ROAD SAFETY HAZARDS AT JAMUNA MULTIPURPOSE BRIDGE (JMB) SITE: IMPLICATIONS FOR BRIDGE MANAGEMENT

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ABSTRACT

The Jamuna Multipurpose Bridge (JMB), the 12th longest bridge in the world, was constructed in 1998 aimed at contributing to accelerate economic development in Bangladesh by eliminating the bottleneck to the east-west corridor and activating economic exchanges between the regions. In recent years, however, the high incidence of traffic accidents and injuries at the bridge sites looms as a great safety concern. On average nearly 100 accidents are taking place each year on the 38 km road segments of national highways consisting of the bridge and its approach roads. Most of the accidents are off carriageway type including hitting objects and are highly clustered at few sites with the significant involvment of heavy vehicles, particularly trucks.

This paper reports on the findings of a study to examine the full extent of the traffic safety problems using accident and injury statistics recorded by the bridge maintenance operator and hence to identify specific locations that have very hazardous characteristics for the development of effective safety improvement programs. Based on the analytical results coupled with in-depth on-site investigations, the study makes recommendations, which have safety implications for the bridge management.

The views expressed in this paper are those of the authors and may not necessarily reflect the views of the Jamuna Multipurpose Bridge Authority and the Accident Research Centre, Bangladesh University of Engineering and Technology.

INTRODUCTION

Being a riverine country, bridges play a significant role in achieving an efficient road based transport system in Bangladesh. The Jamuna Multipurpose Bridge (JMB), the 12th longest bridge in the world was constructed in 1998 aimed at contributing to accelerate economic development in Bangladesh by eliminating the bottleneck to the east-west corridor and activating economic exchanges between the regions. Indeed, the construction of the bridge has created huge accessibility and mobility potential and thereby has increased the prospects of socio-economic development of the people of North-Bengal.

In recent years, however, the high incidence of traffic accidents and injuries at the bridge sites (the main bridge and its approach roads) has become of increasing concern with an average of nearly 100 accidents taking place each year on the 38 km road segment of national highways consisting of the bridge and approaches. The bridge authorities are required to put up appropriate programs for reducing the number as well as the severity of accidents to maintain an acceptable level of safety.

This paper reports on the findings of a study to examine the full extent of the traffic safety problems using accident and injury statistics recorded by the police and the bridge maintenance operator and hence to identify specific locations that have very hazardous characteristics for the development of effective safety improvement programs. The analytical approach invokes the system of accident type/location coding using GIS technology for the generation of precise and good quality accident location plots aiming at site specific treatments- both preventive and improvement measures. Based on the analytical results coupled with in-depth on-site investigations, the study makes recommendations, which have safety implications for appropriate safety measures by the bridge management administrators.

THE CONTEXT OF JAMUNA BRIDGE

The Jamuna River

Bangladesh is known as a country of rivers. About 250 rivers of different nature and dimension criss-cross the country. The river Jamuna (Brahmaputra), along with the lower stretch of the Padma (Ganges) divides Bangladesh into nearly two equal halves. (Wikipedia, 2008).

It is one of the world's largest rivers. During monsoon season, the Jamuna swells to twenty kilometres wide at different places. Flowing south through Bangladesh, the braided Jamuna joins the Ganges and discharges into the Bay of Bengal. The river forms a geographic barrier that divides the western half of the country from the east. All road and rail communication between the two parts of the country used to rely on time-consuming ferry services that were often disrupted because of navigability problems in the rivers. The need for a bridge over the river Jamuna was felt, especially by the people living in north-western Bangladesh, for a long time. (Huq 2002).

The Jamuna Multipurpose Bridge in Brief

The Jamuna Multipurpose bridge is now located near Sirajganj and Bhuapur, connecting the eastern part of the country to the northwestern part. The length of the bridge is about 4.8 kilometers in total. It is the longest bridge in Bangladesh and South Asia and the 12th longest bridge in the world.

The bridge construction involved a wide array of works: the main bridge, the bridge end facilities at the east and west banks of the Jamuna river, the approach roads connecting the bridge with the existing road network, the river training works. The end facilities enhance smooth traffic flow, provide travellers aids, have bus stations, parking areas, rest areas, toll booths, staff housings etc. The approach roads were built to lead cars to enter the bridge. It is 16 kilometers from the east side and 17 kilometers from the west. In the east, the approach road connects to the existing Tangail-Madhupur road near Elenga and in the west, it joins the Hatikamrul-Sirajganj road at new Nalka bridge (Youm 2006).

The bridge contains two lanes of road on each side, as well as railroad tracks, gas pipelines and power lines. The main bridge is a Multi-span girder-type structure with 100 m spans and a total of 48 spans. The main bridge has pile foundation consisting of 90 m long steel tubular piles driven into the riverbed. The superstructure of the bridge consists of steel box girders with a concrete deck or pre-stressed concrete box girders.

