

Characterizing Hazardous Road Locations and Black Spots on Route N8 (Dhaka-Barisal National Highway) of Bangladesh

Farzana RAHMAN¹, Fayaz UDDIN², Md. Mostafizur RAHMAN³, Md. Ariful ISLAM⁴,

¹ Associate Professor, Department of Civil Engineering, University of Asia Pacific, Dhaka-1209.

^{2,3,4} Student, Department of Civil Engineering ,University of Asia Pacific, Dhaka-1209.

Abstract: Road traffic accidents and corresponding causality are the most concerning issues in the transportation sector of a developing country like Bangladesh where road crashes are remarkably high. According to police reported road traffic accident database, every year about 2800 or more accidents occur in Bangladesh. This research analyzes the various accident data from year 2007 to 2012 using Microcomputer Accident Analysis Package (MAAP5) software in route N8 (Dhaka – Mawa – Barisal – Patuakhali National Highway) in Bangladesh. This research reveals accident prone locations which are commonly termed as black spot and Hazardous Road location (HRL) on the route N8 followed by establishing maps by Geographic Information System (GIS). Head-on, rear-end, overturning, side-swipe and hit-pedestrian are the most dominant types of accidents. Analysis shows that maximum number of accidents occurred in fair weather in route N8. The result clearly indicates that buses contribute mostly in the accidents.

Keywords: Accident, Dhaka-Barisal (N8) Highway, Black Spot, Hazardous Road Location, GIS, MAAP5.

1. Introduction

Road safety problem draws significant attention in a developing country like Bangladesh where road crashes are extremely high. Road traffic accidents and the corresponding deaths are the most concerning issue in the transportation sector of the world. According to WHO's global status report on road safety 2013, more than 1.24 million people die each year on the world's roads. Only 28 countries, covering 7% of the world's population, have comprehensive road safety laws on five key risk factors: drinking and driving, speeding, and failing to use motorcycle helmets, seat-belts and child restraints (WHO, 2013). It has been estimated that over 300,000 persons die and 10-15 million persons are injured every single year in road traffic accidents throughout the world. Detailed analyses of global accident statistics indicate that fatality rates per licensed vehicle in developing countries are very high in comparison with the industrialized countries. Statistics demonstrates that Bangladesh is the most dangerous country in terms of number of accident among the South Asian countries. According to police reported road traffic accident database, every year about 2800 or more accidents occur in Bangladesh. But the actual estimated road fatalities are as high as 10,000-12,000 each year (Rabbi, 2013). Other sources estimated the fatalities as high as from 12,000 to 20,000 per year. Thus, the safety problem is very severe by international standards with some 60 to 150 fatalities per 10,000 motor vehicles in Bangladesh compared to around 25, 16, 2 and 1.4 in India, Srilanka, USA and UK respectively (Road Safety Fact, 2012). Moreover, road accidents have been shown to cost around 1% of annual gross national product (GNP) resources of developing countries, which they can ill-afford to lose. Hence it is necessary to incorporate steps which can reduce road accident rates and implement mitigating action, which can be taken to reduce the number and severity of road accident (Baguley et al, 1994; Kalga and Silanda, 2002).

The contributing factors for road accidents are typically classified into those associated with the driver, vehicle, and the environment. Contributing factors associated with the driver include

error, speeding, experience, and blood-alcohol level. Factors associated with the vehicle include its type, condition and center of gravity. Environmental factors include the quality of the infrastructure, weather, and obstacles. The majority of road traffic accidents are attributed to driver factors (Evans, 1991), and this holds for many other modes such as boats (Bob-Manuel, 2002), bicycles (Cherington, 2000) and Snow mobiles (Osterom and Eriksson, 2002).

In Bangladesh there are many sources for collecting road accident data e.g. police records, hospitals, newspaper reporting etc. However the primary source of accident data is the Accident Report Forms (ARF), which is primarily filled up by police personnel. For each accident the ARF is completed by a sub-inspector of police after visiting the accident spot. The ARF is then dispatched to the respective Accident Data Units (ADU) where the information from ARF and location of the accident is incorporated into Microcomputer Accident Analysis Package (MAAP5). The MAAP5 system is used to analyze accident database and provide the pattern of accidents in the country (Road Safety Fact, 2012). Being a developing country the road safety situation in Bangladesh is very severe compared to international standards. Some major reasons contributing to these are drivers fault, lack of infrastructure, topography, road geometry, environment and weather conditions etc. Dhaka – Mawa – Barisal – Patuakhali national highway (N8) is one of the major routes where a lot of road accident took place.

Corresponding author: farzana-ce@uap-bd.edu

This study focuses particularly on accidents in the N8 route aiming to examine the distribution of accident by types with particular emphasis on identification of Hazardous Road Locations (HRL) and Black Spot. Accident databases show that in 2007-2012, 398 accidents occurred in this route. Among them 311 accidents are fatal and fatality index was 1.27.

2. LITERATURE REVIEW

An in depth literature review was conducted before working out the investigation of accident by Microcomputer Accident Analysis Package (MAAP5) and Mapping of Black Spot using GIS on Dhaka – Mawa – Barisal – Patuakhali (N8) highway.

Traffic accident database is extremely inadequate in developing countries. Under-reporting of accidents is another limitation of accident record keeping system. For example approximately 50 percent of fatal accidents are under-reported such as Vietnam, Thailand (WHO, 2013).

