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EFFECT OF ROAD INFRASTRUCTURES ON CASUALTY OCCURRENCE IN BANGLADESH

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ABSTRACT

Every year a considerable number of casualties befall by dint of road crashes which ensure that Bangladesh is a crash prone country. Different independent factors are directly and indirectly associated with these casualties emanated by road incidents. With this note a firm model is incumbent to explore the adverse effects of different structural elements, aka road infrastructures on the injuries caused by crashes in context of Bangladesh for road safety. Considering all districts of Bangladesh, 13 types of road infrastructures, and different types of roads and highways have been taken as predictors to identify their probable detrimental effects on the casualty pattern around the country in terms of road infrastructures. Fatal, grievous, and simple injuries have been taken as response variables in this study. Count data models i.e. Poisson Regression has been applied on the data to come up with a functional form between road casualties and road infrastructures. The reason of choosing the model is that the data consist of non-negative integer values of casualty for all 64 districts from 2009 to 2013. The results display whether several infrastructures e.g. Box culverts, bridges made of PC girder, RCC girder, Steel beam and RCC slab (SBRS), Truss with Steel Deck (TSD) etc. have positive or negative effect on the resulting casualties.

Keywords: *Road infrastructures; crash; injury; poisson; casualty*

1. INTRODUCTION

Road safety has become a global issue of concern for both developing and developed countries where road crash injuries are of concern. It needs efforts from the ground level to avoid thousands of lives being lost in road crashes around the world (Kapila, Prabhakar & Bhattacharjee, 2013). An estimation from World Health Organization (WHO) indicates that worldwide every year approximately 1.2 million deaths and about 40 million injuries result from traffic accidents and it causes considerable economic loss due to treatment cost and productivity loss for those killed or disabled by their injuries (WHO, 2017). The scenario is worse in developing countries. About 90% of worlds' fatalities occur in low and middle-income countries. Crash rates are 10-70 times higher in developing countries than the developed ones (Sheikh, 2004). WHO fears that by 2030 road crash will be promoted to fifth position of leading cause of death that may approximately result in 2.4 million fatalities per year (WHO, 2017).

As a developing country, Bangladesh is no exception. Fatality rate here is almost 25 times higher than that of most of the developed countries, 8 times higher than that of Thailand and 3 times higher than that of India (Jahan, 2006). Every year nearly 5000 accidents occur in Bangladesh (Hoque et. al., 2006) of which about 60% of the accidents occur on national and regional highways and 40% on urban roads (Hoque, 2004).

The risk of casualties and severe injuries are influenced by multiple factors, for example, vehicle features, road network design and operation, driver and driving characteristics, environmental conditions, and so on. The injury risks of individuals in traffic crashes are influenced by a multitude of factors including vehicle features, roadway design and operation, driver characteristics, type of collisions and environmental conditions. However, when the traffic casualties are grouped in a larger spaced based scale such as county, ward or state rather than on a particular road segment or at an intersection, many factors related to road infrastructures can be examined (Rifaat, Rahman, Mohammed & Pasha, 2014). An important aim of transport policy is to reduce the road traffic casualties. To fulfil this objective, it is essential to know what factors are responsible for traffic casualties before any efficient policy response can be identified (Wang, Quddus & Ison, 2009). Considering Bangladesh as its study area, the objective of this research is to identify and examine the effects of district wise road infrastructures on the casualty occurrences of this country.

2. LITERATURE REVIEW

Considerable number of research works explored casualty or injury occurrence with other explanatory variables to show relationships among them. Khan, Shanmugam & Hoeschen (1999) explored the relationship between crash injuries of different types with traffic volume, road segment length, and vehicle miles travelled (VMT). The main focus here was to investigate which count models could perform better. Quddus, Noland & Chin (2002) examined the effect of road types, and their engineering characteristics, type of collision that occurred, type of motorcycle, rider demographic characteristics, and environmental factors on injury severity of motorcycle accidents. In 2006, Chang and Wang developed a Classification Analysis and Regression Trees (CART) model to understand the relationship between injury and driver or vehicle characteristics, and come up with a result of being most contributing variable is vehicle types. Pedestrians, motorcyclists, and bicyclists are considered to be high vulnerable groups associated with injury severity. Mohamed, Saunier, Miranda-Moreno & Ukkusuri (2013) examined pedestrian injury severity analysis using statistical regression and data mining techniques. This study used road geometry, built environment, and socio-demographic characteristics as the contributing factors. From the results, they found that pedestrian age, location type, driver age, vehicle type, alcoholic drivers, road lighting conditions etc. are associated with crash injuries and deaths. Anarkoli et al. (2017) made a research on roll over crash and injury. Random effect generalized ordered probit model was used to analyse injury severity pattern. In the results discussion part, they concluded identifying the major problematic variables of insufficient lighting, rainy weather, improper overtaking, vehicle age, traffic volume, and unsafe roadside conditions. Chong et al. (2017) investigated the paediatric road traffic injuries by performing paediatric retrospective chart view of road crash injuries. Child pedestrians, bicyclists, and motorcyclists were found to be vulnerable.

