminary analysis, it was noticed that a number of fatal accidents is higher for road side; whereas probability of fatality is much higher when pedestrians are hit by vehicles on road center. Vehicles at road center operate with higher speed and collisions with pedestrians impose severe injury. In addition, during the midnight to early morning, drivers are incautious about the pedestrian, this increases the fatal injury. To understand the relationship between injury severity and risk factors, a study (Rifaat and Chin, 2010) pointed to older pedestrians who have higher injury risk compared to younger ones.

Modelling with Ordered Probit Model based on passenger characteristics

To identify the accident severity of passengers, fatality scale was analysed using the unique pattern of pedestrian attributes namely fatal, grievous and simple. Passenger location including on roof,

Table 3. Description of the major variables considered in the pedestrian Injury Severity.

Description	Categorization	Description	Categorization
Pedestrian Injury	= 1; if Simple = 2; if Grievous = 3; if Fatal	Pedestrian Action	= 1; if Walking along the road Side = 2; if Crossing the Road = 3; if No Action
Pedestrian Gender	= 1; if Female = 2; if Male	Time of Accident	= 1; if Peak Hour (0700 to 1000 and 1600 to 1800) = 2; if Midnight to Early Morning (0000 to 0700) = 3; if Evening to Midnight (1800 to 0000) = 4; if Non-Rush Hour (1000 to 1600)
Pedestrian Location	= 1; if on pedestrian Crossing = 2; if Road Center = 3; if Road Side/Footpath	Junction Type	= 1; if Not in Junction = 2; if Not Defined = 3; if Cross/Tee/Roundabout

Table 4. Estimated co-efficient for pedestrian injury severity.

Variable	Category for each variable	Estimate	Std. Error	P-value
Gender	**Female**	**0.188**	**0.077**	**0.015**
	Male			
Pedestrian Position	On Pedestrian Crossing	0.113	0.086	0.185
	Road Centre	**0.210**	**0.088**	**0.018**
	Road Side/Footpath			
Pedestrian Activities	Walking along the road side	0.256	0.085	0.003
	Crossing the road	**0.367**	**0.082**	**0.000**
	No Action			
Time of Accident	Peak Hour (0700 to 1000 and 1600 to 1800)	0.069	0.064	0.277
	Midnight to Early Morning (0000 to 0700)	**0.232**	**0.075**	**0.002**
	Evening to Midnight (1800 to 0000)	0.196	0.073	0.007
	Non-Rush Hour (1000 to 1600)			
Junction Type	**Not in Junction**	**0.181**	**0.080**	**0.024**
	Not Defined	0.166	0.104	0.110
	Cross/Tee/Roundabout			
Threshold	Parameter 1	-6.489	0.650	0.000
	Parameter 2	-5.377	0.649	0.000

inside or outside vehicle and passenger activities including no action, boarding/de-boarding and falling off were considered as the prime independent variables that affect injury severity of passengers. However, several independent variables such as time, collision type, weather characteristics, light effects, vehicle type and defects, fitness certificate, surface condition, etc also influences passenger injury severity (Tables 5 and 6).

Estimated co-efficient for passengers implies that roof (β=0.523) is the most extreme position that provide fatal injury for passengers who board on roof of vehicles. Staying inside vehicles is treated as the safest position; impact less compared to the other two locations. Also, falling off the vehicle also provide statistically significant positive impact on injury severity compared to no action. During festival time, mass movement of people noticed in Bangladesh, due to shortage of public transport, low income people travel in overloaded vehicles; which intensifies the fatalities in the highways. In addition, during the rush time, goods vehicle also carry passengers and this generates severe accidents in Bangladesh. A study (Van et al., 2017) on three accident prone locations of highways in Bangladesh demonstrate that public transport like bus are involved in most of the accidents and maximum number of accidents occur during overtaking, in the form of head-on collision.

FINDINGS AND COUNTERMEASURES

Econometric analysis on general factors identified two

Table 5. Independent variables affect the passenger injury severity.

Description	Categorization	Description	Categorization
Passenger Injury	= 1; if Simple = 2; if Grievous = 3; if Fatal	Vehicle Fitness	= 1; if Yes = 2; if No = 3; if Not Applicable
Passenger Position	= 1; if On Roof = 2; if Outside Vehicle = 3; if Inside Vehicle	Vehicle Defects	= 1; if Multiple = 2; if Lights /Brakes /Steering = 3; if None
Passenger Action	= 1; if Boarding/De-boarding = 2; if Falling Off = 3; if No Action	Passenger Gender	= 1; if Female = 2; if Male

Table 6. Estimated probability for passenger injury severity.

Variable	Category for each variable	Estimate	Std. Error	P-value
Passenger position	**On Roof**	**0.523**	**0.144**	**0.000**
	Outside Vehicle	0.124	0.096	0.200
	Inside Vehicle			
Passenger activities	Boarding/De-boarding	0.147	0.114	0.198
	Falling Off	**0.161**	**0.067**	**0.016**
	No Action			
Vehicle fitness	Yes	0.190	0.103	0.065
	No	0.159	0.112	0.157
	Not Applicable			
Vehicle defects	Multiple	0.168	0.059	0.004
	Lights/Brakes/Steering	0.039	0.107	0.719
	None			
Threshold	Parameter 1	-1.020	0.160	0.000
	Parameter 2	0.150	0.159	0.346

