Development of a GIS based hazardous road location identification system for National Highways of Bangladesh

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Abstract: Developing countries like Bangladesh are now facing a serious road safety crisis and without giving severe importance with significant improvement in the relevant sector, the problem will be worsen in the coming years. Recent analyses illustrate that road crashes are normally clustered in some specific sites, routs or locations and now the main challenge is to find out those locations exactly. Traditional analysis techniques do not have any spatial referencing with the road network but only shows some historical database to identify the crashes locations. Consequently, it's become difficult to find out the crash locations for the time being. A GIS based smart road safety system with digitize road network can help us to identify the crash locations on road which will lead us to locate the hazardous road locations (HRL) after some spatial query. Specific treatments at those locations can greatly reduce the overall number of road crashes. Under this circumstance this study will provide an effective method to identify and analysis of hazardous road locations in national highways of Bangladesh by a digitized road map exclusively for crash investigation using Geographic Information System (GIS). A case study also provided on a national highway, Dhaka-Aricha to verify the method. Crash data has been analyzed for three years, 2008-2010. Criteria of HRL identification is set as the locations where the number of fatal crashes in 0.1 Km to 0.5 Km of road over a period of 3 years equals or exceeds 3 crashes. Characteristics analysis carried also on some selected spots to understand the actual facts behind the crash on those locations with some general countermeasure to twist the locations safe. This low cost method of identification can be used in other national highways of Bangladesh and also in other countries as well because of its easy adoption and compatible nature.

Key word: Road crashes, hazardous road location, Geographic Information System (GIS).

Introduction

Road Traffic Crashes (RTC) comprises a major public health problem in world wide. According to WHO, leading cause of deaths and the 9th leading contributory factor to the burden of disease all around and the situation will be worsen in coming days. About 1.2 million human fatalities are estimated with almost 50 million are injured. It is predicting that this number will rise by about 65% over the next 20 years unless new measures to prevent the hazard are taken (Rahman, 2006, p.24). Most of the case the safety measures to prevent RTC using in developed countries is not compatible for low and middle income countries due to the difference between social, cultural, economic and behavioral distinction. Detailed analyses of global crash statistics indicate that, however, that low and middle income country is accounted for about 90% of all road crashes in recent years when fatality rates per licensed vehicle are very high in comparison with the industrialized countries. Moreover, road crashes have been shown to cost around 1% of annual gross national product (GNP) resources of the developing countries, which they can ill-afford to lose. Hence it is necessary to incorporate steps, which can reduce road crash rates and implement mitigating actions.

Like other developing countries, Road Traffic Crashes are causing a serious concern in Bangladesh when developed and a good number of developing countries are improving the situation. Present road crash analyis system is

confined only some kinds of historical database having a little scope for scientific analysis with those data and what is worth, there is no clear or a gray area to identify the crash prone locations or hazardous locations or black spots, which is now a prime requirement for careful investigation and comprehensive study to solve the epidemiological nature of road crashes.

The road crashes are normally clustered in some specific sites, routs or locations. Hazardous location or locations mean abnormal concentrations of crashes occurrences in some particular road length within the route. At present, in our country the crash locations are manually marked and written by police in crash record form. For this, however, sometimes the exact crash location does not match with the written location or the location does not find out at all. Crash data collected for many years serve as the ground base for program designed to reduce the number of traffic crash. These crashes database are usually in the form of linear record file system, which enable an extensive amount of research using statistical methods, but both the database as well as the analyzed information lacked visibility, which is now one of the primary requirements in a smart technical analysis for better understanding and good decision making. To build a smart road safety system we need to go for modern technology like Geographic Information System (GIS) with a digitized road network especially for road crash analysis where every road segment have their attribute and analyzed separately.

In Bangladesh, we don't have any digitize road map or vector map exclusively for road traffic crash analyses. The digitize map which is using for other purpose have lack of spatial information of every road segment that's why it cannot co-relate with the crash data from police. Geographic Information System (GIS) has been identified as an excellent system for storing and managing these types of data and also as a potential tool from improving crashes analysis process. One of the main reasons is that it provides an efficient system of linking a large number of disparate databases and also provides a spatial referencing system for reporting output at different levels of aggregation (Peled, A. & Hakkert, A.S, 1982). A digitize road network can help us to identify the crash locations on spot and from here we can authentically locate the crash prone locations or hazardous road locations in a road. Specific treatments at such locations can greatly reduce the overall number of road crashes. This type of effective and low cost technology is now a an urgent need for our country and under this circumstance this study will provide an effective system to identify and analysis of hazardous road locations in national highways by a digitized road map exclusively for crash investigation using Geographic Information System (GIS).

In Bangladesh, until recently, very little work has been done to focus on a detailed spectrum of analyses of road crashes for a reasonably full understanding of the crash problems and thereby developing effective countermeasures. Crash data recorded from 2008 to 2010 by the Crash Research Institute (ARI), BUET, has been used as the basis for the study. This study focuses on hazardous road locations on Dhaka-Aricha-Banglabandh national highway named as N-5 plays a vital role in inter-district and interregional transport as it connects the northern and western regions of Bangladesh with Dhaka, the national capital. The length of the road is 513km and has a great effect on national economy and transport. This corridor has chosen for the case study because of its recent crash statics. Total 2594 no. of crashes occurs in between year 2000 to 2010 with 2445 fatalities and 2202 injured and it is also happening in recent year. From the year 2008 to 2010 total number of crashes are 419 with 557 fatalities and 375 injured (ARI Database, 2011).