Moreover, some studies examined injury severity pattern when changing mode of transport from car to bicycle (Nilsson, Stigson, Ohlin & Strandroth, 2017), to investigate the relationship with highway design and crash injury count to identify significant road features (Raihan, Hossain & Hasan, 2017).

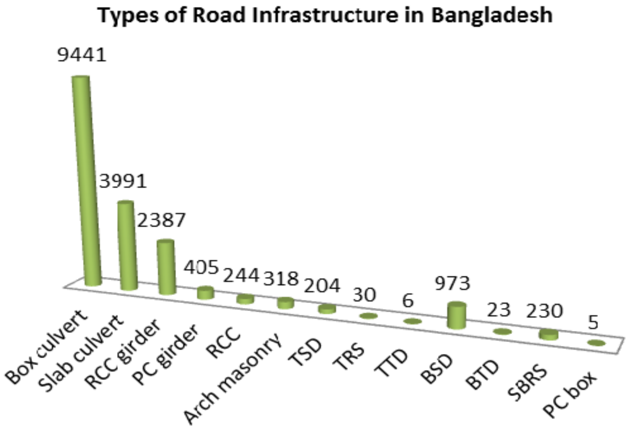
Various studies have been performed using the primary traffic data of Bangladesh. For example, Ahsan et al. (2011) evaluated various types of road traffic injuries resulting from car accident in Bangladesh. Using ordered probit models Kamruzzamana, Haque & Washington (2014) made an analysis on how roadway, traffic, and environmental factors influence injury severity of road traffic crashes. Raihan, Hossain & Hasan (2017) investigated the hazardous clusters of traffic crash and injury to evaluate their performance in manifesting crash causes in Bangladesh.

From the above discussion, it is evident that most of the studies are based on the aggregate level of casualties or injuries that incurred from road accidents but none of these studies have included different types of road infrastructures and disaggregate level of injury data in their research. In this study, we have used 13 types of road infrastructures and their lengths, highway lengths of both urban and rural areas as new contributing factors in road safety literature and traffic injuries. We used the data of all the districts of Bangladesh to investigate the relationship between them.

3. DATA COLLECTION

In our study, district level data had been taken as the unit. We have managed to get data of crash injury of all 64 districts in Bangladesh. Accident Research Institute (ARI), Bangldesh University of Engineering and Technology (BUET) provided all the district wise data of Fatal, Grievous and Simple injuries from years 2009 – 2013. The aggregated sample from 2009 – 2013 are 10947, 5261, 1912 for fatal, grievous, and simple injuries respectively. It is important to note that in Bangladesh crash report data are not comprehensive enough. Some study revealed that most of the crash and injury data collected in Bangladesh are underreported (Raihan, Hossain & Hasan, 2017).

From RMMS (Road Maintenance Management System) data base of Roads and Highway Department (RHD), we have collected 13 types of road infrastructures constructed in Bangladesh. Figure 1 shows the types of infrastructure and the number of structures existing in Bangladesh in all 64 districts.



[Here, TSD = Truss with Steel Deck, TRS = Truss with RCC Slab, TTD = Truss with Timber Deck, BSD = Baily with Steel Deck, BTD = Baily with Timber Deck, SBRS = Steel Beam and RCC Slab, PC = Pre-stressed concrete]

Figure 1: Types of Road Infrastructure in Bangladesh (Source: RHD)

The fair condition of national highway, regional highway and zilla road comprises 2932 km, 2264 km, 8337 km; minor damage condition comprises 661 km, 661 km, 1611 km; major elemental damage are in 644 km, 969 km, 2317 km; major structural damage remain in 108 km, 224 km, 764 km respectively. The data of earthen and pavement roads of upazilla, union and village are extracted from the Local Government and Engineering Department (LGED).

