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Review Article

Identifying Influencing Factors of Road Accidents in Emerging Road Accident Blackspots

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This study deals with identifying the accident blackspots and the influencing factors causing accidents using factored analysis in a medium-sized city (Tirunelveli) in India. From the literature review, the geospatial technique to identify the blackspots and the factors causing accidents was used for analysis. The most influencing factors driving the accidents were identified and ranked based on the repetitive occurrence of accidents in the blackspot area. The spearman ranking system showed the correlation among the factors causing accidents. The factor analysis technique was utilized to identify the key factors driving the repetitive accidents and group them. This study will help transportation planners understand the factors causing accidents and take appropriate measures to reduce the casualties in the road construction planning stage and existing conditions.

1. Introduction

Worldwide, among the total road accident occurrences, nearly 1.3 million are fatal accidents, among which 90% of the fatal accidents occur in low-income people, such as the countries in Africa, and nearly 20–50 million nonfatal accidents contribute to disabilities [1]. From the statistical data obtained, it was observed that low and middle-income people worldwide have a high contribution to the occurrence of road accidents, and it was found that the total cost of accidents was found to be nearly 3 percent of the global gross domestic product [2]. The vulnerable road accident causers are cyclists, motorcyclists, and pedestrians. Road traffic accidents cost shares 3% of the total gross domestic product. It was noted that there was a continuous increase in fatal accidents from 1.15 million to 1.35 million during the period from 2000 to 2018 [3]. Traffic accidents are a major issue all around the world. Negative driving behavior, which is inherently influenced by traffic circumstances and infrastructure, among other factors, is one of the leading causes of traffic accidents [4, 5].

In 2019, nearly 4.37 lakhs road accidents were recorded on Indian roads, among which 1.54 lakhs accidents were fatal, and 4.39 lakhs of accidents were nonfatal but resulted in significant injuries, rendering people incapacitated. Two-wheelers caused the deadliest road accidents in 2019 (58,747 deaths), accounting for 38.0 % of all road fatalities, followed by trucks/lorries (22,637 deaths) (14.6 percent), cars (21,196 deaths) (13.7 percent), and buses (9,192 deaths) (5.9 percent). In India, road accident death has a share of 44% of total accident deaths, and the remaining percentage of accident deaths are due to suicide, forces of nature such as floods, landslide, cyclone, exposure to cold, torrential rain, forest fires, and lightning. In 2019, nearly 57,228 accidents were recorded in the state of Tamil Nadu, and India stands in an alarming zone. Hence, it is necessary to identify the causes of accidents and to take appropriate mitigating measures in the road construction planning stage and for the existing conditions [6–9].

Road networks are complex, dynamic, and uncertain systems that are influenced by human, technological, and environmental elements, which result in road accidents [10]. It was found that there was a strong relationship between the road accident and the geometrical characteristics of the road, such as sight distance, the radius of curvature, and slope [11, 12]. The number of accidents increases with tangent length, peak hour volume, and longitudinal pitch but decreases with the radius of the curve [13]. Furthermore, the efficiency causes are the relationship between speed fluctuations with longitudinal gradient and, as a result, traffic congestion, safety reduction, and the risk of an accident occurring [14]. It impacts driving site distance and driver behavior, such as passing other vehicles. The effects of longitudinal surface friction and pavement are amplified in the plunging slope, increasing the likelihood of occurrence [15]. The following human factors, such as the health condition of the driver and pedestrian, alcohol consumption, use of mobile phones while driving, distraction due to roadside advertisements, and the age of the driver, will have a more significant influence on the occurrence of road accidents [5]. Environmental factors associated with the road accidents, such as fog, ice rain, and rain, will have higher relevance to the occurrence of road crashes [16–20]. Accident analysis based on the type of road based on environmental exposure revealed high significance for road accidents in poor weather conditions [6]. It was revealed in the research that the road surface condition texture depth and the corresponding skid resistance value have a more significant impact on the occurrence of an accident [7].

Accident prediction methodologies have been extensively researched in the past, especially with the collected statistical data, such as the spot map method, accident frequency method, rate quality control method, and accident rate methods in which the following characteristics such as spatial features, vehicle features, and human behavior are not considered [21]. In in-depth accident analysis, driver information, vehicle information, and road environment information are collected for conditions such as precrash, in-crash data, and postcrash [22]. However, such systems rely heavily on traffic flow data, such as average daily traffic and data gathered by traffic cops at accident locations. However, traffic flow data are rarely accessible insufficient amounts or with sufficient precision to support these regression methods. Furthermore, the traffic police may not be able to acquire all the essential data required to perform the analysis. Considering all of the aforementioned criteria, it is necessary to create a model that may aid in predicting risk zones on a specific road network. Use kernel and overlay analyses in a geographic information system (GIS). This study outlines a model created to recognize blackspots on highways. GIS analyses both spatial and nonspatial data. As a result, a model for determining the position of accident spots on roads may be simply incorporated using GIS [23–26].