Figure 1: Dhaka-Aricha-Banglabandh (N-5) National Highway

Materials and Method

Apart from the sufferings and pain road crashes are huge financial burdens for governments at all levels. Several programs and methods have been taken by the authority to mitigate the crisis. However, these program and traditional methods have some limitation. The accurate location of crashes is often miss-coded wrongly, street names spelt, street number code may be wrongly coded. Further difficulties include the lack of common referencing system, lack of consideration of the special analysis and are labor intensive and time consuming (Prastacos, 1991). All these make the identification of high crash road section more difficult especially for the traditional computerized programs now in use. These could also lead to wrong section of roads being identified as hazardous if not the wrongly coded crashes are identified on time.

GIS is found to be suitable for such analysis and able to overcome these handicaps. It has the capability to integrate data from various sources and generate useful information upon which sound decision can be based. GIS in road crash analysis and safety, enhance efficiency in data collection with errors identification at an early stage for prompt action. As a consequence, generation of good quality crash locations plots; and improves decision making by serving as a decision- support system. Data in GIS system for road safety improvement are generally stored in separate thematic layers. Each layer represents theme of the overall system and comprises spatial information and non- spatial information stored in the system database, and sometime auxiliary files (Affum J. K., 1992). All these are linked together to established of georeferenced database. The second phase of the system analysis focused on the use, reconstruction, and accessibility to various data elements. This methodology made it possible to implement most of the queries in a simple and rapid manner, where only in a "microtype" analysis does the system need to select the information contained in the auxiliary files (Lubkin, J.L. 1989).

This study was based primarily on a specially created crash form by Bangladesh police. The form was designed for easier completion and it's fully compatible with crash analysis package MAAP (Microcomputer crash analysis package). The person filling in this form simply needs to circle the relevant value for each crash parameter which has been conveniently classified into various sections. This information is manually keyed in into MAAP using the programmed option available in MAAP. In order to model the mentioned factors and achieve the desired result, a step-by-step procedure as given below has adopted.

- Scan the map containing the desired road network and input this image to ArcMap for digitizing (convert Raster map to Vector map). Because for spatial analysis a digitized map is required.
- Draw vector maps of all the national highways (N1-N8). The projection system used in this study is BTM coordinate system.
- Divide the Dhaka-Aricha-Banglabandh (N-5) national highways with an equal distance of 100m. Digitize the road network with due consideration for separation of every link (100m) and assign “id” number to every link.
- Preparation of crash database for the year 2008-2010. In this study crash data has been collected from crash research institute, BUET.
- Export the crash attribute table in dbase format so that it can be imported by ArcMap.
- Join the road attribute table to the crash database and prioritize the raod network for crash occurrence using total weights assigned to every link
- Create shapefile of crashs for the year 2008-2010
- Query on shapefiles to visualize crash on the road
- Combine the results obtained query analysis to determine the hazardous road location on the road network. There are many criteria’s to select hazardous road location. The identification criteria in this study is, firstly the locations where the number of fatal crashs in 0.1 Km to 0.5 Km of road over a period of 3 years equals or exceeds 3 crashs are identified. Upon further analysis, adjacent locations (within 3 km) with fairly high crashs were aggregated to one hazardous location.

- Characteristics analysis of selected hazardous road locations in national highway. This will help to understand the crash scenario of those roads which will assist in implementation of safety measures of those locations.

Site study showed that some kilometer post sign are not exact which lead the police officers to identity the kilometer post. Therefore in the study some crash locations are not in exact place.

Results

Amongst elements in accident information, the most important element, from engineering point of view, is the exact location identification which is a pre-requisite to identification of hazardous location or black spots. Accidents locations of the highway have shown in figure 2 on road network.