4. METHODOLOGY

In this study, Poisson regression model was used as a method because of its wider use in rare, discrete and non-negative event data modelling. At first, we conducted negative binomial regression to track the dispersion parameter whether it is significantly over dispersed or under dispersed. As we found this parameters' value close to zero, we preferred Poisson regression model to analyse the data.

4.1 Poisson Regression

If event 'n' occurs according to a Poisson process with parameter μ, then the Poisson distribution can be written as:

$$P(n_{it}) = \frac{e^{-\mu_{it}} \mu^{n_{it}}}{n_{it}!} \qquad (1)$$

where, μ_{it} is the Poisson parameter for road segment 'i' in time 't', which is road segment i's expected number of injuries, E[n_{it}], 'n_{it}' is the probability of 'n' injuries occurring on roadway segment 'i' in the time 't'. Poisson regression specifies the Poisson parameter μ_{it} as a function of explanatory variables by using log-linear function:

$$\mu_{it} = e^{\beta X_{it}} \qquad (2)$$

where, $\mathbf{X_{it}}$ is a vector of explanatory variables and $\boldsymbol{\beta}$ is a vector of estimable parameters [38]. The Poisson distribution has the limitation that the variance and mean should be approximately equal i.e.

$$\text{Var}(n_{it}) = E(n_{it}) = \mu_{it} \qquad (3)$$

If this equality does not hold, the data are said to be under-dispersed (E [n_{it}]>Var [n_{it}]) or over-dispersed (Var [n_{it}] > E [n_{it}]). In our case, the assumption is not violated. So, we can go for Poisson regression as stated earlier.

In this study, 95% confidence interval was used, p value was used to describe the variables significance in the developed model. The determinants with p-value less than 0.05 were considered as the statistical significant factors in this model.

4.2 Model Evaluation

The statistical models are evaluated to select the best model from the competitive set of models. The evaluation will be done with the help of two statistics: Likelihood Ratio Test and Log-likelihood Ratio Index
(ρ^2).

$$X^2 = -2[(\boldsymbol{\beta}_R) - (\boldsymbol{\beta}_U)] \qquad (4)$$

Where, ($\boldsymbol{\beta}_R$) is the log likelihood at converges of the 'restricted' model and ($\boldsymbol{\beta}_U$) is the log likelihood at converges of the unrestricted model. The test statistic is X^2 distributed with the degrees of freedom equal to the difference in the numbers of parameters in the restricted and unrestricted model.

To measure the overall goodness of the models, the log-likelihood ratio index will be calculated which is shown below:

$$\rho^2 = 1 - \frac{L(\beta)}{L(0)}{}_2 \qquad (5)$$

where, L($\boldsymbol{\beta}$) is the log likelihood value of the fitted model and L(0) is log likelihood value of the model only with constant term.

5. RESULTS AND DISCUSSION

Table 1 shows the summary of the descriptive statistics of the independent variables and Table 2 shows the results and estimations from the final model. Due to large volume of data we presented the mean and standard deviation of the significant variables in Table 1. In general, the 3 individual traffic injury models fitted the data well with fairly large chi-square goodness of fit. We reported The pseudo square R for all models as well. We considered a varible statistically significant if the p-value is ≤ 0.05. We also presented the discussions on the effects of significant variables in these three categories.