2. Literature Review

Recently, research has revealed that road crashes causing severe injuries have been identified as a significant public health issue. Hence, stringier countermeasures should be initiated to reduce the number of road crashes that cause severe injuries in the short-term and long-term improved outcomes [27]. In a study in Toronto, the statistical accident analysis shows that the fatal accidents are due to the following factors: harsh driving, lack of concentration while driving, and overspeeding. It was found that the harsh driving, speeding, and red light accidents and their corresponding percentage of fatal accidents are 62.9%, 21.4%, and 10.4%. The cluster analysis was used to find attributes responsible for road accidents for final modeling. However, the results are not highly significant, which may reverse the cause [28]. In a study, the accident data related to vulnerable road users, such as pedestrians and cyclists, were collected from 2012 to 2015 from Aveiro, Portugal, to perform statistical accident analysis to identify the severity of vulnerable road users involved in road accidents. The risk factors considered for this study are profile, meteorological data, location, gender, and weather condition. It was found that, considering vulnerable road users, the probability of pedestrians being involved in road accidents increases by 2.7 times on urban roads and 10.6 times for pedestrians [29]. The road accident severity of crash was estimated from the accident data collected for the 14 districts of Kerala, India, for six years from 2014 to 2019. The road partners considered are national highways, state highways, and other roads, and it was found that numerous accidents are occurring, especially in the hilly regions and at the intersection of the road geometry. The final results revealed that most road accidents are caused due to vehicle drivers, and other causes, such as pedestrians and vehicle failure, lead to fatal accidents [30]. The researcher developed a regression model to predict the occurrence of a fatal accident in Ahmedabad city with statistical analysis by collecting the fatal accident data and traffic volume per lane for places Shahibaug and Karanj Bhadra, Ahmedabad, for the period of six years from 2005 to 2010. The regression model developed was found to be satisfactory with a goodness of fit and a successful prediction rate [31]. To have an organized city, at the planning stage itself, we must give special attention to vulnerable road users such as pedestrians and cyclists in order to reduce road accidents. The cluster analysis technique was used to identify the relevant common factors causing the different types of road accidents. This provides better knowledge for transportation planners to know the factors causing the accidents for developing mathematical models to predict the accidents and to take appropriate measures in the planning stage itself [32]. To predict the road accident injury severity and accident prediction model in the United Kingdom, an analytical method of data analysis was used on the accident data collected for the period of 4 years from 2005 to 2019. In this analysis, 63 attributes were considered obtained from three different sources of data, found to influence the accident severity. The machine learning technique, the XGBoost algorithm, was used and compared with other conventional statistical analyses, such as the severity index method, GIS method, and cluster analysis. It was found that this technique out layered the conventional method in accuracy even with imbalanced data [33]. GIS-based accident analysis using the *k*-function to determine the distribution of road accident crashes is highly informative. In order to find out the accident-prone location, kernel density estimation was utilized, and to ensure the existence of a cluster, the *k*-function and nearest distance analysis were performed. Thus, the blackspots are identified. This method was specialized in performing spatial analysis, and its display clearly is an advantage over the other methods of road accident analysis. Based on the results obtained, the budgets are allotted to take action to reduce the occurrence of future road accidents [34]. From the research, it was concluded that the systematic analysis of accident scenarios with the available data and the implementation of countermeasures such as improved road geometric design, traffic control measures, and effective enforcement could reduce the occurrence of road crashes considerably. However, adding the geospatial analysis to the conventional accident analysis has a greater outcome than the conventional accident analysis without using geospatial technologies [35–37], and [38]. Ultimately, people's mobility is severely harmed by traffic congestion and accidents. Accidents are a drain on the national economy because they can result in disability, death, health and property damage, social suffering, and environmental degradation. In all the above, none of the methods identify the most influential factor causing the accident. In this research, the accident analysis was performed by combining the GIS to identify the blackspots, and factor analysis was used to identify the most influential factors causing the accidents and rank; hence, future accidents can be reduced by concentrating our research and remedial measures on the most influential factors causing the accidents.