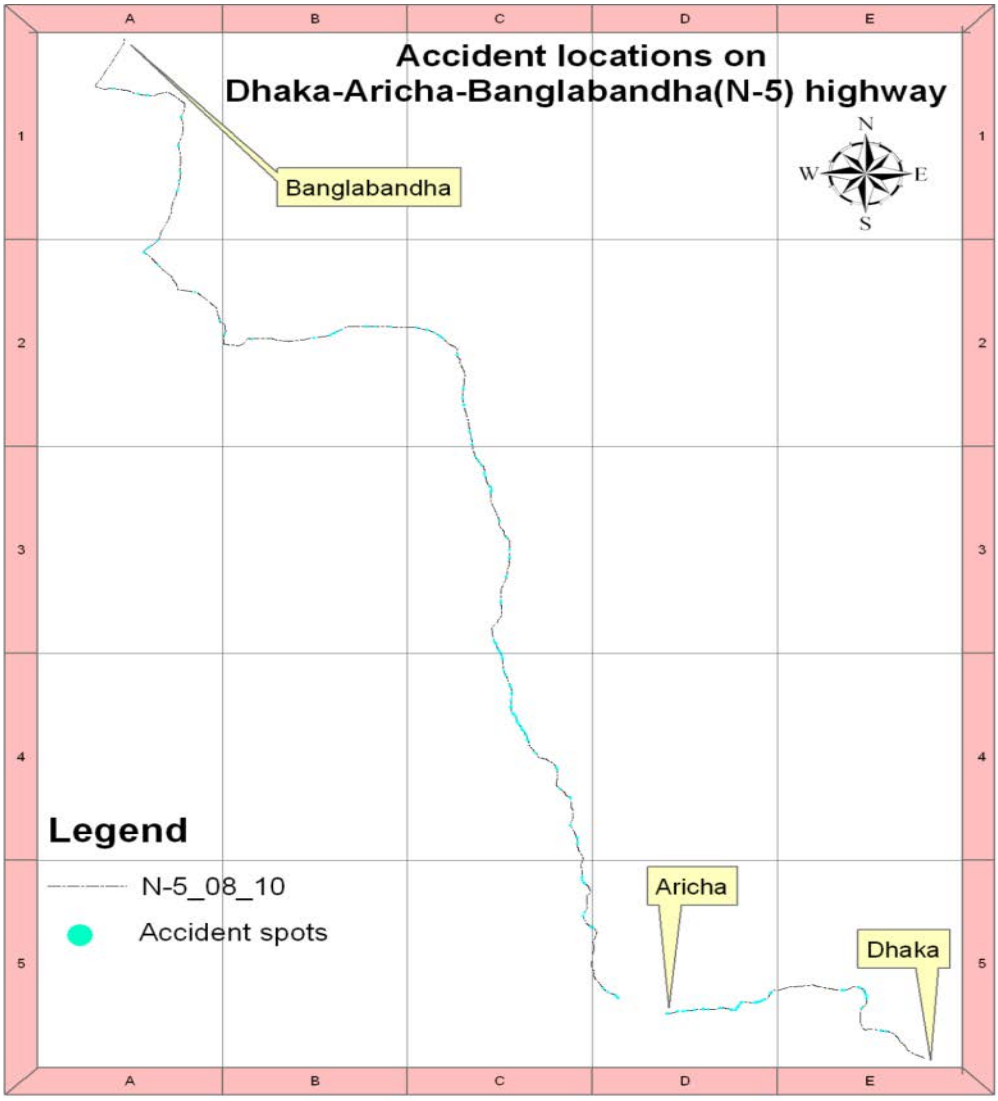

Figure 2: Accident locations on Dhaka-Aricha-Banglabandh (N-5) National Highway

From figure 2 it's clearly visualize that crashes have taken place all over the road though there are some successive segments of road where crashes are in a row. In this figure crashes are have shown in a common identity but to find hazardous road locations or black spots, locations should be analyzed by number of accidents.

In this study for analysis purpose, however, Dhaka-Aricha-Banglabandh national highway is analyzed by two separate sections. First one is eastern side of the river Padma is from Dhaka-Aricha named as N-5(E) which is 87 km long and second portion is western side of the Padma river from Aricha-Banglabandh named as N-5 (w) is 426 Km. This highway encompasses varied geometrical and environmental condition.

Hazardous Locations on Dhaka-Aricha, N-5(E)

From the year 2008 to 2010 total 63 accidents occurred; when majority of these are fatal accidents. 52 fatal accidents have occurred during the time period. Accident scenario of this road segment has given below in table 1. Here, id is for georeferencing link with road shape file and "FA08_10", "NFA08_10" and "TA08_10" is successively represents the number of fatal accident, non fatal accidents and total accidents.

Table 1: Accident statistics of Dhaka-Aricha, N-5(E) highway

Id	Km	FA08_10	NFA08_10	TA08_10	Id	Km	FA08_10	NFA08_10	TA08_10
618	61.7	6	2	8	386	38.5	1	0	1
671	67	6	1	7	579	57.8	1	0	1
577	57.6	4	0	4	605	60.4	1	0	1
768	76.7	4	0	4	613	61.2	1	0	1
824	82.3	3	0	3	627	62.6	1	0	1
311	31	2	0	2	665	66.4	1	0	1
634	63.3	2	2	4	672	67.1	1	0	1
682	68.1	2	0	2	684	68.3	1	0	1
707	70.6	2	1	3	686	68.5	1	2	3
737	73.6	2	0	2	781	78	1	1	2
137	13.6	1	0	1	803	80.2	1	1	2
150	14.9	1	0	1	847	84.6	1	0	1
263	26.2	1	0	1	873	87.2	1	0	1
308	30.7	1	0	1	874	87.3	1	1	2
324	32.3	1	0	1	**Total**	**2.9km**	**52**	**11**	**63**

From the table it's found that among the total 87 km road length accident only occur at 2.9 km of road length. This crashes information has linked with the road network shape file with GIS to locate the hazardous location on road. After this the accident spots is possible to pin-pointed on map. Figure 3 shows the hazardous road locations on Dhaka-Aricha section of highway.

