

GIS-Based Spatial Analysis and Identification of Road Traffic Accident Hotspots: A Case Study of the Dhaka-Mymensingh Highway (N3), Gazipur, Bangladesh

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ABSTRACT

Road traffic accidents are a major public safety concern in Bangladesh, especially along national highways carrying heavy and mixed traffic. The Tongi-Mawna segment of the Dhaka-Mymensingh Highway is one of the most critical corridors in Gazipur, where frequent crashes cause serious human and economic losses. However, limited studies have examined this corridor using recent police-based data with integrated temporal and GIS-based spatial analysis. This study aims to identify and analyze accident-prone locations along the Tongi-Mawna road using geospatial and statistical techniques. Accident records from 2021 to 2025 were collected from nearby police stations. Temporal trend analysis was carried out using Microsoft Excel, while Severity Index (SI), Kernel Density Estimation (KDE), and Getis-Ord Gi* hotspot analysis were applied in ArcGIS to assess accident severity, spatial concentration, and clustering patterns. A total of 304 accidents were recorded during the study period, affecting 335 individuals, including 227 fatalities, 80 serious injuries, and 28 minor injuries. The results show that accident occurrence increased in recent years, with 2025 recording the highest number of crashes. Trucks were the most involved vehicle type, while buses and three-wheelers also showed notable involvement. Male victims accounted for the highest proportion across fatal and injury categories. The SI analysis identified 12 black spots out of 31 accident-prone locations, while KDE and hotspot analyses revealed major accident concentrations in the southern, central, and northern sections of the corridor. The findings indicate that accidents along the Tongi-Mawna road are spatially concentrated and severe in nature. These findings provide valuable information for prioritizing road safety interventions, supporting transportation planning, and implementing targeted measures to reduce crash frequency and severity along the Tongi-Mawna corridor.

Keywords: GIS Analysis, Accident Hotspots, Severity Index, Kernel Density Estimation, Getis-Ord Gi*

1. INTRODUCTION

Road traffic accidents (RTAs) are a major global public health concern, causing significant loss of life and economic burden worldwide. According to the World Health Organization, approximately 1.3 million people die annually due to road traffic accidents, making it one of the leading causes of death globally [1]. The impact is particularly severe in low and middle-income countries, where rapid motorization is not adequately supported by road infrastructure and safety measures [2]. In the Asian region, road traffic accidents remain a critical challenge due to high population density, rapid urbanization, and heterogeneous traffic conditions. Studies have indicated that accident occurrences in Asia are significantly influenced by unsafe driving behavior, poor roadway design, and weak enforcement of traffic regulations [3]. The increasing demand for transportation and industrial

development has further intensified accident risks across major highway corridors in this region. In Bangladesh, the situation is more alarming due to mixed traffic flow, lack of traffic discipline, and insufficient road safety management. National highways, especially those passing through industrial zones, are highly vulnerable to accident occurrence [4]. Research has shown that factors such as overspeeding, improper overtaking, roadside activities, and inadequate pedestrian facilities play a significant role in accident causation [5].

Previous studies have demonstrated that road traffic accidents are not randomly distributed but tend to cluster in specific locations due to roadway geometry, traffic composition, and human behavior [6]. To address this issue, Geographic Information System (GIS) has been widely adopted as an effective tool for analyzing accident data, as it enables the integration of spatial and

