GIS Based Hazardous Index Determination to Discriminate Safe and Unsafe Highway Locations

Abstract:
Road Accident is one of the biggest causes of loss of lives and economic loss in developing countries. While accidents occur almost everywhere, frequent occurrences in certain locations are called Hazardous Road Locations. This paper tries to identify the Hazardous Road Locations by Hazardous Index (HI) using GIS technique combining four accident measures: Accident Rate Method; Accident Frequency Method; Rate Quality Control Method (Rq); and Accident Severity Method (SI). Accident Report Forms (ARF) of the study area – Joydebpur-Jamuna Bridge approach highway, Bangladesh – was collected from the office of police super. The analysis shows that careless driving is the prime reason for accidents (62%). Most of the accidents occurred in the rural parts of the study area where roadside pedestrian casualties happened, in total 55. The study has shown that about 4.30% length of the highway is highly accident-prone. Only about 21.72% length of the highway needs proper counterstrike against accidents through road safety programs.

Key Words: Accident, GIS, Hazardous Road Location, Highway, Bangladesh.

1. Introduction

Road accident is one of the major social and economic problems all over the world, about 1.24 million people are killed and almost 50 million are injured over the world because of road accidents in each year. All most 80% road traffic death occurred in developing countries; nearly 20.1 fatalities are occurred per 100,000 inhabitants in developing countries (WHO, 2013).

Death toll due to road accident is a man-made disaster for Bangladesh. Road crashes claimed the lives of 13 per 100,000 people who died in Bangladesh in 2013 (WHO, 2013). According to Bangladesh Police, nearly 3200 people die on traffic accident in each year although actual fatality number could be 12000 (Mazharul et al., 2010). Annual cost of road accident and injury is varied 1.8 to 2.8 % of national GDP in Bangladesh (Paul et al., 2008). About 80% accident occurred with pedestrian, bicyclists, motorcyclists and users of informal and insecure motorized and non-motorized transport (Mahmud, 2010). These figures indicate a crucial scenario of the road-safety issues – roads in Bangladesh are virtual death traps. While the overall safety scenario is dreadful, accidents are often clustered in a few locations that are called Hazardous Road Locations (HRL) (Hoque et al., 2011). This article presents a scientific technique to detect Hazardous Index (HI).

The identification criteria of HRL equals or exceed three crashes is concentrated in 200 m roadway segment over a period of 5 years. Having clear information on the accident is vital for any scientific analysis, which is often not been recorded in a proper way in Bangladesh. Road traffic crashes will be serious human health problem in upcoming days. If proper steps are not taken against epidemiological nature of road crashes, it will take 3rd place for killing human being in 2020 (Arvind, 2005).