2.1. Accident Database and GIS History and Application in Transportation

GIS is a computer system for capturing, storing, querying, analyzing and displaying geographic data. GIS represents a new paradigm for the organization of the information and the design of information system, the essential aspect of which is the use of concept of location as the basis of structuring of information systems. GIS permits user to display database information geographically. The most useful aspect of GIS as a management tool is its ability to associate spatial objects such as street name, route number, with related information like accident cause etc. In recent years, there has been much discussion about GIS technology and applications across a wide variety of settings. Moreover, there have been many GIS-related developments in transportation planning and engineering (FHWA, 1993; Lewis, 1990; Kim and Levine, 1996). The power of them is rooted in the fact that GIS allows inferences to be drawn about the spatial nature of the data. Examples of GIS applications in transportation include pavement management systems that work with road design, highway mapping, optimal vehicle routing, automated mapping /facilities management (AM/FM) used for infrastructure management, drainage design, traffic modeling and accident analysis, and demographic analysis for funding justification (Antenucci *et al.*

1991). In developed countries, especially the US and Western Europe, GIS technology has been widely applied to urban traffic information management.

Meyer and Sarasua (1996) focus a common and coordinated data system that will serve all aspect of transportation management like congestion, bridge, safety, public transportation etc. Martin (1993) proves that incorporating GIS in a pavement management program improves the reporting and analysis of data through the production of maps and graphic displays. In a separate study by Johnson and Demetsky (1994), the capabilities of GIS in providing a framework for a management system were proven once again. Faghri and Raman (1995) developed a GIS –based traffic system for traffic accident information for Kent Country, Delaware. This system include knowledge about the crash condition such as incident site, frequency and point of road way.

Another study Apparao et al. (2013) focus on identification of accident black spots for highway using GIS for some countries of weak economy. Road traffic accidents have been recognized as one of those adverse elements which contribute to the suffocation of economic growth in the developing countries, due to the high cost related to them, hence causing social and economic concern. So Traffic safety is an important key and integral role in sustainable transportation development areas. Alam and Ahsan (2013) also focus on GIS maps for clear identifying accidents concentrating on the portion of the Dhaka – Chittagong Highway which requires proper treatment and remedial measures to decrease the higher accident rates. Shifun (2007) also did the similar work on a section of Asian highway (Dhaka-Aricha).

2.2. Accident Data Analysis Using MAAP5 and GIS

The accident analysis was done on N1 National Highway by analyzing six years accident data from the year 2004 to 2009. The accident data was collected from the MAAP5 database of Accident Research Institute (ARI) of Bangladesh University of Engineering and Technology (BUET). The Hazardous Road Locations (HRL) and Blackspots were identified by analyzing total and fatal accident data on the highway. Accident data was analyzed at every 100 meter interval on the road. The locations which have three or more fatal accidents and/or five or more total accidents during the six year time period have been identified as HRL (Alam et al., 2013). Shifun (2007) has an analysis on a portion of N5 National Highway named Dhaka-Aricha highway by analyzing seven years accident data from the year 1998 to 2004. The locations which have at least three accidents during the seven year time period have been identified as HRL.

3. ANALYSIS

The study involves crash data collection and analysis by using MAAP5 software to identify black spot or HRL using GIS. GIS has been identified as an excellent storing and managing software for these types of data and possesses a better visualization system.

3.1. Data Collection

The Accident Report Forms (ARF), which is primarily filled up by police personnel is the basic source of accident information. These ARF are then edited by Accident Research Institute (ARI), BUET to function it by MAAP5 software. Findings are organized by accident severity, accident categories, accident period, collision type, vehicle involvement in the accident, routes where accidents took place, pedestrian-casualties etc. Accident data was analyzed for the period of 6 years (2007-2012) for identifying black spot or HRL.

On any road network, it has been seen that accidents are not randomly distributed, but are clustered at certain locations. Accident data was analyzed at 100 meter interval on the N8 route. In a 100 meter segment of a highway if accident number is three or more in 5 year period then the location is termed as black spot. Similarly in a 1000m segment of a highway if accident number is four or more in 5 year period then the location is termed as hazardous road location (HRL). The

procedure followed in identification of Blackspot or HRL on Dhaka-Barisal highway is divided into few steps. The steps are shown in Figure 1:



Fig. 1 Steps Followed in GIS for Blackspot & HRL identification

3.2. Data Analysis using MAAP5 Software

This section discusses the characteristics and striking features of overall road traffic accidents on national highways in Bangladesh. Accident data would be analyzed for the period of 6 years from 2007-2012. The analysis involves the determination of accident and severity in the following two categories:

1. Accident of all route in Bangladesh
 2. Accident of N8 route in Bangladesh (Dhaka – Mawa – Barisal - Patuakhali National Highway)

3.2.1 Accident of all routes in Bangladesh

The analysis involves the determination of accident and severity depending on several features.

Accident Severity: Table 2 shows that accident in different routes of national highways in Bangladesh. Percentage of accident was 19%, 16%, 8%, 8%, 24%, 5%, 7%, 9% and 4% in route number N1 to N9 respectively. It can be observed that 80% of all accidents are fatal and 15% are grievous type. Fatality index appears highest (1.59) in route N4.