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non-spatial information and facilitates visualization of accident patterns [7]. GIS-based techniques support the identification of accident-prone locations and provide a strong basis for traffic safety planning and decision-making. Several spatial analysis methods have been applied in accident studies to identify hotspots and analyze accident distribution. Kernel Density Estimation (KDE) is commonly used to generate density surfaces and identify areas with high accident concentration [8]. Similarly, hotspot analysis using the Getis-Ord G_i^* statistic has been widely applied to detect statistically significant clusters of accident occurrences [9]. Studies such as Afolayan et al. [7] and Khatun et al. [5] demonstrated the effectiveness of GIS-based hotspot identification in detecting high-risk locations and supporting safety improvement measures. Furthermore, severity-based approaches, such as the Severity Index (SI), have been used to rank accident-prone locations based on fatalities and injuries [5]. In addition to spatial analysis, temporal analysis plays an important role in understanding accident trends over time. Statistical tools such as Microsoft Excel have been widely used to analyze yearly variations in accident frequency, severity, and vehicle involvement [8]. Such trend analysis helps in identifying increasing or decreasing patterns of accidents and provides valuable insights into the effectiveness of safety interventions.

Despite the application of these advanced techniques in different regions, limited studies have focused on the Tongi-Mawna segment of the Dhaka-Mymensingh Highway using recent accident data along with combined spatial and temporal analysis. Considering the strategic importance of this highway and its exposure to high traffic demand, a comprehensive analysis integrating both GIS-based spatial methods and statistical trend analysis is essential. Therefore, the objective of this study is to analyze the spatial distribution, temporal trends, and severity of road traffic accidents along the Tongi-Mawna segment using GIS and statistical techniques. The study integrates Kernel Density Estimation, hotspot analysis, and Severity Index methods along with trend analysis to identify high-risk locations and provide insights to support effective road safety planning and improvement measures.

2. METHODOLOGY

2.1 Study Route

The Tongi-Mawna segment of the Dhaka–Mymensingh Highway (N3), shown in Figure 1, is located in Gazipur district under the Dhaka division of Bangladesh. This highway connects Tongi with Mawna and serves as a major transportation corridor linking Dhaka with the northern