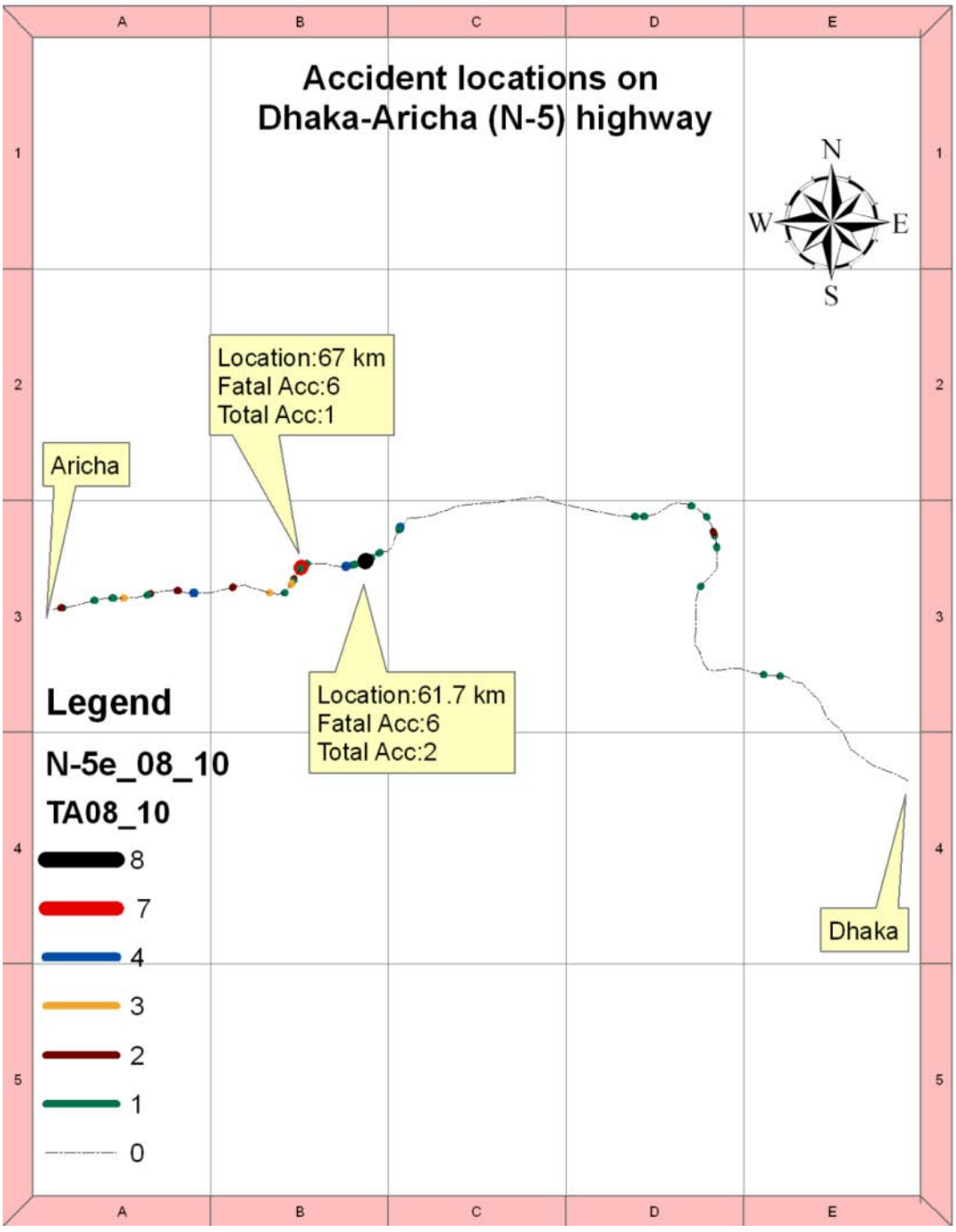

Figure 3: Hazardous locations on Dhaka-Aricha, N-5 (E) National Highway

This figure shows crashes location on road with number which indicates five hazardous locations with km value 57.6, 61.7, 67, 76.7 and 82.3 respectively. From here two locations can be treated as most hazardous. First one is, 61.7 km from Dhaka where total 8 crashes occur during the year 2008 to 2010 when no. of fatal accident is 6. And the second one is, 67 km from Dhaka where total 7 crashes occur and among them fatal crashes is no. 6. First location is a bridge and second one is near a bus stand named kazla bus stand.

Hazardous Locations on Aricha- Banglabandha, N-5(W)

From the year 2008 to 2010 total 129 accidents occurred; when majority of these are fatal accidents. 102 fatal accidents have occurred during the time period. Accident scenario of this road segment has given below in table 2.

Table 2: Accident statistics of Aricha-Banglabandha, N-5(W) highway

Id	Km	FA08_10	NFA08_10	TA08_10	Id	Km	FA08_10	NFA08_10	TA08_10
1250	228.9	4	0	4	1270	230.9	1	0	1
618	165.7	3	1	4	1281	232	1	0	1
1958	299.7	3	0	3	1495	253.4	1	0	1
2119	315.8	3	0	3	1581	262	1	0	1
35	107.4	2	0	2	1624	266.3	1	0	1
1061	210	2	0	2	1681	272	1	0	1
1221	226	2	0	2	1778	281.7	1	0	1
1413	245.2	2	0	2	1781	282	1	0	1
1840	287.9	2	0	2	1830	286.9	1	0	1
3265	430.4	2	0	2	1869	290.8	1	2	3
3606	464.5	2	0	2	1886	292.5	1	0	1
1	104	1	0	1	1941	298	1	0	1
11	105	1	0	1	2088	312.7	1	0	1
52	109.1	1	0	1	2231	327	1	0	1
266	130.5	1	0	1	2301	334	1	0	1
307	134.6	1	1	2	2311	335	1	1	2
319	135.8	1	0	1	2313	335.2	1	0	1
425	146.4	1	1	2	2332	337.1	1	0	1
436	147.5	1	0	1	2352	339.1	1	0	1
558	159.7	1	0	1	2380	341.9	1	0	1
575	161.4	1	0	1	2493	353.2	1	1	2
709	174.8	1	0	1	2515	355.4	1	0	1
751	179	1	0	1	2517	355.6	1	1	2
815	185.4	1	0	1	2601	364	1	0	1
821	186	1	0	1	2607	364.6	1	0	1
899	193.8	1	0	1	2609	364.8	1	0	1
944	198.3	1	0	1	2619	365.8	1	0	1
949	198.8	1	0	1	2620	365.9	1	0	1
965	200.4	1	0	1	2835	387.4	1	0	1
977	201.6	1	0	1	2953	399.2	1	0	1
984	202.3	1	0	1	3006	404.5	1	0	1
991	203	1	0	1	3319	435.8	1	0	1
1010	204.9	1	0	1	3345	438.4	1	0	1
1012	205.1	1	0	1	3374	441.3	1	0	1
1028	206.7	1	0	1	3545	458.4	1	0	1