Table 1 Distribution of accidents by different route

Name of Route	Length (km)	Accident number	Accident per km
Dhaka - Chittagong - Cox's Bazar - Teknaf (N1)	455	830	1.82
Dhaka- Sylhet -Jaflong (N2)	286	684	2.31
Dhaka - Tongi-Mymensingh (N3)	112	347	3.09
Joydebpur -Tangail - Madhupur – Jamalpur (N4)	146	361	2.47
Dhaka -Nabinagar -Manikganj - Bogra - Panchagarh (N5)	507	1036	2.04
Kashinathpur - Pabna- Rajshahi (N6)	150	205	1.37
Daulatdia Ferryghat – Goalchamot- Khulna – Digraj (N7)	252	302	1.2
Dhaka – Mawa- Barisal -Patuakhali(N8)	191	398	2.08
Jamuna Approach Road (N9)	43.1	154	3.57

Table 2 Distribution of accidents by severity

Accident						Casualty					
Route no.	Fatal	Grievous	Simple	Collision	Total	Fatal	Grievous injury	Simple injury	Total	% of total fatality	Fatality index
1	670	108	25	27	830	1242	269	46	1557	19.78	1.50
2	547	108	17	12	684	1025	239	31	1295	16.45	1.50
3	296	39	7	5	347	495	92	11	598	7.60	1.43
4	297	44	11	9	361	575	100	22	697	8.86	1.59
5	803	167	41	25	1036	1386	348	73	1807	22.96	1.34
6	170	25	7	3	205	264	63	9	336	4.27	1.29
7	227	61	8	6	302	437	119	18	574	7.29	1.45
8	311	69	12	6	398	507	154	34	695	8.83	1.27
9	115	26	5	8	154	222	76	14	312	3.96	1.44
Total	3436	647	133	101	4317	6153	1460	258	7871	100	1.43

Road Class: Figure 2 demonstrates accidents in different routes depending on road class. Result shows that 46% of total accident occurred in national highway which was the maximum. 18% of the total accident took place in city road, and 14% was in regional road.

Collision Type: Figure 3 shows that 42% of total accidents was vehicles hit pedestrians type, while head on collisions was about 23% of total accidents. Rear end collisions were 13% of the total accidents.

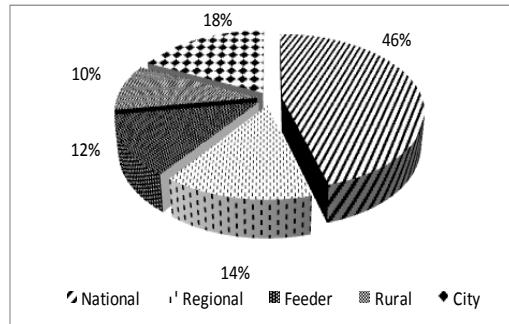


Fig. 2 Distribution of accidents by collision type

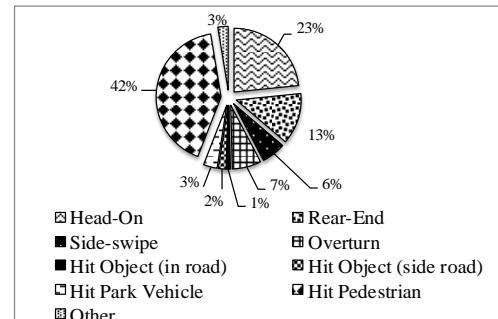


Fig. 3 Accident in different road class

Pedestrians Accident: Figure 4 shows a comparison between total number of accidents and pedestrian accidents in different routes of Bangladesh. Figure 4 demonstrates clearly that in N3, N6, N7, N8 and N9 the difference between the total number of accident and the total pedestrian accident in the routes are comparatively less, which means that pedestrian accident frequencies are higher. Figure 5 shows that 89% of pedestrian accident was fatal and 10% was grievous injury.

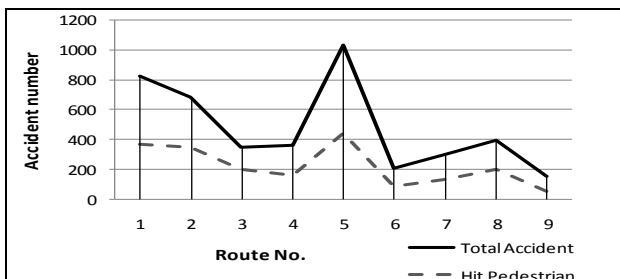


Fig. 4 Accidental number of hit pedestrian and total accident

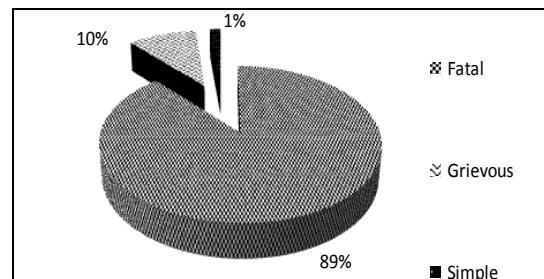


Fig. 5 Distribution of accidents by pedestrians severity

3.2.2 Accident in route N8 in Bangladesh

The analysis involves the determination of accident and severity features according to environmental characteristics, road related characteristics, vehicle, driver, pedestrian related characteristics and other contributing characteristics.