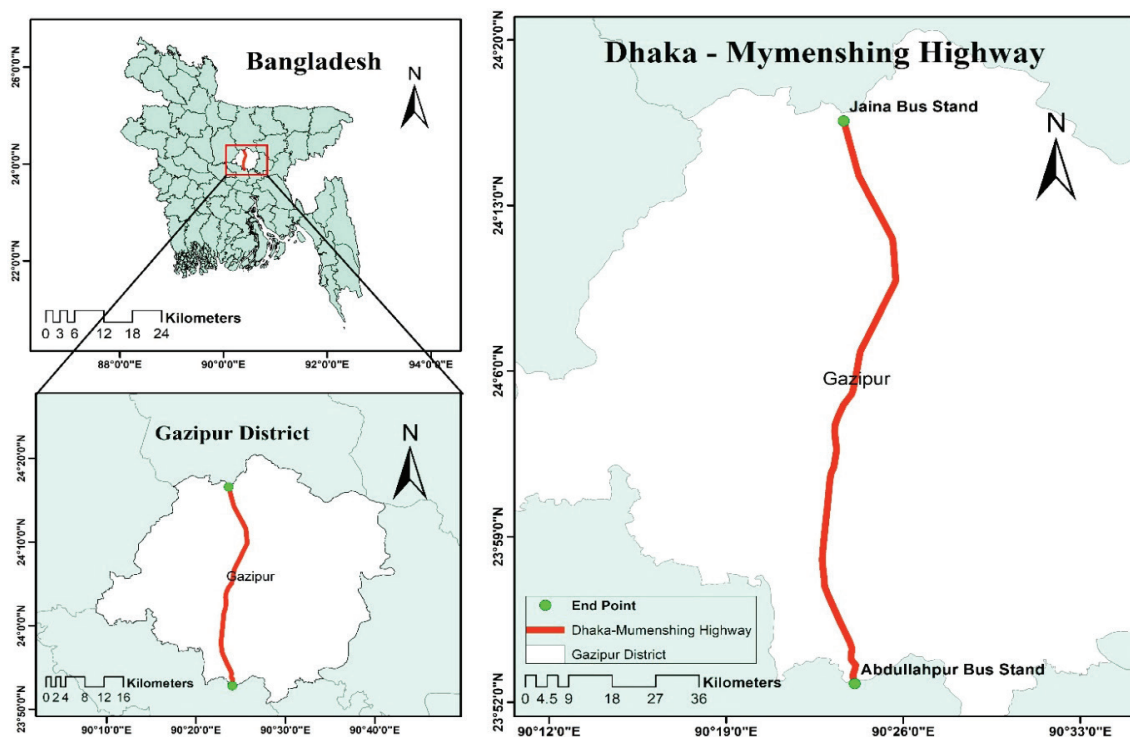


Fig. 1: Study area of the Tongi-Mawna segment of Dhaka-Mymensingh Highway (N3), Gazipur, Bangladesh.

regions of the country. The study route lies approximately between latitudes 23°52'N and 24°13'N and longitudes 90°19'E and 90°26'E, covering a length of about 40 km. The corridor is a multi-lane bituminous road that carries high traffic volume due to surrounding industrial zones, commercial activities, and regional connectivity.

2.2 Data Collection and Analysis

Accident data were collected from local police stations and highway police records for the Tongi-Mawna segment of the Dhaka-Mymensingh Highway (N3) covering the period from 2021 to 2025. A total of 304 accidents were analyzed, including 227 fatal, 80 serious injury, and 28 minor injury cases. The dataset contains information on vehicle type, number of deaths, injury severity, date and time of the collision, and crash location (latitude and longitude).

Accident locations were georeferenced using Google Earth Pro and imported into ArcGIS 10.8 for spatial analysis. Temporal trend analysis was performed using Excel, while spatial analysis was conducted in GIS to identify accident distribution patterns. Kernel Density Estimation (KDE) and hotspot analysis (Getis-Ord G_i^*) were applied to identify high-risk zones, and the Severity Index (SI) method was used to assess accident severity.

2.2.1 Severity Index (SI)

The Severity Index (SI) was used to evaluate the severity of road traffic accidents and to identify accident-prone locations. Since accident frequency alone may not adequately represent the actual impact of crashes, weighted indices are commonly applied to provide a more reliable assessment [10]. In this method, different weights are assigned to accident outcomes based on their level of severity. A weighting scheme of 5, 3, and 1 was used for fatal, serious injury, and minor injury cases, respectively, as widely adopted in previous studies [11]. The Severity Index is calculated as:

$$SI = 5D + 3S + L$$

where D represents the number of fatalities, S denotes serious injuries, and L indicates minor injuries. Based on previous studies and the observed distribution of SI values, locations with SI values greater than 40 were considered as accident black spots [11].

2.2.2 Kernel Density Estimation (KDE)

Kernel Density Estimation (KDE) was applied to analyze the spatial distribution of road traffic accidents and to

identify areas with high accident concentration. KDE is a non-parametric method that converts discrete accident point data into a continuous density surface, allowing visualization of accident intensity across the study area [8]. The density at a given location is estimated using the following equation:

$$f(x, y) = \frac{1}{nh^2} \sum_{i=0}^n k\left(\frac{d_i}{h}\right)$$

where $f(x, y)$ represents the estimated density at location (x, y) , n is the total number of observations, h is the bandwidth, d_i denotes the location of each accident point, and K is the kernel function [8]. In this study, a bandwidth of 4000 m and a cell size of 100 m were used to generate the density surface. Higher density values indicate greater accident concentration and represent potential high-risk zones.

2.2.3 Hotspot Analysis (Getis-Ord G_i^*)

Hotspot analysis was conducted to determine the spatial clustering of road traffic accidents within the study area. This method identifies statistically significant clusters of high and low accident values using the Getis-Ord G_i^* statistic [9]. The G_i^* statistic evaluates the relationship between a location and its neighboring features to determine whether the observed clustering is statistically significant. High positive values indicate hotspots, while negative values indicate cold spots. Values close to zero represent random distribution patterns. The Getis-Ord G_i^* statistic is expressed as:

$$G_i^* = \frac{\sum_{j=1}^n w_{ij} x_j - \bar{x} \sum_{j=1}^n w_{ij}}{S \sqrt{\frac{[\sum_{j=1}^n w_{ij}^2 - (\sum_{j=1}^n w_{ij})^2]}{n-1}}}$$

where x_j is the attribute value at location j , w_{ij} is the spatial weight between locations i and j , n is the total number of features, $\bar{x}$ is the mean, and S is the standard deviation.