Since there are only two narrow lanes on the bridge, the risk of an accident on the bridge is high. For example, when a huge truck covers more than a lane width on the bridge, it is harder for cars to pass behind the truck. So, wider lanes should have been built for safety and increased capacity (Youm 2006).

Site Map: About 100 km northwest of Dhaka

View of Jamuna Multipurpose Bridge

Figure 1: Map of Bangladesh and the location of Jamuna Bridge

Socio-Economic Impact of the Bridge

A detailed overview of sicio-economic impacts has been given by Youm (2006). The most striking impacts are highlighted in this section.

The project had multiple purposes. The two main dimensions were economical and technological. Its main goal was to achieve economic equality between the east and west zones of Bangladesh. Jamuna River was an obstacle for development of the western zone and building the Jamuna Bridge was the right solution to equalize the levels of development between eastern and western zones. Other purposes were to provide numerous benefits to people on both sides and to increase inter-regional activities such as trading. The bridge provided faster transportation for people, products, electricity and natural gas. The project also developed the communication level between places. It enabled people on either side to communicate faster through phone links on the bridge. The bridge has led to the creation of more job opportunities for people on the western side. Now, people who used to be unemployed are working and earning enough money to take care of their family. The bridge has led to an increase in country's gross domestic product (GDP), and has lowered the country's poverty level. One example of a new business is the opening up of Jamuna Resort which is placed a few kilometers away from the bridge. The resort provides job opportunities for tourists visit the area to look at the bridge.

Jamuna Bridge is not only impacting its own nation in a positive way but it is also impacting the surrounding nations, such as India and Myanmar. The Asian Highway and Trans-Asian Railway are going to be built to connect most of the countries in South Asia and South East Asia. When it goes through Bangladesh they are going to take advantage of the bridge and use it instead of building a new structure. The new highway will be beneficial for Bangladesh by opening up access to foreign countries. Trading with the countries in these regions will be easier, therefore Bangladesh will be able to develop further (Youm 2006).

ROAD SAFETY PROBLEMS IN BANGLADESH

The Dimension of the Problem

There is no doubt that road transportation is vitally important to our economic and social welfare and must be so maintained and continually improved with due consideration of safety, minimizing accident hazards and risks. Each year as reported to police, more than 3000 individuals- including from among our peers, our family, our friends and our coworkers- lose their lives in road traffic accidents in Bangladesh and many more sustain disabling injuries. It is estimated that the actual fatalities could well be 10000-12000 each year taking consideration of underreporting and definitional inconsistencies.

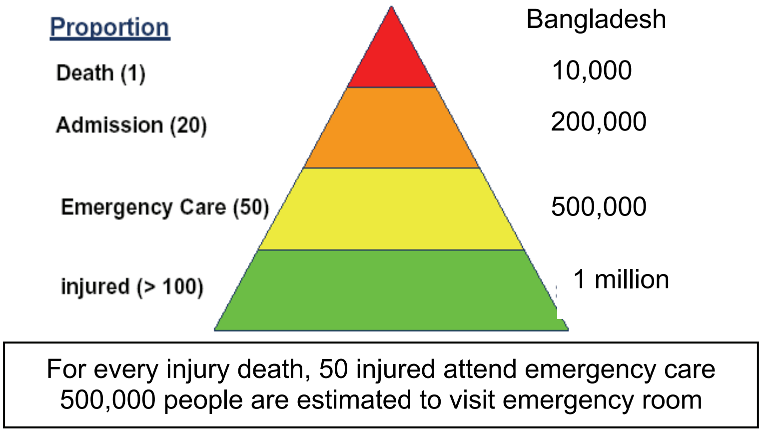

Figure 2: Pyramid of road accident casualties in Bangladesh (Bangladesh Health and Injury Survey, 2005)

In economic terms, road accidents in Bangladesh are costing the community in the order of Tk. 5000 crore (US $ 850 million) which is nearly 2 percent of GDP. This is, of course, a huge sum that the nation can ill afford to lose (Hoque et. al, 2007a).