3. Objectives of the Study

The objectives of the study are listed as follows:

(1) To identify the emerging blackspots in Tirunelveli city using geospatial analysis

(2) To identify and rank the road accident-causing factors and classify the influencing factors into groups based on characteristics causing accidents by factor analysis in Indian cities

4. Study Area

The study area considered for this research is Tirunelveli city in the state of Tamil Nadu in India. It is the sixth largest district in the city. Palayamkottai is the central business center located on the eastern bank of the Thamirabarani River. The town has a number of educational institutions and administrative offices like district police headquarters, medical colleges, commercial shops, and hospitals, attracting more traffic from the outskirts of the city, causing high traffic flow in the city [9, 27, 29, 31, 33, 39–53]. The Municipal Corporation Act of 1994 established a municipal corporation to operate Tirunelveli. The city has a population of 473,637 people and occupies an area of 169.9 km^2, as shown in Figure 1. Tirunelveli is well connected to the rest of Tamil Nadu by roads and rail. The split of road length is shown in Table 1. Nellaiyappar Temple and other textile shopping malls, retail stores, markets, educational institutions, hospitals, railway junctions, and other tourist attractions are all located in the study area. It draws a more significant number of visitors and daily shopping to the Tirunelveli district, causing traffic congestion, accidents, and unwelcome delays. Hence, it demands access to the trends of road accidents and recommends preventative steps to avoid an accident in engineering aspects.

5. Data and Methods

5.1. Data Collection. In order to perform the accident identification of blackspots using geospatial techniques and to perform factor analysis, the road crash data, such as geometric characteristics and human and environmental factors, were collected from the Tirunelveli traffic police headquarters. For the last three years, covering all months from 2018 to 2020, total collision accidents of 3693 comprise fatal accidents, unfortunate injury accidents, minor injury accidents, and noninjury accidents, as given in Table 2. To even out random variances, three years of data were employed. Apart from that, three years is a good compromise between a lengthy period of forgetting many mishaps and a short period of not changing the location too often. The police department provided information such as the time, place, type of collision, and other details such as the automobiles involved in the accident. A Trimble Geo-Explorer 2008 series handheld receiver was used to obtain the coordinates of all accident locations. It was accurate within 3–5 meters. They were moved to a GIS database after obtaining all of the secondary data. The following concerns were identified during the collection of secondary data to obtain a considerable number of road crash data in a limited time period. So that the location was not significantly altered and effective mapping of the incidents was possible with a small deviation of 3–5 m from the actual position, as shown in Figure 2.

The road inventory survey conducted on the highway to analyze numerous elements that may directly or indirectly contribute to the causes of accidents is the primary data for the method of prioritization. The following are the main variables to consider. Based on a research review and personal experience, the number of lanes in each direction and the presence of traffic signs and road markings are all factors to consider. Conditions of drainage, pedestrian crossings are readily available and the impact of traffic merging and converging.

The collected accident data locations were geo-coded as x and y coordinates using a handheld GPS. In addition to that,

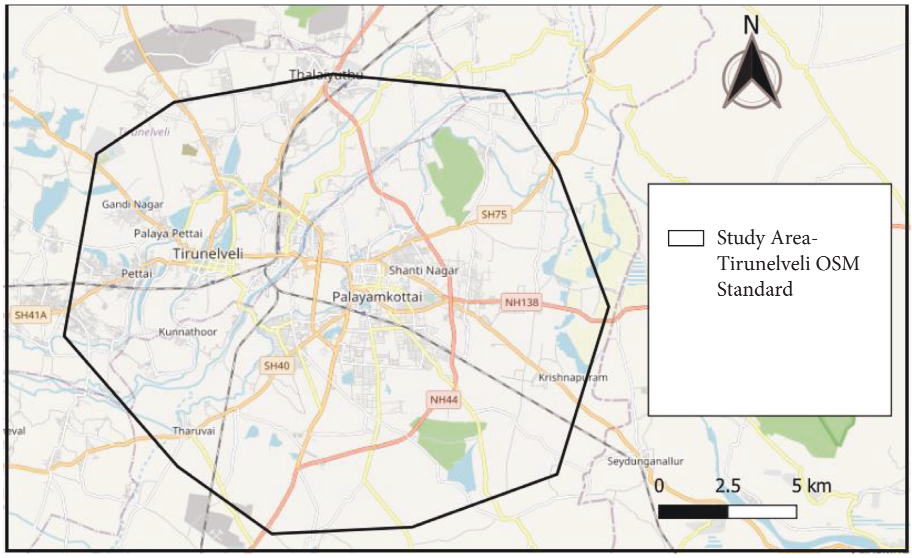

Figure 1: Location of study area.