1037	207.6	1	0	1	3546	458.5	1	0	1
1041	208	1	0	1	3688	472.7	1	0	1
1065	210.4	1	0	1	3781	482	1	0	1
1083	212.2	1	0	1	3942	498.1	1	0	1
1103	214.2	1	1	2	3968	500.7	1	0	1
1108	214.7	1	0	1	4040	507.9	1	0	1
1131	217	1	0	1	4085	512.4	1	0	1
1165	220.4	1	0	1	**Total**	**8.6 km**	**102**	**27**	**129**
1181	222	1	0	1					

Like the previous one it's found that among the 426 km road, accident only occur at 8.6 km of road length. This crashes information has linked with the road network shape file with GIS to locate the hazardous location on road. Figure 4 shows the hazardous road locations on Dhaka-Aricha section of highway

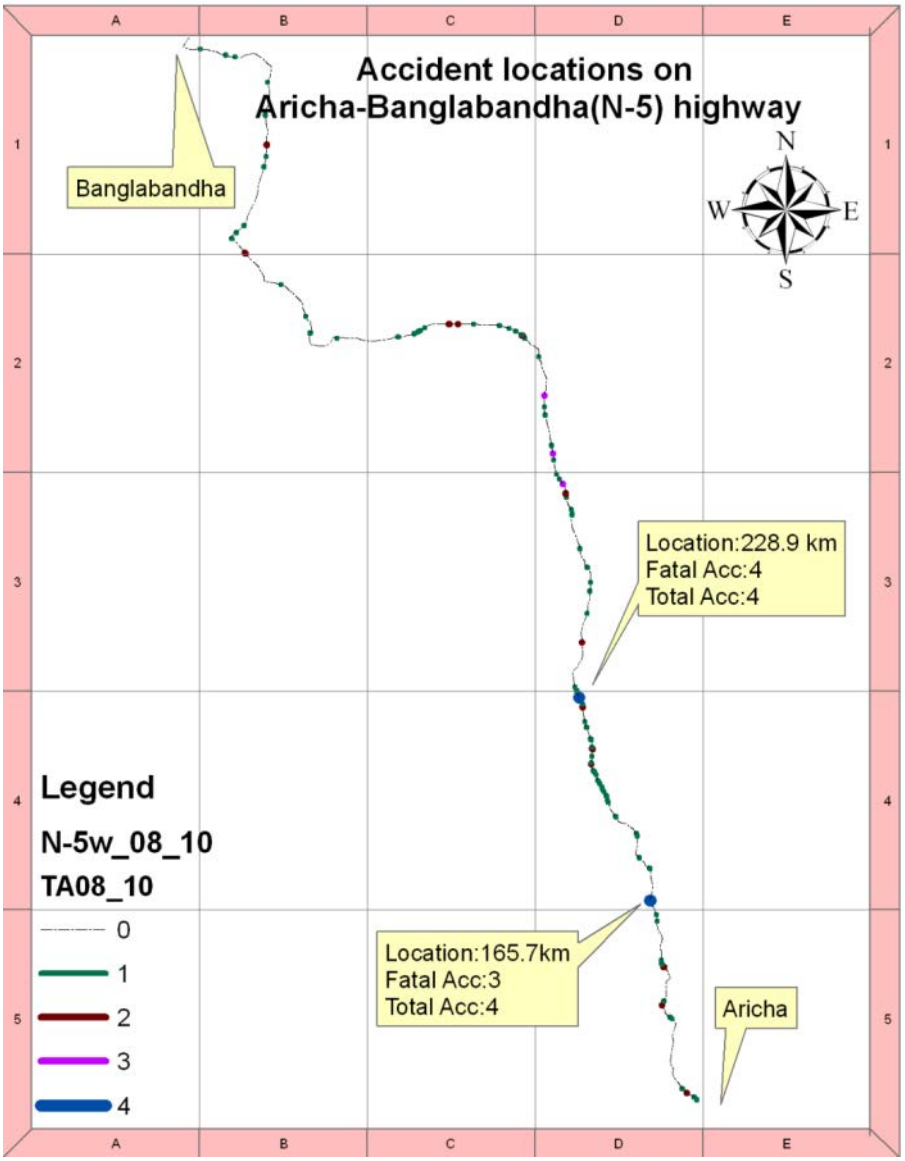

Figure 4: Hazardous locations on Aricha-Banglabandha, N-5(W), National Highway

This figure shows crashes location on road with crashes number. Here four locations are identified as hazardous whose distance from Dhaka is 165.7km, 228.9km, 299.7km and 315.8km respectively. From here two locations can be treated as most hazardous. First one is, 165.7 km from Dhaka where total 4 crashes occur during the year 2008 to 2010 when no. of fatal accident is 3. And the second one is, 228.9 km from Dhaka where total 4 crashes occur and among them fatal crashes is no. 4. First location is hatikamrul bus stand and second one is near a bus stand named baghopara bus stand.