Striking Accident Characteristics

A comprehensive analysis was undertake of all reported accidents in Bangladesh in the period 1998-2005. Most striking characteristices of accidents are:

- The statistics revealed that Bangladesh has one of the highest fatality rates internationally in road accidents, over 100 deaths per 10,000 motor vehicles.
- About 70 percent of road accident fatalities occurred in rural areas including rural sections of national highways.
- Of the total reported accidents nearly 37 percent occurred on national highways.
- Accident type analysis showed ‘hit pedestrian’ as the dominant accident type both in urban and rural areas, 45 percent involvement in fatal accidents. Other common accident types are: rear end collision (16.5%), head on collision (13.2%) and overturning (9.3%).
- Heavy vehicles such as trucks and buses including minibuses are major contributors to road accidents (bus/minibus 33%, trucks 27%) and in fatal accidents their shares are 35 percent and 29 percent respectively.
- The incidence of overall child involvement in road accident fatalities in Bangladesh is found to be also very high, accounting for about 21 percent.
- Accidents occur more frequently at day time (6 AM to 6 PM) in rural areas: day time 75 percent, night time 25 percent; and in urban areas: day time 65 percent, night time 35 percent.
- About 2.5 percent of reported accidents occurred on bridges and culverts.
- The principal contributing factors to accidents are adverse roadway roadside environment, poor detailed design of junctions and road sections, excessive speeding, overloading, dangerous overtaking, reckless driving, carelessness of road users, failure to obey mandatory traffic regulations, variety of vehicle characteristics and defects in vehicles and conflicting use of roads
- The widespread underreporting and incomplete collection of specific details of accident data are a major problem. This limits proper accident analysis to be carried out towards improving and monitoring road safety. (Hoque et al 2007b, ARC 2006).

Trends of Accidents at Bridges

Accidents at the bridge have shown an increasing trend (Table 1) thereby demonstrating that safety hazards at bridges are of particular concern in Bangladesh. Indeed, bridge related accidents are more severe than accidents as a whole with many major fatal accidents with often devastating consequeces of fatalities and injuries. For example, on April 22, 1991 at about 8.30 A.M. an overloaded bus struck a bridge railing on the left side and plunged into 40 feet deep ditch which resulted in 57 fatalities and 150 injuries on the spot. This is one of the worst road accidents in the history of the country.

Table 1: Trends of Road Traffic Accidents at Bridges

Year	Total Accidents	Percent of Bridge Accidents
2003	4093	1.59
2004	3535	1.61
2005	3262	1.72
2006	3497	2.06

ACCIDENTS AT THE JAMUNA MULTIPURPOSE BRIDGE (JMB) AND APPROACHES

Total accidents and casualties statistics

Apart from the police, the Jamuna Multipurpose Bridge Authority (JMBA) and its maintenance operators maintain accident statistics on a regular basis. These data have been analysed in some greater details. Table 2 presents the distribution of accidents and casualties reported by the JMBA. There were 71 fatalities in 273 accidents during the period of 2004-2006, and average of nearly 25 deaths in about 100 accidents yearly in a section of 36.1 km of the highway section. This number of deaths is considered to be high when compared with the situation of overall deaths on national and regional highways in Bangladesh. The lower number of deaths in 2006 is of particular note and is apparently attributable to reporting inconsistency of the bridge management operator and the reasons require special investigation. However, according to police data, there were 65 recorded accidents in 2006 in which the number of fatalities was 53. This is much higher than the numbers in previous years which clearly demonstrates the deteriorating safety situation in this particular segment of the national highway network. Despite some data inconsistencies and limitations, the safety investigation was based on reported accidents of the Bridge Authority which are generally much higher and more informative.

Table 2: Trends of Accidents and Casualties in Jamuna Bridge and Approach Roads

Year	Accidents	Fatalities	Serious Injuries	Simple Injuries	Casualties	Accident per KM per year
2004	85	32	59	51	142	2.23
2005	108	30	92	138	260	2.83
2006	80	9	24	32	65	2.10
Total	**273**	**71**	**175**	**221**	**467**	**2.39**

Predominant Accident Type

In this study, accident types have been analysed according to the Definition of Coding Accidents (DCA) which revealed the following predominant types:

- off carriageway, hit objects (DCA 704 & 703): accidents (42%), casualties (17%)
- rear end (DCA 301): accident (11%), casualties (7%)

- head on (DCA 201): accident (10%), casualties (36%)
- out of control on carriageway (DCA 705): accidents (7%), casualties (10%)
- hit parked/standing vehicle (DCA 601): accidents (4%), casualties (5%)
- hit pedestrian (DCA 001, 003, 004): accidents (4%), casuaties (2%)
- off carriageway to left (DCA 701): accidents (4%), casualties (1%)

It was found that head on collision (201) is the leading cause of fatalities accounting for nearly 42 percent of all fatalities, followed by overturn on road (705) (14%), overturn road side (left)(702) 7%, hit pedestrian (crossing near side) (001) (6%). Remedial improvements for reducing these few specific accident types demand priority consideration in the overall bridge safety improvement program. It however remains for further work to examine the encroachment rates of off carriageway accidents by taking into consideration of appropriate exposure measures to determine how much worse is this site compared to the expected norm internationally.

Vehicular Involvements

The toll collection system in the bridge classifies vehicles into seven categories viz. large bus, small bus, large truck, medium truck, small truck, light vehicles and motorcycle. These categories of vehicles are allowed to cross the bridge. However, other vehicles including non-motorized vehicles can operate on the approach roads. Vehicular involvements in accidents are shown in Table 3.