Table 1: Classification of roads and their length in Tirunelveli city.

S. no.	Classification of roads	Length (Km)
1	National highways	174.824
2	State highways	442.839
3	Municipalities roads	1,001.54
4	Panchayat union	1,254.10
5	Panchayat road	1,658.35
6	City roads	840.399
7	Other roads	114.450

the road information included the texture depth, geometric characteristics, abstraction, road marking, road signs, and sight distance and other information such as year, month, date, time, vehicle type, cause, fatality, and so on. Additionally, the road network is digitized from the Toposheets. On the digitized road network, the GPS location data merged with the road map.

6. Methodology

In this research, importance of accident analysis was confirmed by the accident severity index value, which is 24.5, followed by the identification of blackspots using geospatial analysis, and the corresponding factors causing the road accidents were identified and ranked using factor analysis. This research paper focused on a macro level; the micro level factors such as the volume to capacity ratio and collision rate ignored.

6.1. Accident Severity Index. The accident severity index considers the seriousness of the accident as well as the availability of medical services in the area. The number of individuals killed in 100 accidents was the accident severity index [54, 55]. Figure 3 depicts the Tirunelveli district's accident severity index, which is relatively high. The accident severity index in 2018 was 20.6; in 2019, the accident severity index increased to 24.5. This indicates that the number of people who die per 100 accidents has been rising . Additionally, the accident severity index of 24.5 is a significantly higher rate. Furthermore, the high level of the accident severity index could be due to insufficient data collection and reporting. Hence, the identification of blackspots and corresponding influencing factors should be identified and ranked to reduce further accidents in the road planning stage and existing conditions.

6.2. Identifying Blackspot. On a national and worldwide level, research on traffic accident analysis has been ongoing. The main objective of the study was to identify the cause of the accident and the appropriate remedial measures to minimize the occurrence of road crashes. As a result, the first step must be to identify hazardous locations, sometimes known as blackspots [56]. Earlier conventional methods were used to find the blackspot locality in which only the number of accidents is considered. In most of the traditional methods, they used the statistical Poisson distribution, and the Empirical Bayes technique was utilized [9, 31, 39, 42–53, 57]. The goal of the identification procedure is to pick a few sites from a large number of possibilities to increase safety. The justification for the identification procedure should meet the following criteria: economic efficiency, road user justice, and professional accountability [39]. Developed countries, like the United States, Canada, and the European Union, have developed area-specific guidelines to identify and manage blackspots [58].

6.3. Spatial Accident Data Analysis. Researchers should have a clear understanding of the spatial and temporal incidents that caused the accident to undergo statistical mapping and modeling using unique data [59–61]. In this research, the software Arc GIS was used to analyze the accident spots. The relevant data used were field verified to have high-level accuracy. To perform the blackspot analysis, the emerging

Table 2: Accident data for Tirunelveli city.

Year	Fatal accident	Grievous accident	Minor accident	Noninjury accident	Total accident
2018	282	180	709	44	1214
2019	282	162	759	49	1256
2020	290	190	704	56	1223

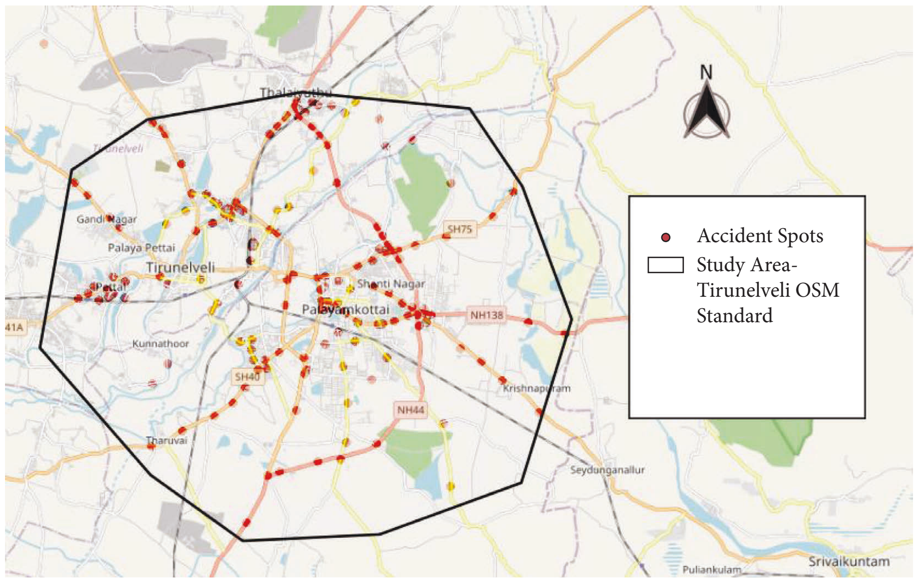

Figure 2: Map showing geo-referenced accident data (fatal, grievous, minor, and noninjury accidents, Tirunelveli city).