Table 1: Descriptive statistics of the significant independent variables

Variables	Mean	Standard Deviation
Road Infrastructure National Highways (km)		
PC Girder	546.78	1001.84
Steel Beam and RCC Slab	55.03	132.03
Box culvert	225.70	255.54
Truss with RCC Slab	89.29	368.35
Truss with Timber Deck	24.32	137.53
RCC	24.59	78.25
RCC Girder	497.46	732.42
Pre-stressed concrete	111.73	537.85
Regional Highway (km)		
Arch Masonry	6.78	18.87
Baily with Steel Deck	149.45	270.11
Steel Beam and RCC Slab	18.48	75.48
RCC Girder	312.12	354.15
Slab Culvert	36.06	68.39
Zilla Road (km)		
Arch Masonry	5.86	10.77
PC Girder	368.16	598.53
Baily with Steel Deck	558.37	783.18
RCC Girder	908.43	638.26
RCC	48.03	71.65
Pre-stressed concrete	4.91	38.94
Slab Culvert	122.49	115.80
Truss with RCC Slab	22.76	107.74
Highway length (km)		
National Highway	55.92	50.62
Union Road	704.37	357.85
Upazilla Road	602.80	210.04
Village Road	1768.79	950.32
Lengths that are not surveyed	22.71	31.09
Union Road (km)		
Rigid Pavement	12.11	31.79
Brick pavement	49.78	69.41
Structure Span	1012	650.78
Upazilla Road (km)		
Rigid Pavement	20.02	36.15
Brick Pavement	22.67	27.12

Earthen	116.87	121.75
Structure Span	965	594.15
Village Road (km)		
Structure Span	1296	931.94
Earthen type	1600.80	873.48
Rigid pavement	11.54	20.98
Number of existing gap	438	388.75

In National Highways, PC girder, Box culvert, RCC bridge, and RCC girder made structures promote casualty swelling that means if the number and length of these structures increase the probability of any of the casualty occurrence due to road crashes also increase. Narrow widths of the structures, less carriageway, less shoulder width may be the reason of this unsafe condition. On the contrary, SBRS, TRS, TTD structures that are made of steel materials tend to decrease casualties. This result indicates that steel made structures may promote safety improvement in the national highways for any types of injury occurrence which indicate satisfatory roadside condition for driving ensuring drivers' cautious driving.

In the rigional highways different type of road incrastructures had mixed effect on the casualty occurrences. We discovered structures that are construted with Arch masonry and RCC are safe for slight injury and serious injury occurrences respectively. On the other hand, BSD, SBRS type strucutres are found less safe for this particular type highway which is the opposite scenario we found in the case of national highways. Drivers attitude may one of the reasons for this result. In regional areas drivers may face less hindrance in speeding up as the traffic volume of those roads is less than this of the national higways. So, speeding is one of the causes of injuries and deaths in this region due to the presence of these types of structure. Maintenance should be considered as one of the key issues as timely maintenance and retofitting of the structures are contributory factors to the sustainability of that particular structure for a long time without interruption in the operation of traffic network.

Table 2: Parameter estimates of all 3 casualties

Variables	**Estimated coefficient (β) and p-values of casualty models**		
	Fatal	**Grievous**	**Simple**
Road Infrastructure National Highways (km)			
PC Girder	0.00018 (0.000)	-	-
Steel Beam and RCC Slab	-0.00069 (0.000)	-	-
Box culvert	-0.00077 (0.000)	0.00078 (0.000)	0.00063 (0.000)
Truss with RCC Slab	-	-0.00084 (0.000)	-
Truss with Timber Deck	-	-	-0.00164 (0.000)
RCC	-	-	0.00226 (0.000)
RCC Girder	-	-	0.00015 (0.014)
Pre-stressed concrete	-	-	-0.00031 (0.003)
Regional Highway (km)			
Arch Masonry	-	-	-0.00544 (0.002)
Baily with Steel Deck	0.00103 (0.000)	-	0.00010 (0.010)
Steel Beam and	0.00406 (0.000)	0.0054 (0.000)	-