Trucks including large trucks and small trucks are the highest contributors to road traffic accidents which accounted for nearly half of the all vehicular involvement in accidents. The involvement of light vehicles in accidents (21%) is much higher compared with their share in traffic flow (15%). Light vehicles have also higher rate of accidents in terms of accident per million veh-km (6.9 accidents per million veh-km compared to average of 4.8 accidents per million veh-km). In contrast, buses are under represented in accidents which is contrary to their over involvement in accidents nationwide.

Table 3: Different Types of Traffic Flow and Involvement in Road Accidents

Vehicle Type	Jamuna Bridge and its Approach Roads			
	Percent of Traffic Flow	Percent in Accident Involvement	Involvement Index	Accidents per Million Veh-km
Trucks	48	50	1.04	5.0
Buses	35	26	0.76	3.7
Light Vehicles	15	21	1.42	6.9
Motor Cycle	2	2	0.83	4.0
Others	Na	1	na	na
Total	**100%**	**100%**	**1.00**	**4.8**

Temporal Characteristics

The occurrence of the accidents and fatalities was examined by the time of day. Figure 3 shows the hourly distribution of accidents and fatalities of the bridge and bridge approaches, also shows the distribution of hourly traffic volume. It can be seen that accident and fatalities remain fairly evenly distributed with the peak occurrence at late hours of the night and at early hours of the day. It showed that accidents are over involved in the morning times with respect to the level of traffic flow. The high incidence of casualties at during 0100-0200 hours and 1900 to 2000 hours was mainly attributed due to accidents involving many casualties. The variation of hourly distributions of heavy vehicles is shown in Figure 4. Trucks predominated in the late night hours and the early morning hours. These temporal variations perhaps could help develop strategies for selective enforcement measures particularly for heavy vehicles in the period of high accident involvement.