Environmental characteristics

i) Year: Table 3 illustrates yearly distribution of accident and corresponding causality. In 2007 casualties per accident rate was 1.45 and in 2010 the rate was the maximum (2.12). In 2012 casualties per accident was 1.70. Although accident frequency is decreasing but casualties per accident are rising.

Table 3 Distribution of accidents and casualties by year

Year	Accidents number	Casualties number	Casualty/accident
2007	100	145	1.45
2008	110	178	1.62
2009	64	132	2.06
2010	41	87	2.12
2011	40	80	2
2012	43	73	1.70
Total	398	695	1.75

ii) Month of year: Figure 6 shows that accidents were higher during the month of December, March, April, May, and January.

iii) Time of Day and Lighting Condition: Figure 7 illustrates hourly distribution of accident in route N8. It is clear that accidents are more frequent between 9.00am-12.00pm. It is about 23% of total accident. In between 12.00pm -3.00pm the accident frequency is also high.

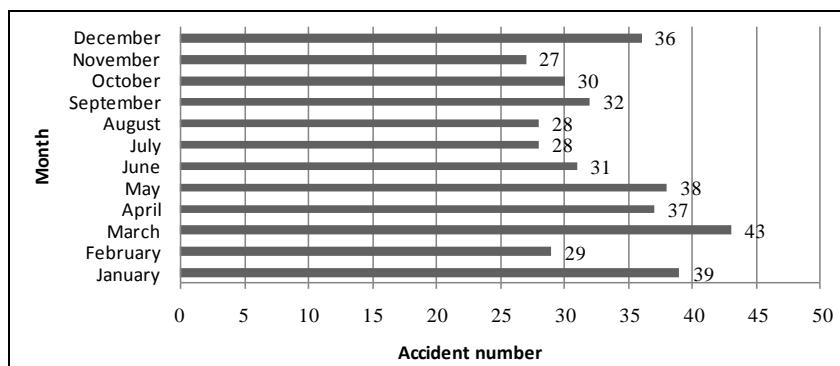


Fig. 6 Accidents distribution by month

Figure 8 makes clear that, most of the road accident and corresponding casualties occur in day period. The frequency of accident in dusk is 12% of total accident in route N8. At night when it is dark 11% of total accident took place. It should be noted that at night traffic volume in route N8 is comparatively low.

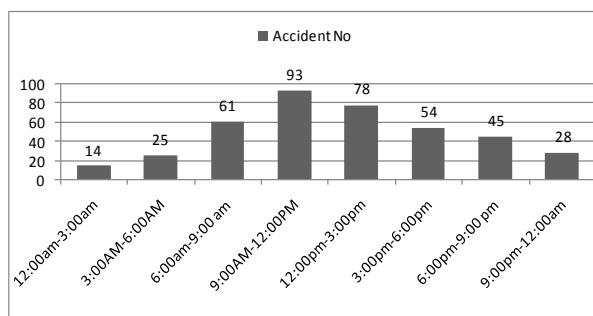


Fig.7 Accident distribution by lighting

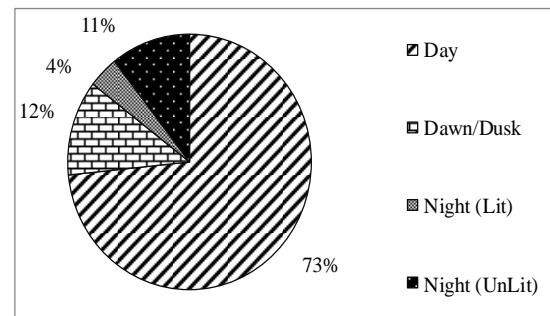


Fig. 8 Accident distribution by time of the day

iv) Weather conditions: Table 4 shows the relationship of weather and vehicular contribution with accident rate. Analysis shows that maximum number (94%) of accidents occurred in fair weather in route N8. Bi-vehicular accident frequency represents the accident between two vehicles occurring in a particular weather. Bi-vehicular accident frequency is 57.15% in rainy weather. It is determined by the percentage of accidents occurring in contribution to two vehicle divided by the total number of accidents in that particular weather.

Table 4 Distribution of accidents by weather

Weather	Accident Number			Total	Bi-vehicular accident frequency
	1	2	3		
Fair	242	132	1	375	35.2%
Rain	6	8	0	14	57.15%
Wind	0	1	0	1	100%
Fog	5	3	0	8	37.5%
Total	253	144	1	398	

Road related characteristics

i) Type of junctions: Figure 9 shows the distribution of accident in different types of junction. 82% of total accidents occur in non-junction in route N8. In other types of junction and T junction the percentage of accidents are 9% and 5% respectively. Figure 10 shows that, the distribution of fatal accident in different types of junction. 84% of total accidents occurred in non-junction referring to straight portion of road in route N8. In round junction and T junction the accident frequency is 7% and 4% respectively.