3. RESULTS AND DISCUSSION

3.1 Accident Trend Analysis

The analysis of accident data along the Tongi-Mawna road from 2021 to 2025 provides important insights into the temporal variation and severity distribution of road traffic accidents. Fig. 2 presents the yearly distribution of fatal, serious injury, and minor injury cases, while Fig. 3 illustrates the overall proportion of accident severity within the study corridor. During the study period, a total of 304 accidents were recorded, including 227

fatalities, 80 serious injuries, and 28 minor injuries. The results indicate that fatal accidents constitute a dominant proportion of total accident cases, reflecting the high severity of road traffic incidents along this route.

As shown in Fig. 2, the highest number of accidents was observed in 2025, whereas the lowest occurred in 2022. A noticeable increasing trend in accident frequency is observed from 2022 onwards, accompanied by a significant rise in both fatal and serious injury cases.

Fig. 3 further reveals that fatal accidents account for 68%, followed by serious injuries (24%) and minor injuries (8%). This distribution clearly indicates that a large proportion of accidents results in severe outcomes.

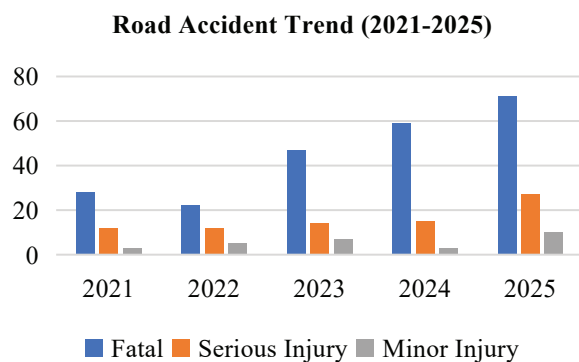


Fig. 2: Year-wise accident distribution (2021-2025)

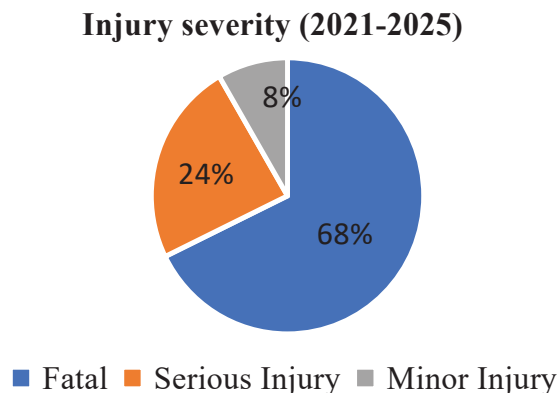


Fig. 3: Accident severity distribution (%)

3.1.1 Vehicle Involvement in Road Traffic Crashes

The involvement of different vehicle types in road traffic crashes (RTCs) was analyzed to identify the major contributors to accident occurrence along the Tongi-Mawna road. Table I presents the distribution of accidents by vehicle category. The results indicate that trucks account for the highest proportion of accidents (46.3%).

Among other vehicle types, buses (20.9%) and three-wheelers (17.9%) also show significant involvement in accident occurrence. In contrast, other vehicle categories such as cars (5.0%), motorcycles (5.0%), CNG (2.5%), and private cars (1.0%) contribute comparatively lower proportions.

The high involvement of heavy vehicles, particularly trucks and buses, suggests their significant role in accident occurrence, which may be associated with traffic volume, speed variation, and mixed traffic conditions along the study corridor.

Table I: Distribution of accidents by vehicle type.