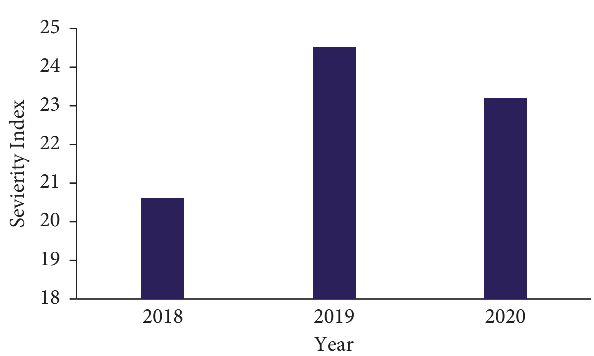

Figure 3: Severity index and the corresponding year.

hotspot analysis (EHA) methods were utilized in the ArcGIS software. In this research, x and y identify the location of transactions, and z is the time of registered property transactions in that location or area of the city [62].

To identify the blackspots, the three-step kernel tool consisting of a kernel density estimator, kernel function, and bandwidth was utilized for density estimation, provided with mapping of the cluster, and collection of events was done using the Getis-Ord GI^* function given in equation (1). The collect event function was utilized to perform the operation, which produces a new output containing the weighted point feature class with a field count expressing the summation of a number of accidents in a specified geographical location. The Getis-Ord GI^* hotspot function utilizes the weighted point feature as an input parameter to cluster the accuracy of blackspots in the research area [25, 27, 40]. To determine the Gi^* value, the following equation was utilized.

$$Gi * (d) = \frac{W_{ij}(d)X_j - W_{ix*}}{S^* \left((nS^* 1i) - W * 2/i/1\,(n-1) \right) 1/2}, \qquad (1)$$

where $W_{ij}(d)$ represents the values for j within d of target cell i, W_i^* represents the summation of all weights, S_{1i}^* represents the summation of all squared weights, and S^* represents the standard deviation in cell data.

In the Gi^* statistical analysis, the z score was calculated. Based on the GiZScore, the kernel density blackspots were identified and produced a raster file showing the accident clusters with low or high intensity [33, 41]. This investigation primarily yielded geo-databases, queries, and density maps based on various parameters. GIS analysis helped to identify the blackspots in Tirunelveli. A method of heat map plug-in of QGIS was utilized to locate accident blackspots. Point data are examined in this manner to build an interpolated surface depicting the density of occurrence. Each raster cell was assigned a density value, and the entire layer was represented using a gradient. The final visualization, which influences how the viewer interprets the data, is subjective. The final interpretation may differ depending on the number of classes and cell ranges used to create the gradient. Five different categories were evaluated for constructing the heat map, with a cell range of 200 m, as shown in Figure 4.

For mapping, free available geo-referenced IRS P6 LISS-III (Indian Remote-Sensing Satellite-P6, a linear imaging self-scanner) was utilized and obtained from the Bhuvan India portal. The data obtained are listed. A heat map is