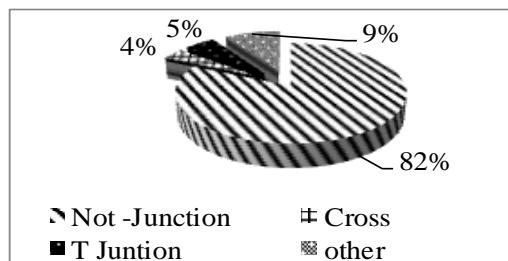


Fig. 9 Total accident distribution by different junction

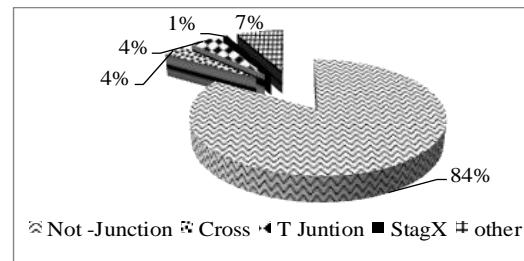


Fig. 10 Fatal accident distribution by different junction

ii) Road Divider: Result depicts that maximum accident (95%) occurs in the locations where no divider is present.

iii) Road geometry: Table 5 demonstrates the distribution of accident based on different road geometry. Most accident occurred in straight road in route N8.

Table 5 Distribution of accidents by road geometry

Road geometry	Accidents No
Straight	361
Curve	27
Slope	8
Curve & Slope	0
Crest	2
Total	398

Vehicle Related Characteristics

i) Vehicle damage: Figure 11 shows the distribution of accidents based on vehicle damage. It is demonstrated that 20% of the vehicles are suspected for both front damage and multiple damage. 50% of the vehicles had no damage. They are presumed to be responsible for pedestrian causality.

ii) Vehicle type: Figure 12 indicates contribution of different types of vehicles in accident. The result clearly reveals that buses contribute mostly in the accidents. Heavy trucks and motor cycles also contribute a lot to the accidents.

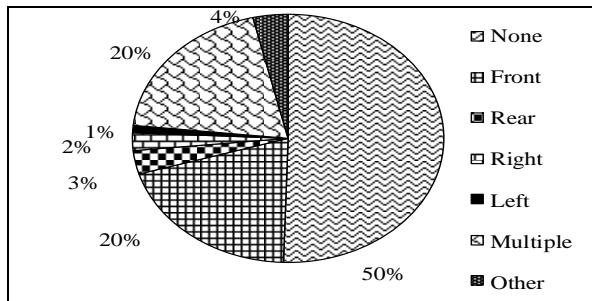


Fig. 11 Distribution of accidents based on vehicle damage

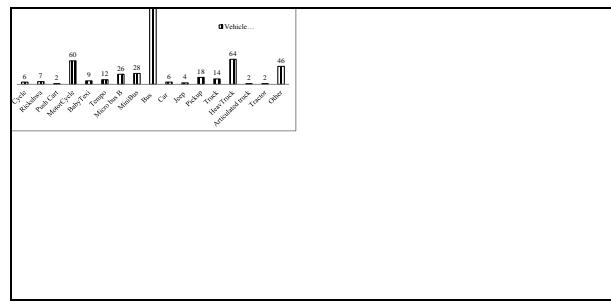


Fig. 12 Types of vehicles contributing in accident

Pedestrian related characteristics

i) Pedestrian Location and Action: Figure 13 shows the distribution of accident based on pedestrian position. When pedestrians walk/stay in road side then maximum (39%) accident occurs. 31% accident took place while pedestrians were on the road. Figure 14 shows the distribution of accident depending on pedestrian action. Fatal accidents as well as total accident frequencies are much while the pedestrian were walking on the edge or on the side of the road or along the shoulder.

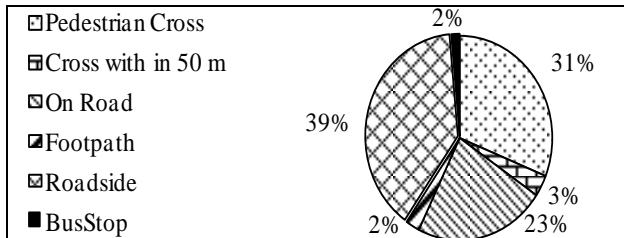


Fig. 13 Distribution of accident based on pedestrian position

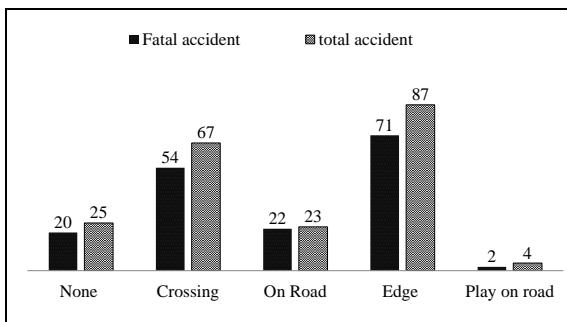


Fig. 14 Distribution of accident depending on pedestrian action

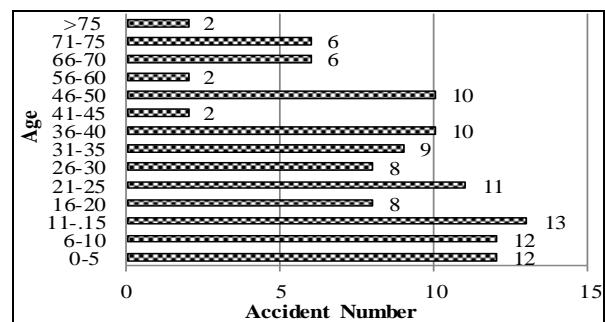


Fig. 15 Distribution of accident based on pedestrian's age

ii) Pedestrian age: Figure 15 shows the distribution of accidents based on pedestrians' age. It is found that accident frequency is most for youth group age ranging from 11-15 years. Accident number is also high for 46-50, 36-40, 21-25, 6-10 and 0-5 years' old groups. Result shows that 82% casualties occurred for male pedestrians.