The scenario extracts from the above analysis illustrates that bus stands are playing a main role in hazardous road location. May be the reason is for local unsafe activities around the bus stopes with aggressive driving. To find the exact causes which make those segments hazardous, an extensive characteristics analysis is required.

Discussion

The above analysis revealed four most hazardous locations which should be examined very carefully to understand the crash behavior to mitigate the risk. Here crash characteristics of those most hazardous locations would be analyzed.

Location 61.7 km (Bridge)

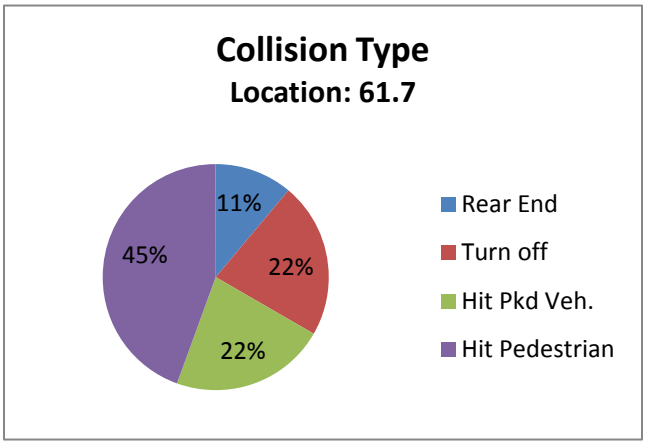

Figure 5: Collision type of location 61.7km

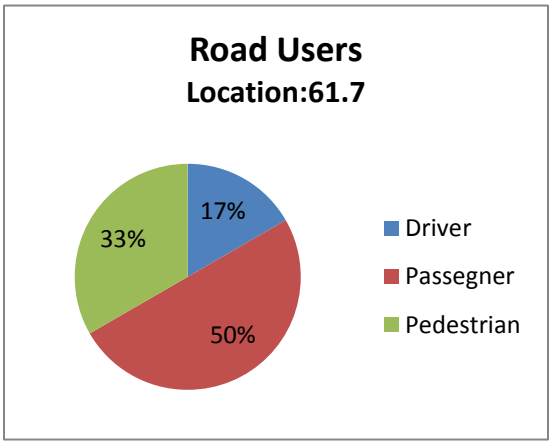

Figure 6: Casualties of location 61.7km

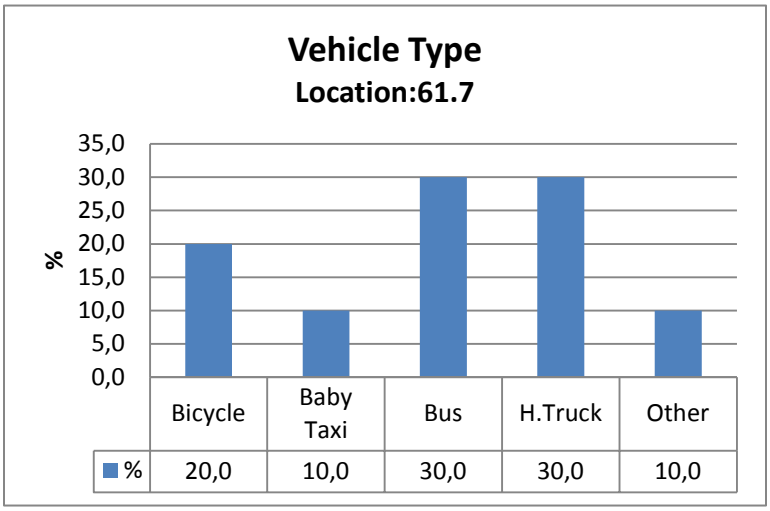

Figure 7: Vehicle involvement of location 61.7km

From the figure 5, 6, 7; it's seen that hit pedestrian is the highest no of collision type with 45% crashes. Turn off vehicle and hit parked vehicle are next in position with an equal sharing of crashes as 22% but interestingly passenger casualty is higher (50%) then pedistrian casualty (33%). Involvements of bus and trucks are the highest with an equal no. 30% when bicycle comes after them with 20%.

Location 67km (kazla bus stand)