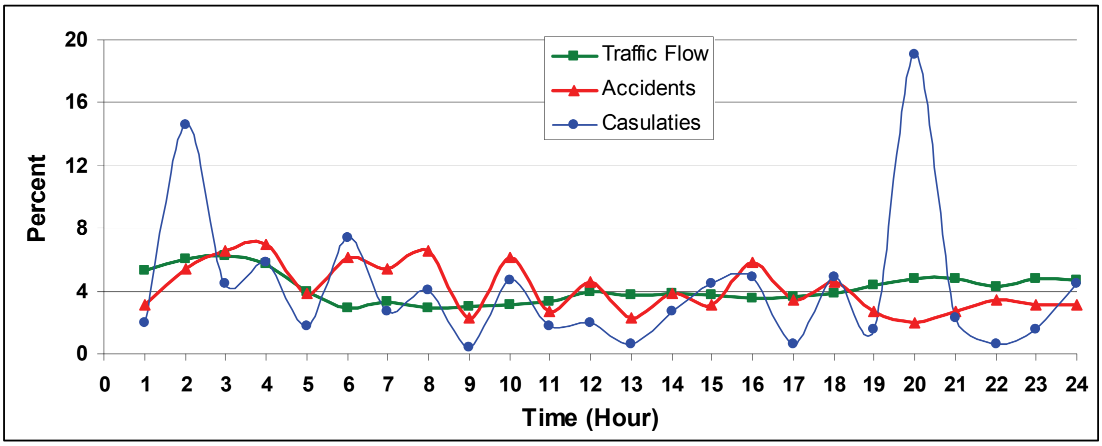

Figure 3: Hourly Distribution of Accidents, Casualties and Traffic Flow

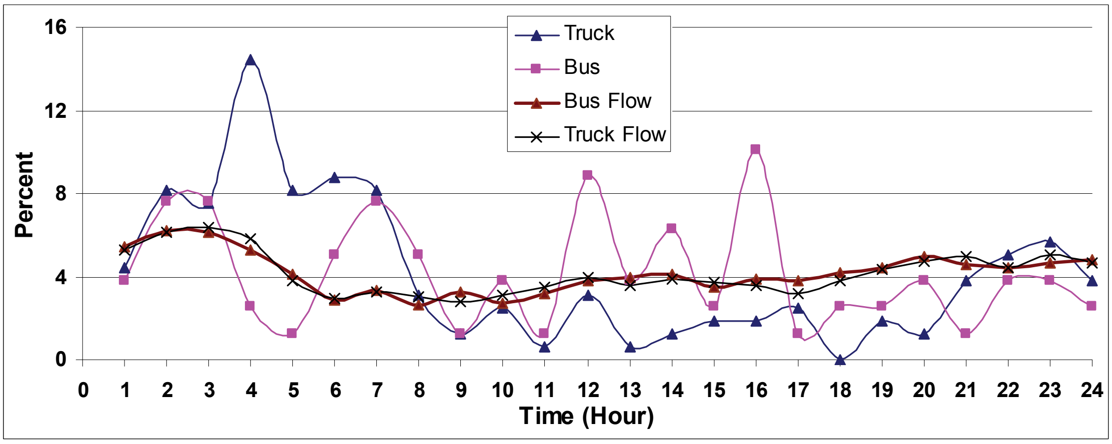

Figure 4: Hourly Distribution of Vehicle Involvement and Traffic Flow

Roadway Environmental Features

The detailed geometric and traffic control devices on the bridge and its approaches could be seen in Islam (2004). The road cross section of the bridge is shown in Figure 5. The bridge approach roads are having 7.3m wide single carriageway for two-way traffic with 1.5m wide treated shoulders. Due consideration has been given to provide requisite road marking, signage and other delineation devices to regulate, warn and guide traffic. However, there is a lack of drivers understanding and compliance of these devices as revealed from studies on heavy vehicle drivers and their understanding of road safety (Kondaker et al 2005). The posted speed limits on the bridge and the approach roads are 40 km/hr and 80 km/hr respectively. The sample speed survey on the approach roads showed incidence of much higher operating speeds of some vehicles.

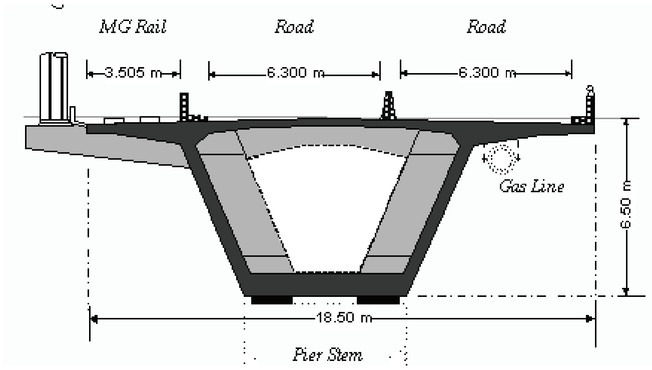

Figure 5: Cross section of the Bridge (www.citechco.net/jmba/bridge.html)

HIGH ACCIDENT SITES AND THEIR CHARACTERISTICS

The Context of Accident Distribution

In Bangladesh, the distribution of accidents occurrence on road network is characterized as 'clustering' at few sites. For example, hazardous road location (HRL) consisting of 64.5 kilometres length, representing only 2 percent of the national highway network accounting for about 37 percent of reported accidents and 40 percent fatal accidents of known locations on the national highways in Bangladesh. In Metropolitan Dhaka a total of 54 intersections having 10 or more accidents of all severities in the period of 1998-2005 were identified as hazardous. These intersections accounted for nearly 77 percent of all intersection accidents and almost 78 percent of total pedestrian accidents at intersections in the Metropolitan City. These characteristics demonstrated that accidents are amenable to site specific treatments through wide spread implementation of cost-effective countermeasures, low-cost road environmental improvements in particular.

Importantly, traffic engineering approaches to road safety typically rely on treatment of individual sites, identified through their recorded accident history. Indeed, hazardous road location program forms the most cost-effective way of road safety improvements. A proactive approaches to traffic engineering safety also involves identified sites which have the potential to develop a poor safety record and treating them before these happens. In view of these, an attempt was made in this study to identify sites (sections and/or spots) with high occurrence of accidents and severity. Also, examined the site properties and probable contributory accident factors

High Accident Frequency Sites in the Study Area

Identification of high accident frequency sites and accident "black-spots' depends critically upon the information about the precise location of accidents. Geographic Information System (GIS) based accident database was prepared in which each accident location was assigned unique chainage value with respect to the initial chainage of the 38.1 km roadway under study. Accident location was coded with precision of 0.01 km. Figure 6 shows the geographic distribution of accidents. It can be seen from the Figure that accident clustered very highly at certain locations. The highest accident concentration was at two roundabouts, on at the west approach and the other one at the east approach having 82 and 22 accidents respectively in the period of 2004 to 2006. These two locations are further examined for remedial improvements. The accidents and fatalities on the three segments viz. east approach, main bridge and west approach are summarized in Table 4. Also shown in the table are the accidents rates, number of accidents per kilometre. The rates of accidents and casualties varied considerably by segments with highest concentration on the east approach, nearly 8.1 accidents and 15 casualties per kilometre. However it was found that on both approaches, accidents clustered at relatively small number of sections. On the east approach, nearly 91 percent of the total accidents took place at only 4.52 (28%) km of the 16.00 km of the approach road. Similarly, on the west approach, nearly 92 percent of the total accidents took place at only 0.98 (6%) km of

17.30 km of the approach road. On the main bridge, among the 25 accidents, 20 (80%) accidents are clustered in 4 locations within 0.75 (16%) km of entire bridge length.