2. Materials and Methods

2.1 Study Area

For the purpose of this article, Joydebpur-Jamuna Bridge approach highway (N-4 and N-405) has been taken as a study site (Figure 1). This corridor plays an important role in Bangladesh roadway transportation by connecting Dhaka with the northwest and southwest parts of the Bangladesh. Daily traffic volume of the highway corridor varies from 10000 to 12000, and has been identified by Accident Research Institute (ARI) as one of the most accident-prone road. The highway corridor is part of the AH1 in the Asian Highway network.
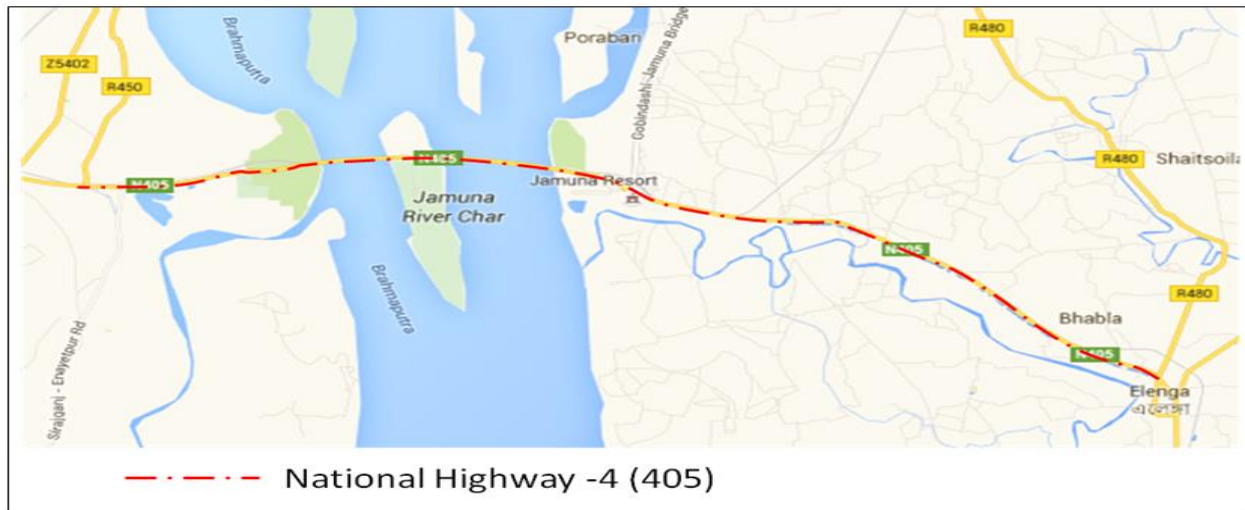

Figure 1: Study Area

2.2 Method

An Accident Report Form (ARF) was first introduced in 1995 with the help of World Bank (Ahsan et al, 2011). Five years accident data (313 ARF), from July 2009 to June 2014, is collected for the study purpose from the office of Superintendent of Police of Tangail and Gazipur. Annual average daily traffic (AADT) data of Joydebpur to Jamuna Bridge approach highway corridor is collected from Roads and Highways Department of Bangladesh for the purpose of finding the concentration of vehicles on the corridor. The highway corridor is divided into four sections on the basis of traffic volume. Hazardous Index is calculated by dividing the corridor into 200m for specific analysis of each segment of the highway.

Method

Accident Rate Method (Ra) **:** A*1,000,000/ (365*T*V*L) (Utainarumol, 1999)
 Where
      T = time of analysis period (in years or fraction of years),
      V = average annual daily traffic (AADT) during study period, and
      L=length of highway segment (in km)

Accident Frequency Method (Fa): Number of crashes were occurred in each 200m roadway segment over a period of 5 years (Utainarumol, 1999). Two or more accidents occur on a segment deliberate as unsafe even if those are non-fatal accident.

Rate Quality Control Method (Rq): **Ra/Rc,**

The rate quality control method is used Poisson distribution to determine the significant of the accident rate at each location (Utainarumol, 1999).

  Where: Rc=Ravg+ K (Ravg/E) ^.5 + 1/ (2E)

   Ra= Accident rate,

   Rc= Critical accident rate for highway segment (Accidents per million vehicle-km),

   Ravg = average accident rate for all highway segments of similar characteristics or on similar road types,

   E = (365*T*V*L)/1,000,000 million vehicle-km of travel on the highway segment during the study period.

K= a probability factor determined by the desired level of significance for the equation. The value of K corresponding to 98% confidence level is 2.327.

If Ra>Rc, then the segment consider as unsafe.

Accident Severity Method (SI): SI= (12F +4.5GI+3SI+PDO) /Total Accidents (Nicholas, 2009).

  Where,

   SI = Severity index,

   F =Number of fatalities,

   GI = Number of grievous injuries,

   SI= Number of Simple injuries,

   PDO = Number of property damage only (PDO),

   Total = Total number of all types of accidents

   SIavg= Average severity index of the average severity of four similar highway segments based on traffic volume (accident free segments are not considered in those average values). If SI>SIavg, then the segment consider as unsafe.