Contributing factors for accidents

Figure 18 clearly illustrates that pedestrian, road fault and over speed are the most important causal factors behind accident.

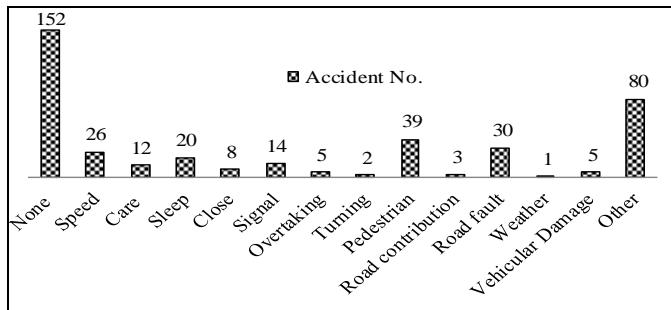


Fig. 16 Contributing factors for accidents

i) **Drunk driving:** It is evident from figure 17 that most of the drivers were not suspected for drinking alcohol.

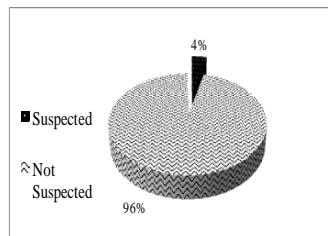


Fig. 17 Suspicion drunk driving

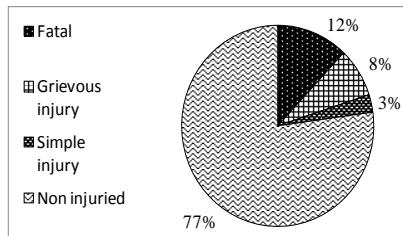


Fig. 18 Distribution of accident based on driver's injury

ii) **Driver injury:** Figure 18 demonstrates that percentage of driver's injuries is comparatively low while 12% are fatal accidents.

3.3 Black-spot or HRL Identification

The study investigated a total length of 191 km of route N8. The highway under study encompasses varied geometrical and environmental condition. For accident analysis purpose, the highway was divided into 1910 divisions where each section covered 100m length. The HRL and Blackspot location of route N8 is presented in Figure 19. In Dhaka – Mawa – Barisal - Patuakhali National Highway seven black spots and seven HRL were identified.