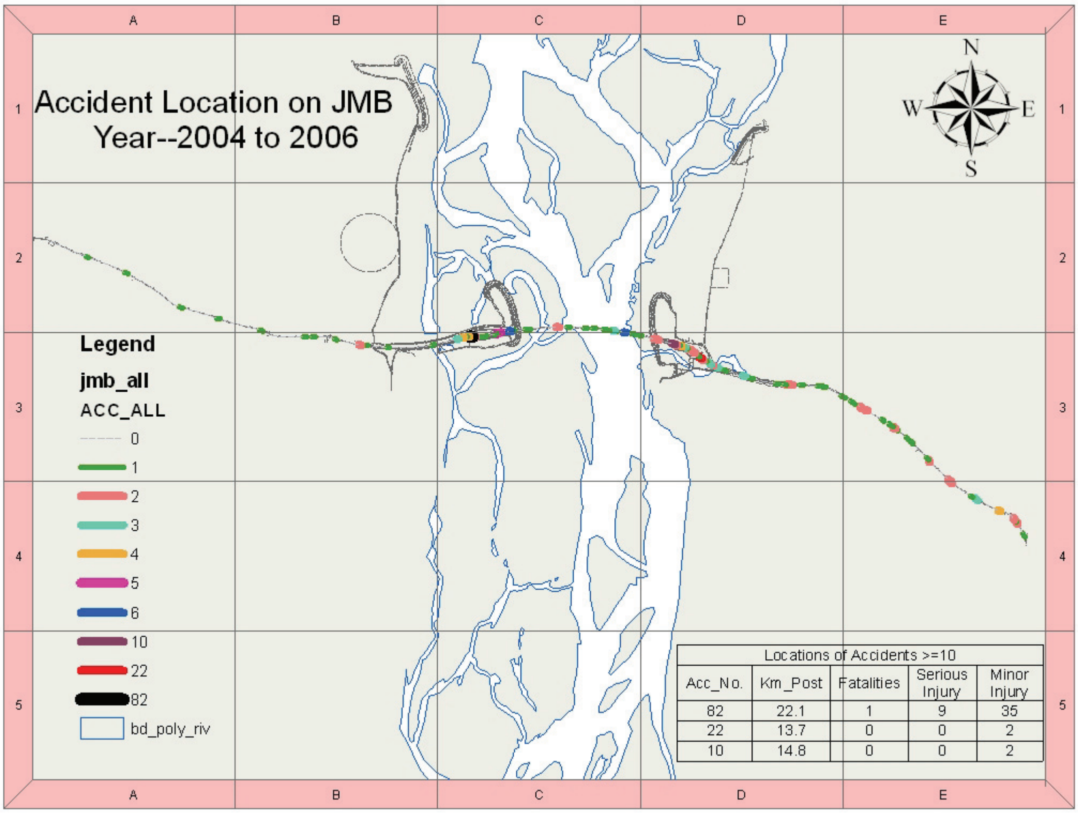

Figure 6: Accident Locations and Number at Jamuna Bridge and Its Approaches by GIS

Table 4: Distribution of Accidents by Segments in 2004-2006

Road Segment	Accidents	Fatalities	Injuries	Total Casualties	Casualties/ Km	Accidents/ Km
East Approach	129 (47%)	43 (61%)	202 (51%)	245 (52%)	15.38	8.06
Main Bridge	25 (9%)	3 (4%)	20 (5%)	23 (5%)	4.79	5.21
West Approach	119 (44%)	25 (35%)	174 (44%)	199 (43%)	11.50	6.88
Total	**273 (100%)**	**71(100%)**	**396(100%)**	**467(100%)**	**12.28**	**7.17**

Priority Locations/Sites/Spots

Further investigation was also made of the locations having frequent accidents (10 or more) and/or fatalities (5 or more). A total of 10 such locations were identified and considered to be hazardous. These locations are shown in Table 5. These 10 hazardous locations represent only 2.63 (7%) km of the entire study segments (38.10 km) and account for 167 (61%) accidents (61%) and 42 (59%) fatalities and therefore, demands closer examination and priority consideration for treatments. Details of these sites are being investigated.