The HI is calculated by applying the following function:

Hazardous index, HI= (Fa+Ra+Rq+SI)/4 …………………………………………………………(1)

Where, Fa = rank of location by accident frequency method;

Ra = rank of location by accident rate method;

Rq = rank of location by rate quality control method; and

SI= rank of location by accident severity method.

HIavg=. Average hazardous index of the average of four similar highway segments based on traffic volume (accident free segments are not considered in those average values). If HI>HIavg of a segment consider as unsafe. If HI>HIavg, SI>SIavg, Ra>Rc, then the highway segment consider as extremely risky for travelling and need urgent treatment. If HI<HIavg or HI=0 of a segment consider as safe.

2.2 Data Input

GIS is a smart technique to incorporate spatial and non-spatial data to find out the hazardous road location through analyzing those accident related information. The scanned map of Joydebpur to Jamuna Bridge approach highway network was scanned and digitized. The projection system used in this study is BTM coordinate system. All vector data like line, polygon and point features contain various attribute table related to accident information for finding hazardous index of the study area, which differentiate the highway segments as safe or not safe for travelling and present graphically at the same time.

Ground control points (GCP) of road crash locations on the highway corridor is collected through Global Positioning System (GPS) and Google Earth software. Field survey is required to get the true conditions of road features. Road victim provided more information about characteristics of road crashes in detail manner, which is very important to find the environmental, operational and behavioral deficiencies of accident-prone locations for take action to reduce accidents in those locations. The iterative procedure is shown below.
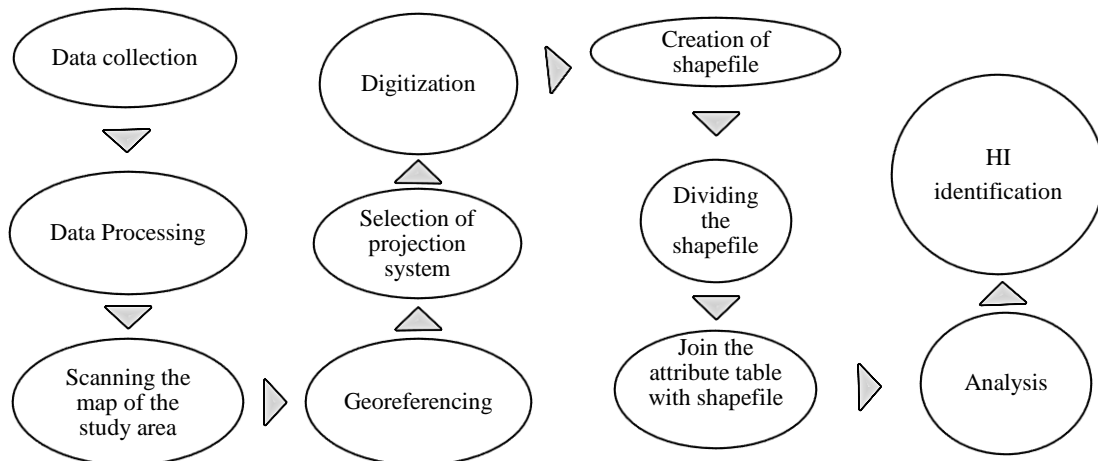

Figure 1: Methodological Framework

3. Analysis and Findings

3.1 Type of Collision

From the 313 ARF, total 1339 casualties are occurred, between them fatality rate 32.49%, grievous injury rate 34.20%, simple injury rate 32.26% and normal collision rate 1.05% during the study period. Pedestrians are most vulnerable road user of the study area, which constitutes 31.62%. Head on type collision constitute 27.47% and side swipe type collision occurred 9.58%. This, however, refers to the problem of road geometry and reckless driving.