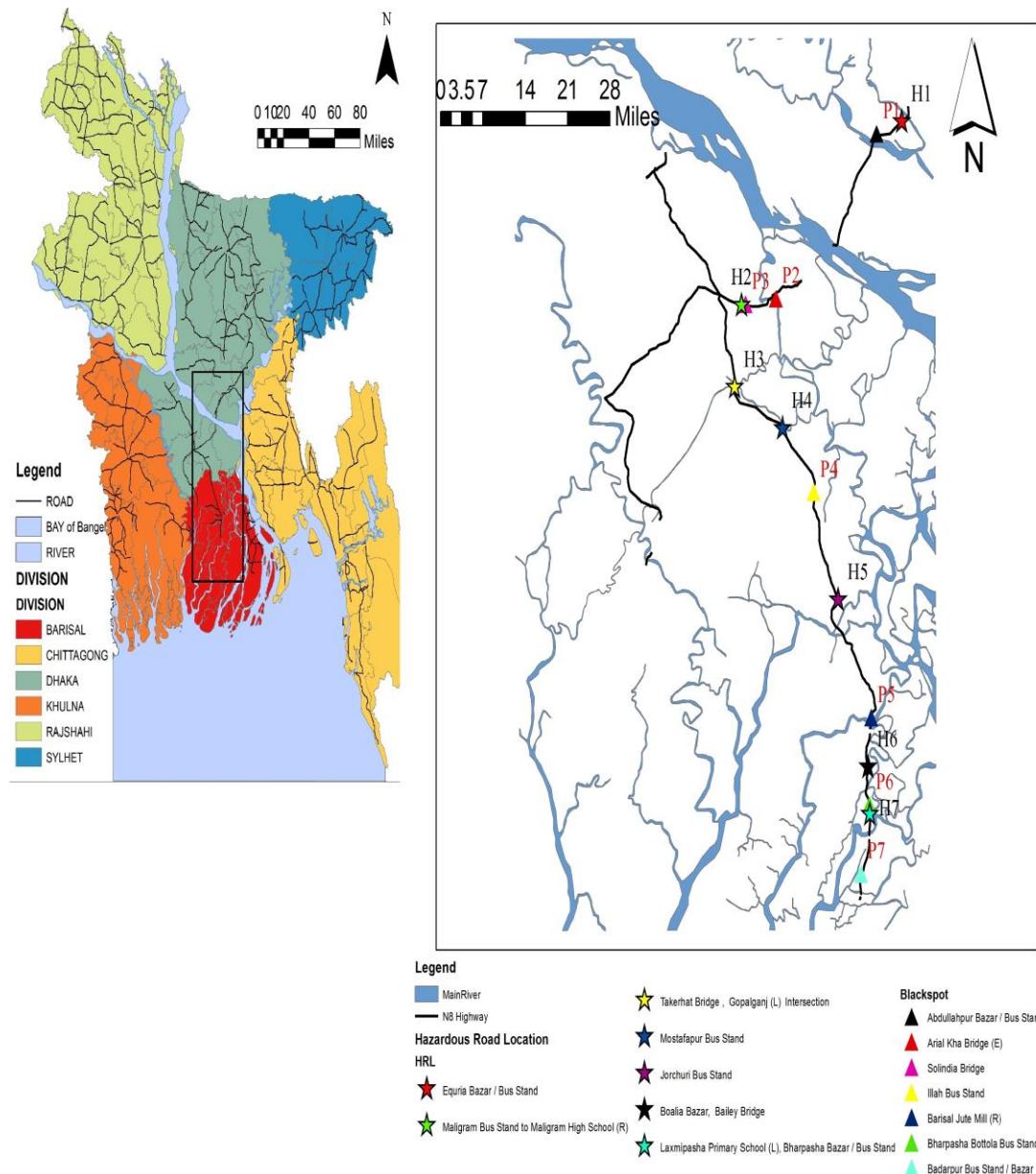


Fig. 19 Blackspot and HRL on N8 highway (Map.1)

Table 6 Blackspot or HRL on Dhaka-Barisal highway (2007-2011)

Type*	km Post	Length (m)	Location	Total accident
H1	7 to 7.5	500	Equria Bazar / Bus Stand	5
P1	13.9 to 14	100	Abdullahpur Bazar / Bus Stand	4
P2	50.8 to 50.9	100	Arial Kha Bridge (E)	3
P3	57.6 to 57.7	100	Solindia Bridge	3
H2	59 to 59.7	700	Maligram Bus Stand, Maligram High School (R)	12
H3	184.5 to 185.3	800	Takerhat Bridge, Gopalganj (L) Intersection	5
H4	199.6 to 19.8	200	Mostafapur Bus Stand	6
P4	214.9 to 215	100	Illah Bus Stand	4
H5	236.8 to 237	200	Jorchuri Bus Stand	4
P5	266.2 to 267.3	100	Barisal Jute Mill (R)	3
H6	271.1 to 272.1	1000	Boalia Bazar, Bailey Bridge	4
P6	278.5 to 278.6	100	Bharpasha Bottola Bus Stand	3
H7	280.1 to 280.4	300	Laxmipasha Primary School (L), Bharpasha bazar /Bus stand	4
P7	289.6 to 289.7	100	Badarpur Bus Stand / Bazar	4

* P= Black spot and H=Hazardous Road Location

4. SITE INVESTIGATION

Road conditions were investigated in black spots or HRL on N8 highway route. Following observations were obtained:

- Narrow road
- Narrow and risky bridge
- No shoulder No road marking
- Broken road surface
- Road blockage by para-motorized
- Shoulder damage due to rutting of soft soil
- Unsafe pedestrians action
- No-warning helmet during motorcycle driving
- Over-speeding and Over-taking tendency
- Have not proper space for bus stop/stand



Fig. 23 Narrow Bridge



Fig. 24 Risky Bridge



Fig. 25 Shoulder Damage



Fig. 26 Shoulder Damage due to Rutting of Soft Soil



Fig. 27 Soil Displacement from edge



Fig. 28 Road blockage by Para motorized vehicle

5. FINDINGS

From this study it is found that a total of 398 accidents have occurred on Dhaka – Barisal Highway during the six year duration from 2007-2012 and 311 accidents among the total are fatal. So, it is clearly visible that about 78% of the accidents are fatal which have caused severe casualty and loss to life as well as the economy of our country. The GIS maps prepared from six years accident data (2007 to 2012) have shown that 7 black spots and 7 hazardous road locations are situated on route N8. About 9% of the total accidents occurred in this portion of Dhaka-Barisal highway. Most important feature in this route is pedestrian causality which account for 51% of total accident. So it has been clearly identified that accidents are concentrated on this portion of the Dhaka –Barisal Highway. This portion requires proper treatment and remedial measures to decrease the higher accident rates. Dhaka-Barisal Highway has been selected from all the 14 hazardous locations on the basis of the highest number of accidents. Details accident analysis on this route on various parameters has given the following accident scenario: about 80% of the total accidents are fatal and per accident fatalities is 1.27. Accident and corresponding causality is 1.75. In 2007 casualty/accident rate was 1.45 and in 2010 the rate was maximum (2.12). In 2012 the casualty/accident was 1.70. Accident frequency is higher in the month of March, April, May, December and January. The accident frequency is highest between 9.00am-12.00pm. It covers 23% of total accident. Head-on, rear-end, overturning, side-swipe and hit-pedestrian are the most

dominant types of accident. Accident and casualty statistics of 6 years (2007-2012) shows that, these five types account for 90% of total accidents in route N8. Analysis shows that maximum (94%) accident occurs in fair weather in route N8. But analysis of bi- vehicular accident shows highest accident frequency (57.15%) in rainy weather. Road fault and over speed is the most important casual factors behind accident. Bus and motor cycle are most accident prone modes of transport. 50% vehicles have found that no damage was occurred during accident. They are supposed to be responsible for pedestrian causality. Pedestrian casualties occur half of accidents. When pedestrians walk/stay in road side then maximum accident occurs. Most of the driver was not suspected for drinking alcohol. The driver injuries percentage is comparatively low.