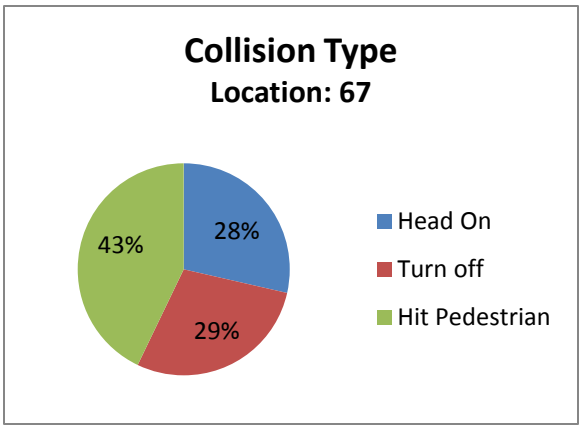

Figure 8: Collision type of location 67km

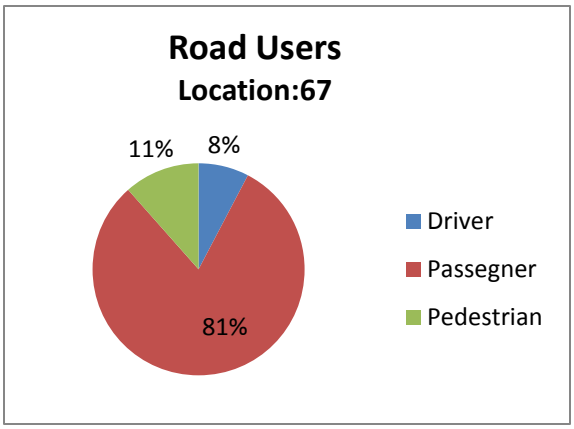

Figure 9: Casualties of location 67km

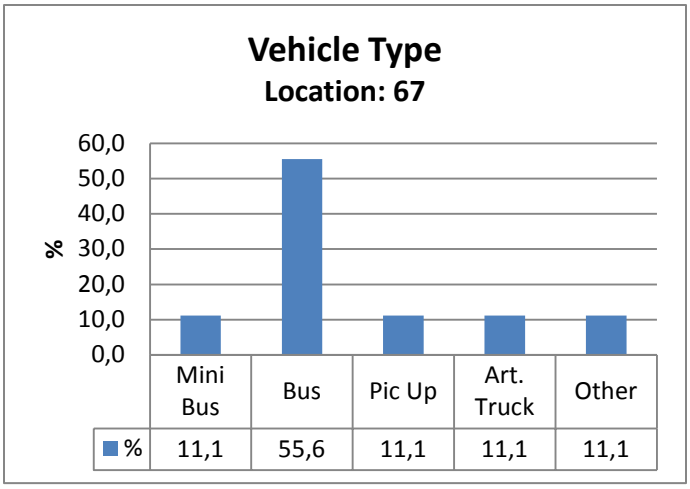

Figure 10: Vehicle involvement of location 67km

From the figure 8, 9 and 10; it's seen that hit pedestrian is the highest no of collision type with 43% crashes. Turn off vehicle and head on are next in position with almost equal sharing of crashes as 29% and 28% respectively. Pedestrian casualty is most significant like81% when passenger and driver casualties are very little. Involvements of bus in crashes are the highest then other vehicle with about 57%.

Location 165.7km (hatikamrul bus stand)

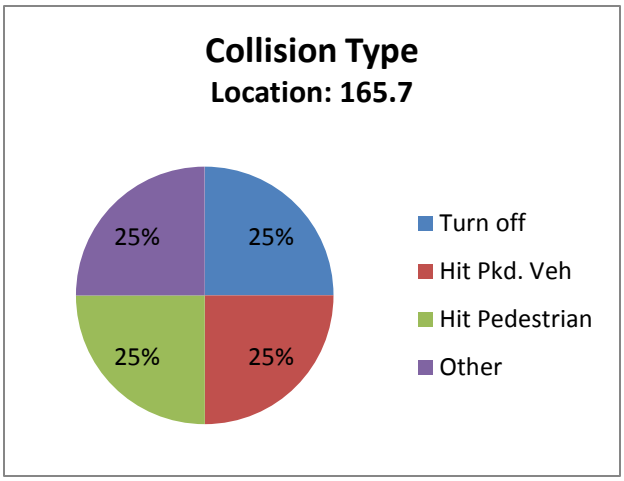

Figure 11: Collision type of location 165.7km

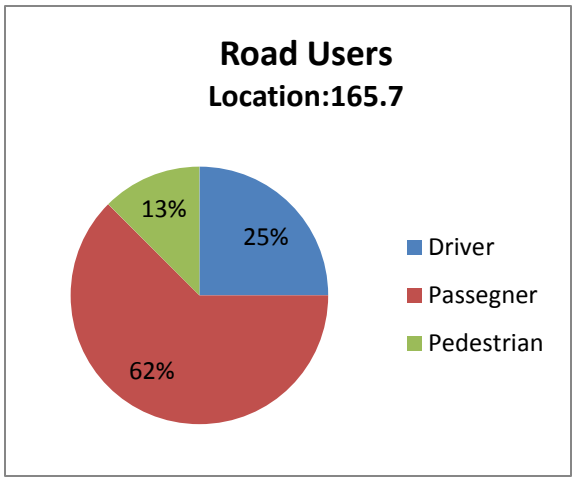

Figure 12: Casualties of location 165.7km

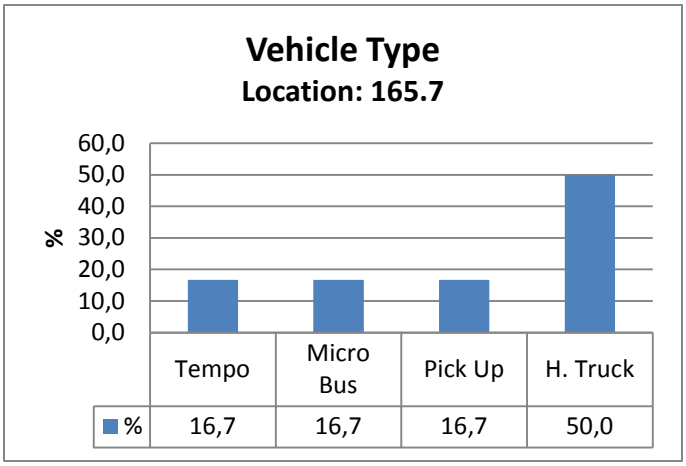

Figure 13: Vehicle involvement of location 165.7km

From the figure 11, 12, 13; it's seen that hit pedestrian, turn off, hit parked vehicle and others type of collisions are sharing equal role in this segment with 25% crashes but interestingly pedistrian casualty is higher (62%) then other though driver casualty comes after next (25%). Involvements of heavy trucks are the highest with 50% sharing then other vehicles.