3.2 Contributory Factor of Accident

Careless driving constitutes 62% accidents. Speeding is also highly contributing to road accidents, about 20% and 9% road crashes occurred due to bad overtaking tendency. Some other

factors, e.g, bad driver signal, weather, drunk driving, driver fatigue, etc combined in total 10% of the total accidents.
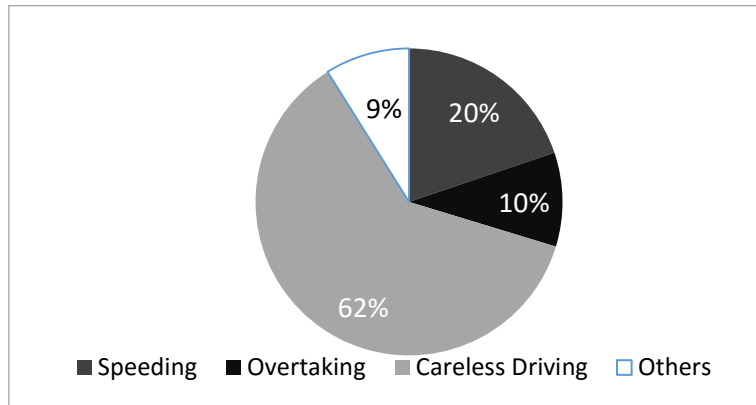

Figure 2: Causes of Traffic Accidents

3.3 Location

Result shows that 72% accident occurred in rural part and 28% in urban segment of the highway. Several factors, e.g., absence of traffic control system, mix of slow and fast moving vehicles like three wheelers, tempu, auto-rickshaw, CNG.

3.4 Pedestrian Casualties on Road Location

Most of the pedestrian accidents occurred on roadside, in total 55. Number of casualties in pedestrian crossing is 42 casualties. Most of the footpath along the highway is occupied by unexpected activities, e.g., keeping materials for construction, market activities on footpath, etc. thus pedestrian have to share the highway with vehicles leading to major cause of road fatalities. Pedestrian casualties on road location are shown in the figure 3.
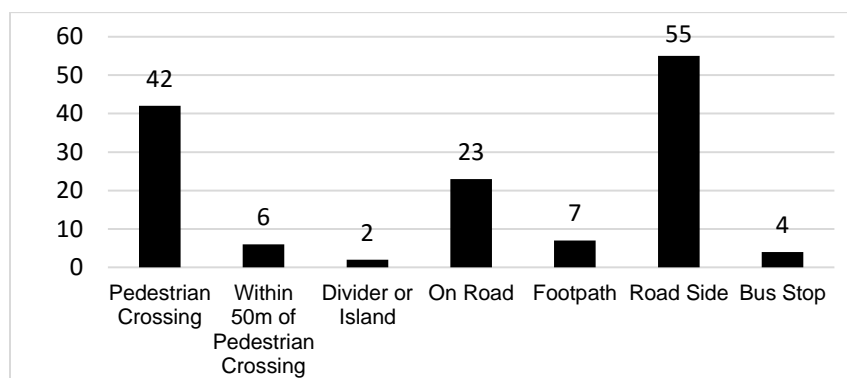

Figure 3: Pedestrian Severities on Road Location

3.5 Pedestrian Activity on Road

The analysis result shows that most of the pedestrian accident occurred when pedestrian walk along on road edge. 53 casualties occurred when pedestrian walk along road side. Road crossing is one of the vulnerable activity for pedestrian, 48 casualties occurred during road crossing.