most statistically significant independent variables: Collision type and Lights that influence the injury severity on highways and pedestrians identified as the most vulnerable group of road users who face severe injury when hit by vehicles. Road side commercial activities are very common in Bangladesh and due to lack of road safety knowledge, general people incautiously cross the highway without following any definite pattern that boosts the fatality on motorways. In addition, over speeding vehicle and reckless driving increase crash severity on highways when it collides with pedestrians. Road side market development should be restricted as this type of shopping attracts pedestrian movement along the highway. Ensuring implementation of "The Highway Act, 1925" (The Highway Act, 1925, 2017) and Road Safety Strategic Action Plan, 2011-2013 may reduce roadside activities. In addition, formal and non-formal educational programs, adults and mass communication program may change the attitude of the pedestrian towards movement on highways. Moreover, to ensure safe movement of pedestrians, adequate crossing arrangements like foot over bridge, underpass, and pedestrian signal crossing should be facilitated on the highway. Surveillance camera should be installed in the accident-prone location on the motorways to help identify reckless driving and help the enforcing agencies (Highway Police) to maintain strict traffic rules including speed limit. Engineering measures like constructing physical barrier at major accident location also help to restrict the pedestrian from frequent movement on the highways and speed reducing arrangement lessen the fatality rate.

Statistical analysis on vehicle characteristics, non-motorized vehicles and motorcycle were found to be the vulnerable groups of vehicles followed by public transport like buses that operate on the highways. Due to unavailability of public transport, local people rely on non-motorized vehicle to cover short distances and without having alternative routes, motorcycle as well as non-motorized vehicles share the space on highways with the comparatively high-speed vehicles which creates fatal accident when they collide with heavy vehicles. Socio economic condition of Bangladesh makes the people move through the motorways, separate lane for non-motorized vehicle and motorcycle significantly reduces crash frequency as well as severity on the highways. To segregate non-motorized vehicles, Road Master plan (2009) provided specific guideline on how to construct such lanes. However, due to lack of adequate funding (The World Bank, 2016) such initiatives are still in the planning state. Infrastructure development agencies like Roads and Highways department should take immediate initiatives to provide such lane on the highways. In addition, preliminary actions should be taken on those vehicle operators that are unwilling to wear seat belt and motorcyclist who do not to wear helmet as it amplifies death rate resulting from head injury. In accordance with legislation, proper enforcement and awareness building among drivers and motorcyclists help to reduce fatalities on highways. Considering the vehicle maneuver, most fatal accident occurs when vehicle is in straight course, this can be mitigated by ensuring the speed management on highways and traffic police is the key agency to monitor speed enforcement on highways. Integrated multimodal transport policy (IMTP) (Integrated Multimodal Transport Policy, 2008) emphasized road maintenance instead of overall road safety. The policy should be reviewed in the light of "safety first" and provide strict enforcement on speed restriction (THE MOTOR VEHICLES ORDINANCE, 1983, 1988) to reduce severity on highways. Also, faulty vehicles should be prohibited from operating on highways, in accordance with highway police; BRTA is the concern agency to monitor the vehicle fitness. Institutional development of BRTA, including modern equipment and trained manpower, may help to identify the defective vehicles easily and quickly. MOT (Minister of Transport) test of UK may be the good model for BRTA that includes different parts of the vehicle under investigation before issuing fitness certificate.

Regarding passenger behavior, boarding on roof of the bus is treated as the most fatal position for passengers. During festival time, huge traffic movement observe din Bangladesh, due to deficiency of vehicles and considering low-priced journey, homebound underprivileged people choose the most unsafe position for travel that is roof of the bus or goods vehicle. In addition, boarding or alighting from a moving vehicle is a common scenario in Bangladesh. At present, uniformed police officer stops the vehicle and keep it standing until every illegal passenger gets off the bus and returns the fair if paid (Road Transport and Traffic Act, 2011). Legislation should be modified and should make the driver liable for travelling beyond the capacity of the vehicle. Law and enforcing agencies should strictly be disallowed such tendency and obstruct the people not to move over the top of the bus or to travel as overloaded passengers.

Concept of road Safety audit yet to be practiced in Bangladesh should be mandatory for all motorway construction and long-term maintenance project; implementing agencies to identify the ambiguity of road safety measures and possible remedies before opening for traffic. Moreover, in Bangladesh, numerous organizations working on road safety issue have no proper integration. The state should establish a leading agency that will coordinate the concerned authority to implement road safety policy successfully. In addition, to make children aware about road injury, road safety issue should be included in the national curriculum and training institute for the driver; this may help to reduce the fatality. In accordance with awareness building, rapid response unit like AA (Automobile Association) of UK and establishing trauma center at required interval on national highways will ensure treatment for injured people

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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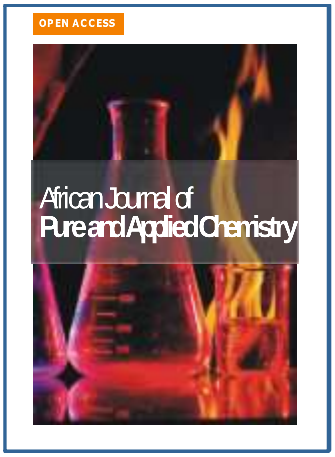

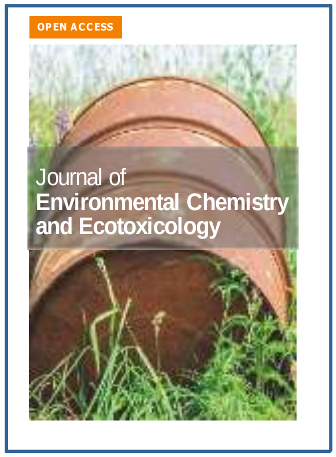

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