Category	Vehicular types	%
Vehicle factors	Truck	46.3
	Bus	20.9
	Three-wheeler	17.9
	Car	5.0
	Motorcycle	5.0
	CNG	2.5
	Private Car	1.0

3.1.2 Severity and Consequences of Road Traffic Crashes

The severity of road traffic crashes was analyzed based on fatal, serious injury, and minor injury categories, along with gender-wise distribution. Table II presents the classification of accident victims during the study period. Fatal cases dominated across all years, with male victims accounting for the highest proportion. For example, in 2025, male fatalities reached 55.7%, compared to 13.6% for females. A similar pattern was observed for serious injuries, with males consistently representing a larger share than females. Although minor injury cases were comparatively fewer, male victims remained predominant throughout the study period, indicating their higher exposure to road traffic risks.

3.2 Accident black spots identification analysis

3.2.1 Accident severity

Based on the calculated severity index (SI) values, accident-prone locations were identified and ranked accordingly. Table III presents the ranking of locations along the Tongi-Mawna road. Out of a total of 31 accident-prone locations, 12 locations were identified as black spots. Among these, Master Bari, Tongi College Gate, and Mowna Chowrasta were identified as the most critical locations due to their higher accident severity. The other

black spots include Jaina Bazar, Hotapara, Borobari Bazar, Bagher Bazar, M.C. Bazar, Wapder Mor, Rangila Bazar, Rajendropur Chowrasta, and Board Bazar. In contrast, the remaining locations exhibit comparatively lower severity and are not classified as black spots. Overall, the results indicate that certain sections of the corridor experience a higher concentration of severe accidents and therefore require priority in road safety improvements.

Table II: Distribution of accident victims by severity and gender (2021-2025).

Year	Category	Variable	n	%
2021	Death	Female	6	14.3
		Male	21	50.0
	Serious injury	Female	2	4.8
		Male	10	23.8
	Minor injury	Male	3	7.1
2022	Death	Female	5	15.2
		Male	14	42.4
	Serious injury	Female	3	9.1
		Male	7	21.2
	Minor injury	Male	4	12.1
2023	Death	Female	17	25.8
		Male	28	42.4
	Serious injury	Female	3	4.5
		Male	11	16.7
	Minor injury	Female	2	3.0
		Male	5	7.6
2024	Death	Female	14	20.9
		Male	38	56.7
	Serious injury	Male	12	17.9
		Female	1	1.5
	Minor injury	Male	2	3.0
		Female	12	13.6
2025	Death	Male	49	55.7
		Female	8	9.1
	Serious injury	Male	15	17.0
		Female	4	4.5

3.2.2 Kernel Density Analysis

Fig. 4 shows the spatial distribution of road traffic accidents along the Tongi-Mawna corridor. High accident density is observed in the southern section, particularly around Tongi College Gate, Gazipura, and Borobari. Another concentration of accidents is found in the central section near Mowna Chowrasta, Rangila Bazar, and M.C. Bazar. In contrast, the northern and intermediate sections exhibit relatively lower accident density.