Location 228.9km (baghopara bus stand)

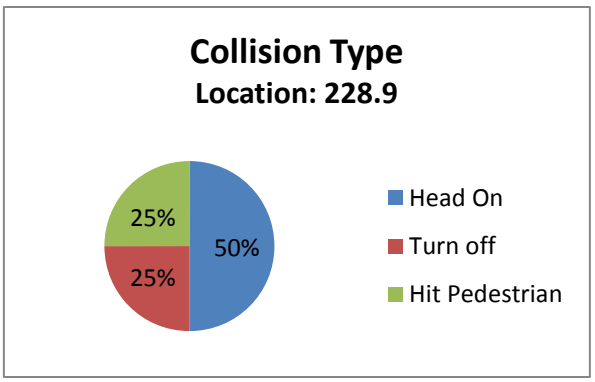

Figure 14: Collision type of location 228.9km

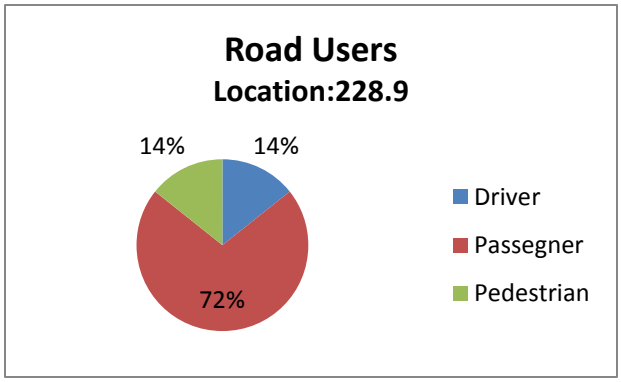

Figure 15: Casualties of location 228.9

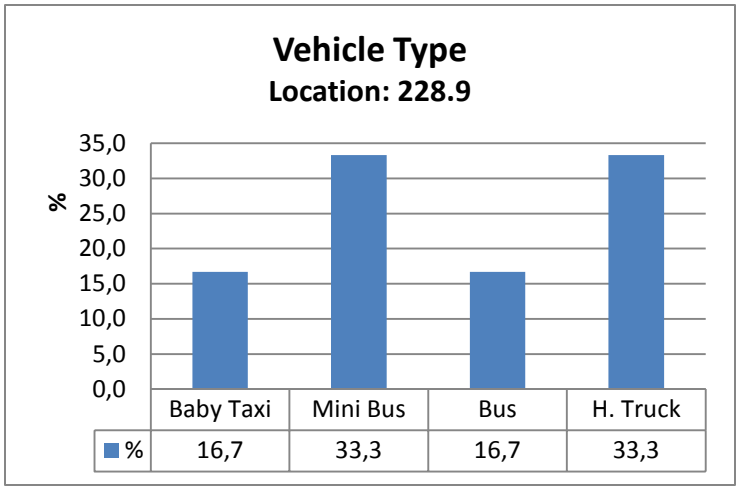

Figure 16: Vehicle involvement of location 228.9

Unlike previous segment from the figure 14, 15, 16; it's seen that head on collisions (50%) dominates then other collision like turn off and hit pedestrian which effects on road user casualty chart which illustrate significant passenger casualty (72%). Most of the vehicle involves in crashes in this segments are heavy trucks and the mini-bus with 33% of crashes.

In sum, it can be said that all the segments are very much vulnerable for pedestrian followed by head on collisions as well. Specific safety measures should be implemented to make those segments safe both for pedestrian and passengers after extensive field survey.

Conclusions

Road safety has been an increasing concern to community in recent years in Bangladesh. This paper has discussed about the implementation of GIS in crashes analysis to make an effective way of analysis and represent the accident with the exact location and verification of the method for a major highway of Bangladesh. In the period of 2008 – 2010, crashes occurred in only 2.2 percent length of N-5 which clearly demonstrates that accidents are amenable to targeted and site specific. Four specific sections of these two national highways worthy of being treated as hazardous locations have been identified. In recent years, Dhaka-Aricha-Banglabandha highways have become very busy roads as it passes through three divisions of Bangladesh. On the basis of the results and findings, the necessary remedial measures should be provided to make the operation of this most important and widely used national highway (N-5) of Bangladesh safe and efficient. Some potential measures are as follows:

- Effective and user friendly pedestrian facility such as briar, overpass, underpass, zebra crossing, pedestrian signal etc should be established in those sections on the basis of its function. Also focus on speed reduction near bus stoppages also near schools, bazaar and residential should be considered.
- Head on and turn off collisions is also the dominating collision types at all the segments of the highway. Undivided highway, reckless overtaking are the main causes of head on collision. So divided highway and special overtaking sections should provided. To arrest the vehicle turning off, vehicle fitness should be examined frequently.
- Appropriate signs, road markings, fencing, guardrails, junction modifications, and improvements to visibility should be considered as remedial measure.
- Dangerous and inappropriate operation of heavy vehicles (buses and trucks) such as reckless overtaking, overloading and braking/stopping on roads and road sides are particularly a serious problem in all those segments. So, adequate enforcement should also be considered.

Acknowledgements

The approach presented here is aimed at the conception of an important database which will allow the analysis of road traffic crashes on our highways using Geographic Information System (GIS). This modern technology is a powerful tool which will facilitate fast retrieval of information and easy to update when the need arises. In addition, it has the capability of adapting to the changing needs of the road planners and engineers in the process of these technocrats would want to re-design the road transport facility for the safety of its users.

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