Table 5: Priority Locations/Sites/Spots

Locations	Length	Accidents	Fatalities	Serious Injuries	Simple Injuries	casualties	Acc./km
Section 1 (6.1-6.4 km)	0.3	5	5	15	22	42	16.6
Section 2 (7.9-8.4 km)	0.5	4	5	12	16	33	8.0
Section 3 (12.7-13 km)	0.3	5	10	16	2	28	16.6
Section 4 (13.2-13.6)	0.4	11	4	4	6	14	27.5
ETC at 13.7 km	-	21	0	0	2	2	-
Section 6 (14.2-14.7 km)	0.5	12	2	6	10	18	24.0
East Toll Plaza, At 14.8 km	-	10	0	0	2	2	-
WTC at 22.1 km	-	82	1	9	34	44	-
Section 9 (22.2-22.63 km)	0.43	13	3	3	21	27	30.2
Section 10 (25.9-26.1 km)	0.2	4	12	45	21	78	20.0
Total	**2.63**	**167**	**42**	**110**	**136**	**288**	**63.5**

IN-DEPTH ANALYSIS AND ON-SITE INVESTIGATION OF ACCIDENTS AT ROUNDABOUTS

Accident study group of the Accident Research Centre (ARC) has formed a team of a team of investigators visiting accident sites soon after a major fatal accident had occurred as well as identified hazardous road locations. As a part of this program, in-depth and on-site safety investigations have been carried out at the high accident frequency locations in order to collect information relating to accidents occurrence and accident sites and to asses environmental, road, driver and vehicle properties in both qualitative and quantitative ways. Particular attention has been given to two roundabouts including its adjacent areas. Typical accidents hazardous are shown in Figure 7.

Figure 7: Typical Accident Hazards at the Two Roundabouts

Based on this information, in-depth analysis and on-site investigation, collision diagrams of accidents were prepared and are shown in Figures 8. The collision diagram is a very useful concept and a valuable tool for site specific accident diagnosis and in developing commensurate countermeasures. It shows the patterns of accident types and gives the clues to the reasons of accidents and thus direct to the appropriate remedial measures. The collision diagrams clearly show the dominant legs of the roundabouts vehicles are approaching from as well as their paths. These perhaps indicate difficulties for the driver to make correct judgement as well as visibility problems which could well be related to the geometrical configurations of the roundabouts. From the collision diagrams, it can be seen that at the east roundabout, the most frequent accidents are off carriageway (including hitting objects), which accounting for nearly 80 percent of the total 21 accidents. On the west roundabout, same accident type was also prevalent accounting for nearly 90 percent of total 82 accidents of the period of 2004-2006.

Two different characteristics of accident patterns are noted at the roundabouts. On the east approach vehicles are predominantly hitting the roundabout while approaching the bridge and on the west roundabout the vehicles are hitting predominantly while leaving the bridge. It has been noticed that accidents predominated in the west bound traffic i.e. vehicle travelling from Dhaka, the capital city of Bangladesh, to the north-west part of Bangladesh. The high incidence of speeding has also been noticed in this direction of traffic. As indicated earlier, involvement of buses and trucks in accidents are predominant. However, the over involvement of light vehicles in accidents were noticed. Their involvements in accidents at east and west roundabouts were 20 percent and 47 percent respectively and are much higher than their shares in traffic composition, 15 percent. Many vehicles indeed went directly on to the roundabouts, 43 percent and 63 percent respectively. There still remains further investigation of the other factors including roadway environmental and driver behavioural aspects.

The preliminary investigations suggest the following contributory factors:

- inadequacy of roadway geometric design features for correct negotiation of drivers

- the degree of inconsistency in the roadway system that drivers are perhaps not aware and their misjudgement
- driver fatigue, excessive speeding and poor visibility
- inadequacy of advanced warning signing and delineation devices
- general tendency of drivers for inappropriate overtaking and manoeuvring
- skid resistance, lane width and roadside designs
- overloading, vehicle conditions and stability.