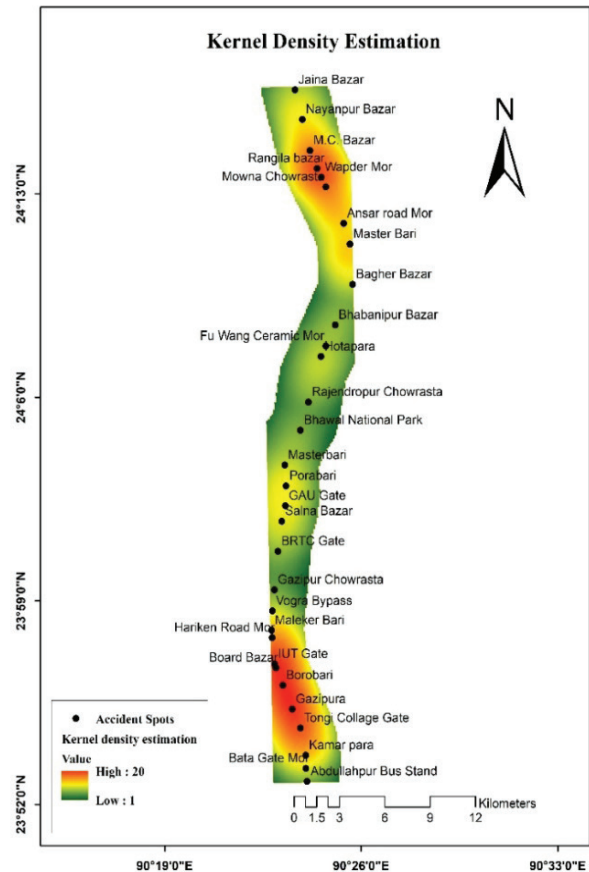


Fig. 4: Kernel density map of road traffic accidents.

3.2.3 Accident Hotspot Analysis Fig. 5 represents the spatial clustering of accident-prone locations along the Tongi-Mawna corridor, while Table IV presents the statistically significant hotspot locations with their corresponding confidence levels. The results indicate that major hotspot clusters are concentrated in the central and northern sections of the corridor. The most significant hotspot locations include Mowna Chowrasta, Master Bari, Bagher Bazar, Ansar Road Mor, Rangila Bazar, Wapder Mor, and M.C. Bazar, which exhibit high accident concentration with strong confidence levels. Additionally, Jaina Bazar and Navanpur Bazar are also identified as hotspot areas in the northern section, while Tongi College Gate and Gazipura represent notable hotspots in the southern part of the corridor. In contrast, several locations such as Masterbari, Porabari, Salna Bazar, and BRTC Gate are identified as cold spots, indicating comparatively lower accident concentration. Some intermediate locations show moderate or insignificant clustering.