6. CONCLUSION

This study suggests the factors contributing to accidents are road environment, weather, geometry, driver's characteristics and vehicular factors. This study will finally use GIS for identifying Black spot or HRL. This paper underlined salient features of road accident characteristics and delineated typical safety issues .Further site investigation is required to design appropriate remedial measures. The most evident point of this route is that about half of total accident results pedestrian causalities. Therefore pedestrian safety is a major concern for those routes.

Some more general recommendations are as follows:

- Narrow road and bridge is the main reason of accident in few Blackspot or HRL in N8.
- Markets located beside highways should be replaced to other place.
- Space should be provided for bus stop/ stand.
- Para-motorized vehicles block the highway space. So a proper management of these vehicles should be ensured.
- Adequate enforcement should be provided to ensure that the drivers follow the traffic rules strictly.
- Some facilities for pedestrians such as overpass, underpass, zebra crossing, pedestrian signal etc should be provided where required.
- Exclusive lanes for non-motorized vehicles should be provided which may reduce rare end collision.

Recently Padma Bridge Project has been started at Mawa-Jajira point beneath the route N8. So future expected average daily traffic (ADT) of N8 will be higher than other routes. So it is high time for analysis accident, establish engineering countermeasure and improve road safety for decreasing accidents for efficient operation of Dhaka-Mawa-Barisal-Patuakhali Highway.

References

1. Accident Database 2007 to 2012, ARI, BUET, Bangladesh.
2. Antenucci, J., Brown, K., Croswell, P. Kevany, M., Archer, H. (1991). Geographic Information System: A Guide to the Technology.
3. Apparao. G, P. Mallikarjunareddy and Gopala, R. (2013). Identification of Accident Black Spots for National Highway Using GIS.
4. Baguley, C. McDonald, M. Towards Safer Roads in Developing Countries. (1994). *A Guide for Planners and Engineers*” Transport Research Laboratory, pp. 1-60.
5. Evans L. (1991). Traffic safety and the driver, Van Nostrand Reinhold: New York.
6. Bob-Manuel, K.D.H. (2002). Probabilistic prediction of capsizing applied to small high speed craft, Ocean Engineering 29: 1841-1851.
7. Cherington, M. (2000). Hazards of bicycling: from handlebars to lightning, Seminars in Neurology, 20 (2):247-253.
2. Osterom, M., and Eriksson, A. (2002) Snow mobile fatalities: aspects on preventive measures form a 25-year review Accident Analysis & Prevention, 34: 563-568.

3. Faghri, A. and N. Raman, A GIS-Based Traffic Accident Information System. (1995). *Journal of Advanced Transportation*, vol. 29, no. 3, pp. 321-334.
4. Kalga, R.R. and Silanda, S.N. (2002). Accident rates Prediction on Arterial Roads of Durban, South Africa, *Indian Highways Journal*.
5. *Global Status Report on Road Safety (2013)*, World Health Organization (WHO).
6. Hasanat-E-Rabbi, S. (2013). *Modeling Critical Overturning Criteria for Single Vehicle Run-off-road Crashes for Bangladesh Context*. M.Sc. thesis, Department of Civil Engineering, BUET, Dhaka, Bangladesh.
7. Highway Statistics, FHWA. (1993). Available from internet: <http://www.fhwa.dot.gov/>.
8. Hoque, M. S., Muniruzzaman, S. M., Ahmed S. N. (2005). Performance Evaluation of Road Safety Measures: A Case Study of the Dhaka-Aricha Highway in Bangladesh, *Transport and Communications Bulletin for Asia and the Pacific No. 74*.
9. Kim, K. and Levine N. (1996). Using GIS to improve highway safety.
10. Johnson, B.H and M.J. Demetsky. (1994). Geographic Information System Environment for Transportation Management *Transportation Research Board*, Washington D.C, pp. 67-73.
11. Lewis, S.M. (1994). The Use of GIS in the federal highway Administration's office of Policy Development In *Proceeding of the 1990 GIS for transportation Symposium, San Antonio, Tex., Mar., pp.10*.
12. Liang.L.Y, Ma'some D.M., Hua L.T. (2005). Traffic Accident Application Using Geographic Information System, *Journal of the Eastern Asia Society for Transportation Studies*, Vol.6, pp. 3574 - 3589.
13. M. D. Meyer, S. Washington, R. Guensler, S. Hallmark (1996). Integrating Travel Demand Forecasting Models with GIS to Estimate Hot Stabilized Mobile Source Emissions. In *Proceedings of the 1996 AASHTO GIS-T Symposium, Kansas City, MO*.
14. Martin, D. (1993). Council invites experts to rethink IT Plan, Computing.
15. Monisha, A. and Hasib, M. Ahsan. (2013). Identification and Characterization of Hazardous Road Locations on Dhaka-Chittagong National Highway Dhaka, Bangladesh.
16. *Road Safety Fact. (2012)*. ARI, BUET, Bangladesh.
17. World Heath Organization, WHO. (2013). Status report on road safety 2013 – Supporting a decade of action. Design and layout by L'IV Com Sàrl, Villars-sous-Yens, Switzerland, Printed in Luxembourg, available at www.who.int/