RCC Slab			
RCC Girder	-	-0.00067 (0.000)	-
Slab Culvert	-	-	0.00241 (0.000)
Zilla Road (km)			
Arch Masonry			0.00525 (0.021)
PC Girder	0.00071 (0.000)	0.00087 (0.000)	-
Baily with Steel Deck	-0.00161 (0.001)	-	-
RCC Girder	-0.00029 (0.000)	-	-
RCC	-	-	-0.00299 (0.000)
Pre-stressed concrete	-	-	-0.00266 (0.001)
Slab Culvert	-	-	-0.00321 (0.000)
Truss with RCC Slab	-	-	-0.00164 (0.000)
Highway length (km)			
National Highway	0.00894 (0.000)	-	-
Union Road	-	-0.01188 (0.000)	-
Upazilla Road	-	0.00280 (0.000)	-
Village Road	-	0.00020 (0.001)	-
Lengths that are not surveyed	0.008 (0.000)	-	-
Union Road (km)			
Rigid Pavement	0.0083 (0.000)	-	0.00402 (0.000)
Brick pavement	0.003716 (0.001)	-	-
Structure Span	-	-0.0078 (0.000)	-
Upazilla Road (km)			
Rigid Pavement	-	-0.00364 (0.014)	-
Brick Pavement	-	-	0.003275 (0.005)
Earthen	-	-	0.001614 (0.000)
Structure Span	-0.000029 (0.015)	0.00587 (0.000)	-0.00412 (0.000)
Village Road (km)			
Structure Span	0.000061 (0.000)	0.00142 (0.000)	0.0002237 (0.003)
Earthen type	-	-0.00092 (0.000)	-
Rigid pavement	-	0.01873 (0.000)	-
Number of existing gap	-0.000048 (0.000)	-	-
Number of observation	64	64	64
LR χ^2	882.70	377.11	749.89
Pseudo R^2 (%)	0.7807	0.6481	0.4757
Log likelihood	-124.01048	-102.38766	-413.17315

Our results indicate that, in Zilla roads, serious injuries are not so frequent with the presence of any of the structures along the roads. It shows the same results that were found in the national highways for causing fatal and slight injuries. Some facts are needed to be clarified here is that if the roads here do not promote severe injury occurrence, the reason may be the reduced speeding of the vehicles. In Zilla roads, roads are narrow and drivers face obstacles in the roads while driving, so they may not feel comfortable to speed up their vehicles in those roads. On the contrary, if the scenario is opposite that means if frequent casualty occurrence is found here then the possible reasons may be the inattentiveness of both drivers and pedestrians. In Zilla areas several village roads are present. So, open air markets beside the roads, risky crossing of the road without looking elsewhere is frequent. Also, vehicle type is an important factor that is needed to be mentioned here. In some cases fatality occurred because of the collision of motorcycle and tructors though both of the vehicles are low speed vehicle.

From our analysis the results show that national highways and the roads that are not surveyed yet, tend to increase more casualties. In the highways, the exposure and road environment are different from place to place. Drivers may feel uncomfortable in unfamiliar roads and the perception reaction time in those new roads may decrease. As a result, the probability of occurring casualty increases. In the sub-urban areas i.e., union roads and upazilla roads made of brick pavement are likely to increase fatal and slight injury casualties. Also, rigid pavement roads are vulnerable for fatal injuries in union areas. During rainy season these roads in the sub-urban areas may deteriorate in quality. As the demand and traffic flow in these road networks are less, these roads may not be constructed with great care. In the sub-urban areas if a road gets damaged, it takes many days and months to repair it in a good way for traffic movement. Also, the ESAL (Equivalent Single Axle Load) value that was initially taken for the road design may over exceed the demand of the road. Because, heavy vehicles mingling around those areas are likely to be responsible for road damage more than relatively lighter traffic.

Earthen type structures in the village areas are likely to be safe against serious injuries. Also, the number of structural spans show mixed result for the occurrence of casualties in the union, upazilla, and village areas. Another statistically significant variable in the model is the existing gap which means the gap in the continuous road network. These gaps decrease the demand of traffic by providing alternative routes and modes. By minimizing traffic exposure these gaps may reduce casualty occurrence.

6. CONCLUSIONS

In this paper, we present the effects of road infrastructures on different types of traffic casualties occurred in Bangladesh. It is an initial attempt that we made to show whether there exists any relationships among them. From the research output, we found some notable relationships, for example, steel made structures are found safe for the national highways, some concrete made structures in the regional highways are found safe for fatality and slight injuries, more national highways promote more injuries, rigid and brick pavements are found vulnerable for fatal injuries, lengths that are not surveyed yet may provide vulnerable environment for the drivers, vehicle occupants, and for the pedestrians.

There are some limitations in the model used in this study. We did not consider the traffic volume of each of the roads due to resource constraints. As we have made an early attempt to come up with a relationship between road infrastructures and traffic injuries, there are plenty of opportunities to improve this concept by conducting several researches. We can include different types of vehicles in the model to show which vehicle influence more on the traffic injuries if road infrastructures are present in that road. We can also include weather factors, socio-economic demographic factors in the model to show the variation of the result and to discover more significant findings.

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