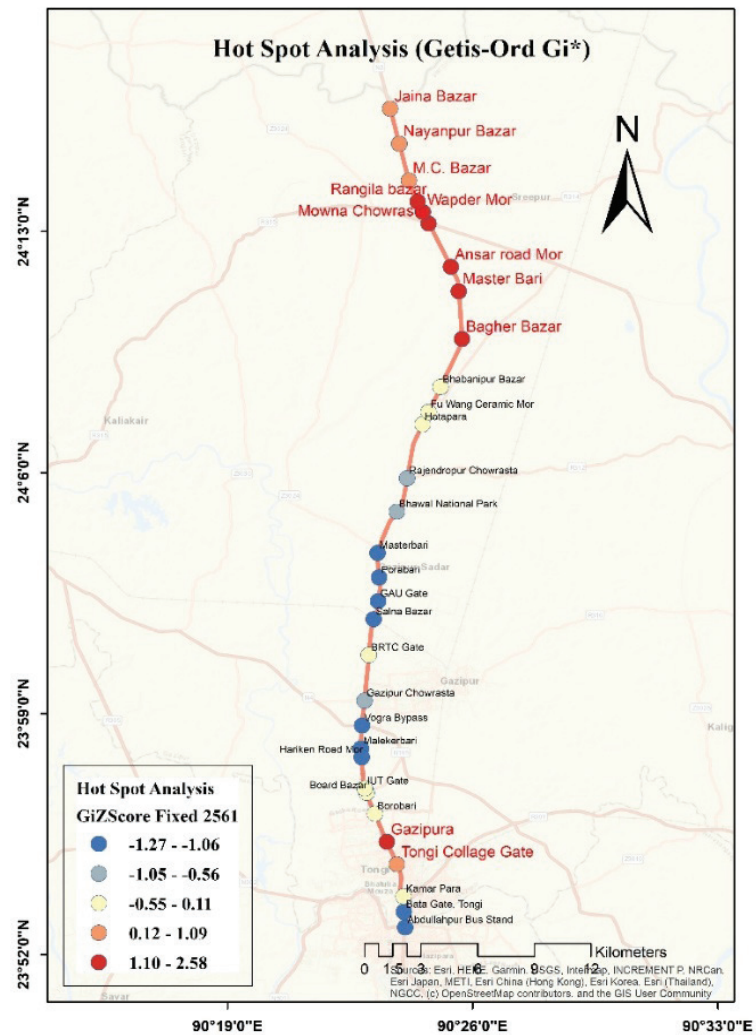


Fig. 5: Hotspot analysis map (Getis-Ord Gi*).

Table III: Ranking of accident-prone locations based on severity index

Serial no.	Black Spots	Latitude	Longitude	SI Value	Ranking
1	Master Bari	24.18776211	90.42667181	88	1st
2	Tongi Collage Gate	23.91029655	90.39726615	75	2nd
3	Mowna Chowrasta	24.22058696	90.41238251	68	3rd
4	Jaina Bazar	24.27618117	90.39407239	61	4th
5	Hotapara	24.12329333	90.40944852	57	5th
6	Borobari Bazar	23.93485769	90.38683245	55	6th
7	Bagher Bazar	24.16469792	90.42825994	53	7th
8	M.C. Bazar	24.24142719	90.40296643	45	8th
9	Wapder More	24.22611919	90.40965315	44	9th
10	Rangila Bazar	24.2311956	90.40715139	42	10th
11	Rajendropur Chowrasta	24.09723283	90.40209846	42	11th
12	Board Bazar	23.94486925	90.38279666	40	12th

Table IV: Statistically Significant Hotspot Locations and Confidence Levels

Serial no.	Name	latitude	longitude	No. of Accident	Confidence Level
1	Jaina Bazar	24.27618117	90.39407239	15	95
2	Nayanpur Bazar	24.25924386	90.39843356	6	95
3	M.C. Bazar	24.24142719	90.40296643	11	95
4	Rangila Bazar	24.2311956	90.40715139	10	99
5	Wapder Mor	24.22611919	90.40965315	10	99
6	Mowna Chowrasta	24.22058696	90.41238251	16	99
7	Ansar Road More	24.19959633	90.42295326	5	99
8	Master Bari	24.18776211	90.42667181	20	99
9	Bagher Bazar	24.16469792	90.42825994	13	99
10	Gazipura	23.92117358	90.39245258	7	99
11	Tongi Collage Gate	23.91029655	90.39726615	18	95

4. CONCLUSION

This study investigated the spatial and temporal characteristics of road traffic accidents along the Tongi-Mawna segment of the Dhaka-Mymensingh Highway using GIS-based techniques and statistical analysis. The findings reveal that road traffic accidents remain a serious safety concern along this corridor, with 304 recorded accidents during the study period, including a notably high proportion of fatal cases. The temporal analysis further indicates an increasing trend in accident occurrence in recent years, with 2025 recording the highest number of accidents. The results also show that heavy vehicles, particularly trucks and buses, are major contributors to accident occurrence along the study route. In addition, the severity analysis demonstrates that male victims account for the highest proportion across fatal and injury categories, reflecting their greater exposure to traffic risk. The severity index analysis identified 12 black spots out of 31 accident-prone locations, indicating that several sections of the corridor experience a higher concentration of severe crashes. The spatial analyses provide further support for these findings. Kernel density analysis highlights pronounced accident concentration in specific sections of the corridor, while hotspot analysis identifies statistically significant clusters of accident-prone locations. Taken together, these results confirm that road traffic accidents along the Tongi-Mawna corridor are spatially concentrated rather than randomly distributed.

Overall, the combined application of GIS-based spatial analysis and statistical methods proved effective in identifying accident-prone locations and understanding accident patterns along the Tongi-Mawna corridor. The findings provide useful information for planners,

engineers, and traffic authorities to support targeted road safety planning and accident risk reduction.

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