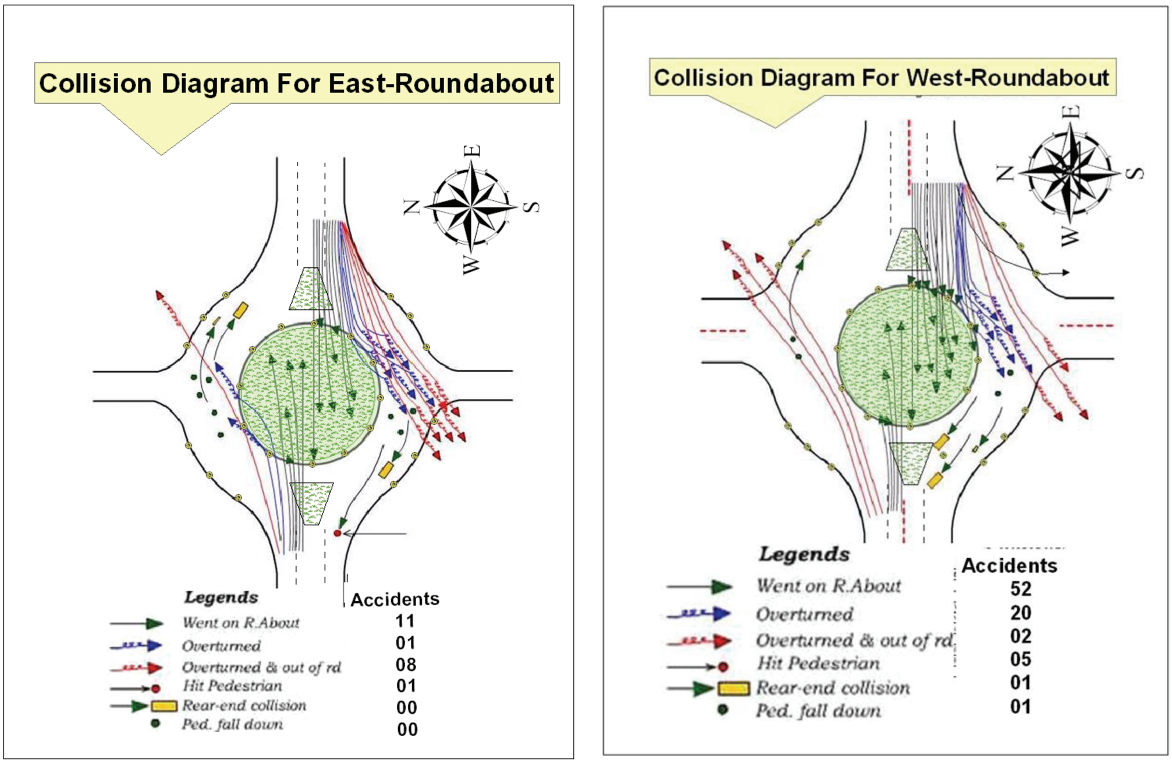

Figure 8: Collision diagram of east and west roundabout

It is clear from the above that there a range of road designs and traffic operational factors which could take better account of the safety needs of vehicular traffic. Indeed, such roadway design and traffic factors could be significant as Lay (1988) has noted that "it is sometimes easy to forget that human error or misjudgement alone does not cause a road crash. Furthermore, poor road design may enhance the driver's tendency to err or misjudge". He asserted that "real advances in road safety can best be guaranteed – as in the past – through building greater safety into roads and vehicles".

STUDY CONCLUSIONS AND RECOMMENDATIONS

The Bridge Authority has been increasingly concerned with the alarming nature of prevailing road safety problems at the bridge and its approach roads and has been keen to provide a high level of safety by minimizing accidents and casualties. At present, however, there is a lack of detailed knowledge about the problem characteristics, based on which remedial measures could be developed. Systematic studies and investigation of accidents in this regard can indeed lead to produce such and most cost-effective countermeasures relating to aspects of the road environment, behavioural and vehicle issues.

The analyses and results of the accident study documented in this paper demonstrated the value of identifying striking accident characteristics particularly in terms of event specified accident types and their clustering at specific sites as well as site characteristics and contributing factors. Based on these findings, a range of potential and cost effective countermeasures can now be developed and systematically implemented. Of most importance in the prevailing context are road and road environment related countermeasures which include, in particular, traffic engineering blackspot treatment programs, roadway design modifications and improvements, road side hazard treatments, improved markings, signage and delineations, skidding and visibility. Countermeasures relating to speeds, vehicles, drivers and enforcement are also important. The aspects of driver's fatigue, attitude, training, licensing; vehicle conditions and breaking system, stability, overloading, improved tyre maintenance; speed limits, speed detections and driver speed perception; selective and targeted police enforcement are of equal importance and demand increase attention in the safety management strategies.

Importantly the benefits of such road safety engineering and behavioural measures could be best achieved by the understanding of and constant reference to the fundamental safety principles and operational elements of safer road designs. The main principles of a safe road environment that should be considered are:

- to provide guidance: guide the driver through unusual sections
- to provide information: inform the driver of conditions to be encountered
- to warn: warn the driver of any substandard or unusual features
- to control: control the driver's passage through conflict points or sections and
- to forgive: forgive the driver's errant or inappropriate behaviour.

All of those principles are overwhelmingly important in the context of safety improvement programs at the Jamuna Bridge and its approach roads. Apart from the remedial improvements (reactive approach), the application of pro-active road safety approach is vitally important and demands priority consideration. A formal road safety audit process- systematic examination of roadway elements for safety would focus on explicit safety implications and recommend desirable changes or modifications in highway design and operational aspects appropriate to the local safety needs/standards. Indeed, the road safety audit is one of the newest and most effective accident prevention tools being used throughout the engineering profession to ensure that safety principles are built into the design, construction and maintenance of highways as a means of accident prevention. Clearly, many of the accidents and casualties at the high accident locations and other sites could have been prevented by implementing simple physical measures based on proper safety checks or audits. Its wider application in the study route/corridor and in particular at the roundabouts and approach roads is highly recommended.

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