Lacking of proper walking place beside highway, pedestrian would like to used highway to walk then accident occurred which constitute 23 casualties. Beside bus stand, island, bazaar, etc. people wait for vehicle to travel then careless driving constitute 13 casualties. When children play on highway segment then two casualties occurred. Pedestrian casualties during accident are given to the figure 4.
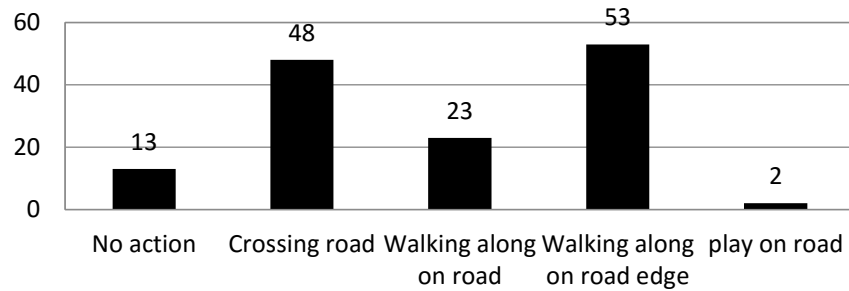

Figure 4: Pedestrian Activity on Road

Hazardous Index Analysis

Keeping lower edge at hazardous locations, discriminant analysis is conducted on accident cases. The highway is divided into 4 groups (AADT-4741, 4212, 9090 and 12114) on the basis of AADT value of the highway corridor.

Hazardous road locations are the most accident prone locations, where accident concentration is abnormally high. According to the criteria, if three or more accidents concentrated in 200m of highway segment that segment is considered as hazardous road location. Total 18 hazardous segments are located on the highway.
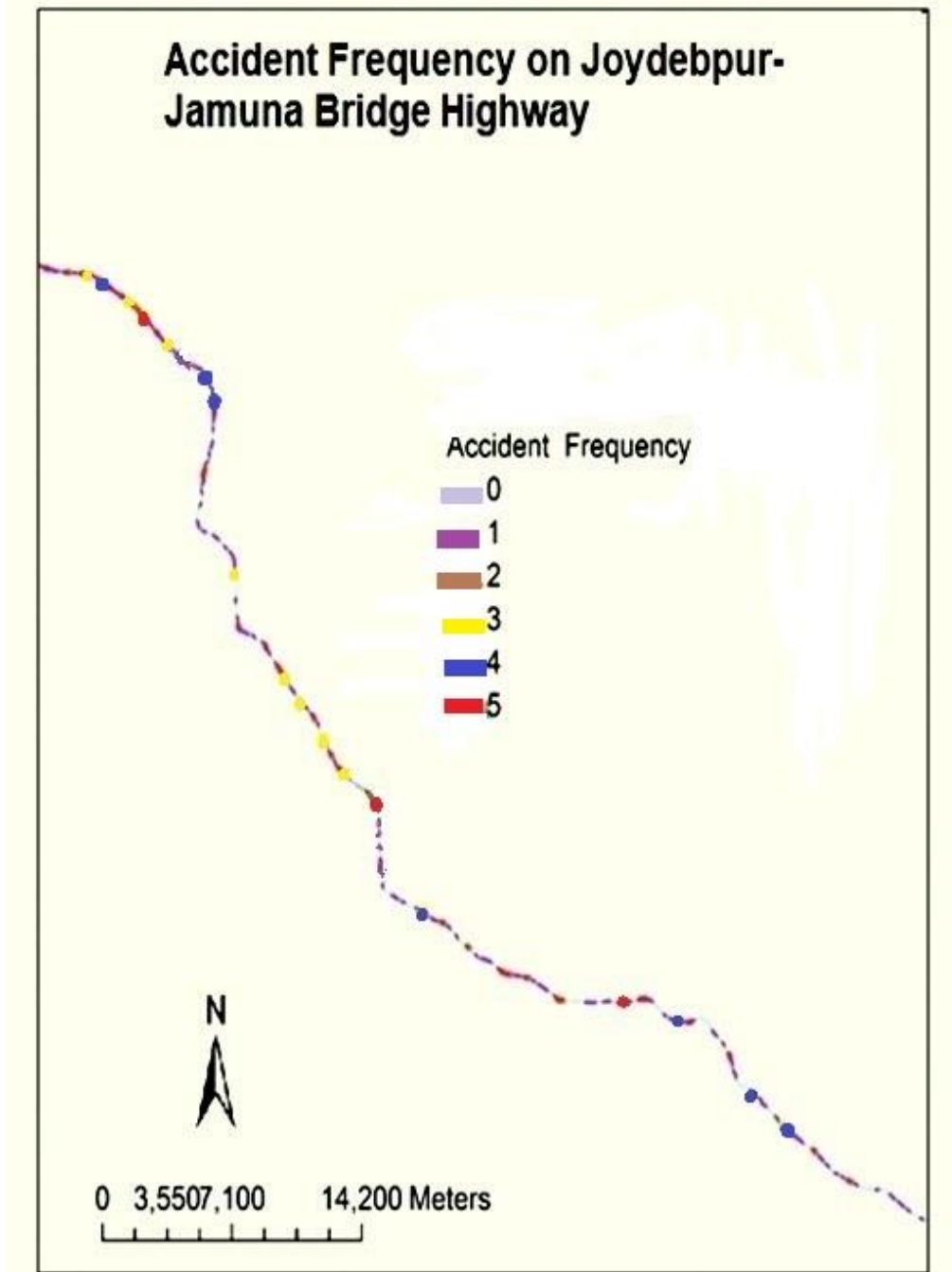
Figure 5: Hazardous road locations on Joydebpur-Jamuna Bridge Highway

Hazardous Index (HI) of each segment of the highway determines the accident condition of the segment. Highway segments are differentiated as safe or not safe through the HI value.

Table 1: Hazardous Index in Different Segment

Hazardous Road Segments(Km)	Accident Frequency	Accident Rate	Rate Quality Control	Accident Severity	Hazardous Index
16.6-16.8	4	1.20	1.30	33.75	10.06
21.2-21.4	4	1.20	1.30	58.13	16.16
24.2-24.4	4	1.20	1.30	36.75	10.81
27.0-27.2	5	1.51	1.62	43.20	12.83
40.4-40.6	4	1.20	1.30	49.87	14.10
46.8-47.0	5	1.51	1.62	41.50	12.41
69.8-70.0	4	1.20	1.30	36.37	10.72
70.4-70.6	4	0.90	.95	33.37	9.80
72.6-72.8	5	1.13	1.18	36.60	10.98
82.8-83.0	4	.90	.95	26.25	8.02

The research result shows that, eight extremely risk highway segments are located there, in where 11.18% accidents are occurred. According to the criteria, HIavg is 6.04 and SIavg is 21.83. In first sections, total six segments are unsafe for travelling on the basis of HI but Fa depicts only three segments and SI shows five segments are unsafe. Forty three out of forty nine segments are safe in the first section of the highway corridor. In second section, only six segments are unsafe out of thirty four segments based on HI and SI value. Two accidents occurred in three segments of that section. Third section is the most vulnerable in where, fifty three segments are unsafe, two or more accidents are occurred in thirty four locations. In the last section, twenty six locations are unsafe although two or more accidents occurred in twenty five segments.

4. Conclusion
Several conclusions can be made from the above case study analysis and discussion, first, passenger vehicles are prone traffic accident with the highest percent of the total casualties. Traffic accident occurs due to careless driving and speeding. Secondly, pedestrian casualties are frequent, especially in rural part of highways – this is mostly due to the lack of highway infrastructure to create a safety buffer. Thirdly, traffic accidents are concentrated in the non-junction part of the highway, as it allows drivers to drive carelessly and speeding. Finally, accidents are concentrated in certain Hazardous location hot-spots - Some specific locations are founded as highly accident prone location. 4.30% length of the highway is highly accident prone, and 51.44% accidents are occurred in 15.51% locations. All accidents are occurred in 51.79% length and 48.21% highway is accident free. Result shows 21.72% highway segments are unsafe for travelling. Counterstrike measures is also required for careless driving and speeding to improve the overall road safety situation.

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