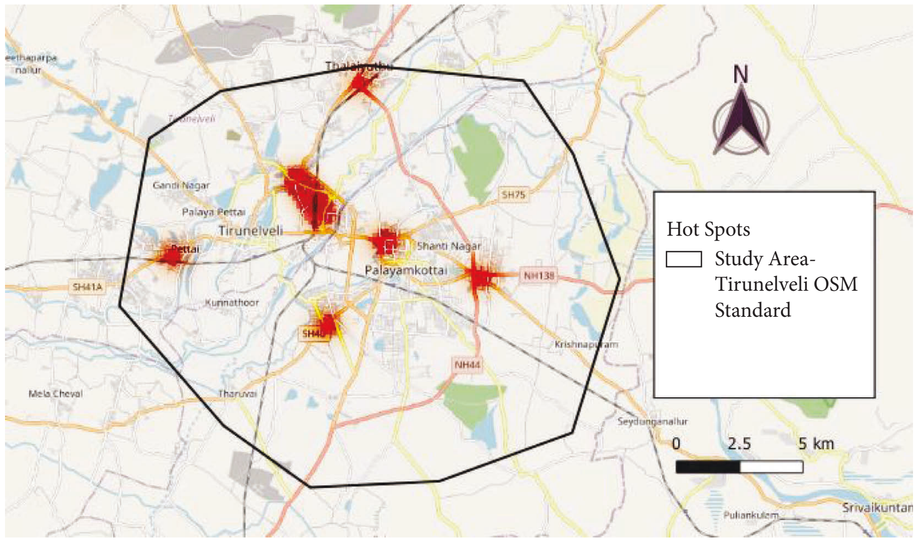

Figure 4: Density map showing the accident blackspots.

Table 3: Blackspot location and number of accidents.

Blackspots location	Total number of accidents, 2018–2020
Two-tier bridge (Tirunelveli junction)	23
In front of Tirunelveli court	16
Vannarpettai junction	24
Samathanapuram junction	31
Thatchanallur (bypass road junction)	26

created with five classes using the QGIS Heat Map plug-in. As illustrated in the density map shown in Figure 4, blackspots are formed in relation to the classes. From the density map, five accident blackspots were identified, as shown in Table 3.

6.4. Blackspot Location Causes and Remedial Measures

6.4.1. Two-Tier Bridge (Tirunelveli Junction). The cause was due to the road width getting narrowed due to the roadside market and lack of pedestrian footpath, road marking, improper lighting, sight distance at the junction, over speeding, pedestrian crossing, and improper geometric characteristics. Roadside shops should be removed, and geometric features should be rectified.

6.4.2. In Front of Tirunelveli Court. This cause was due to the movement of pedestrians from the court to opposite side hotels and shops, leading to heavy pedestrian and motorcyclist crossing.

6.4.3. Vannarpettai Junction. This cause was due to the hospitals, textile shops, and hotels being located, leading to heavy pedestrian flow and vehicle movement and PCU higher than the actual capacity during festival time and parking of vehicles on the roadside. The following remedial measures involve the construction of a subway for pedestrians, the provision of footpaths on either side of roads, and the construction of a median.

6.4.4. Samathanapuram Junction. The cause was due to the roadside occupied by shops, lack of road marking and lighting improper geometric characteristics, and the remedial measures such as geometric characteristics such as channelization, the smooth radius at the curve, median, and island to reduce the conflicts.

6.4.5. Thatchanallur (Bypass Road Junction). The cause was due to the national highway passing through this place having high pedestrian movement on either side of the road and crossing of pedestrians from one side of the road to the other, vice versa, having a higher design speed, and the remedial measures are the construction of a subway for catering to the pedestrians moving through that place.

6.4.6. Data Analysis in Blackspots. The factors that caused the accident crash were recorded, such as traffic characteristics, geometrical characteristics, human behavior, and vehicle characteristics. Table 4 is utilized for data analysis to rank the most influential factor causing the accident using the factor analysis in the Statistical Package for the Social Sciences software. The fitness of data suitable for the factor analysis was checked by Bartlett's test. To confirm the adequacy of information, it was studied using the Kaiser–Meyer–Olkin test for factor analysis [29].

Table 4: Accident-causing factors, frequency index, and ranking.

S. no.	Characteristics	Factors	Frequency index	Ranking
1	Traffic	V/C ratio	0.72	8
2	Road geometry	Ununiformed width of the carriageway	0.69	12
		Lack of sight distance	0.75	6
		Radius of curvature	0.63	16
		Gradient	0.21	27
		Super elevation	0.45	22
		Controlled intersection	0.32	24
		Uncontrolled intersection	0.89	3
		Lack of auxiliary lanes at the intersection	0.21	28
		Bridge approach	0.53	19
		Lack of footpath	0.83	4
3	Road characteristics	Skid resistance	0.72	9
		Roughness	0.43	23
		PSI	0.64	15
4	Street furniture	Traffic signs	0.59	18
		Road marking	0.53	20
5	Human factors	Age	0.69	13
		Male	0.72	10
		Female	0.32	25
		Drunk and driving	0.943	1
		Over speeding	0.92	2
6	Environmental factors	Rainy	0.68	14
		Sunny	0.52	21
		Day time	0.63	17
		Night time	0.74	7
7	Vehicle factors	Low-performance vehicle	0.72	11
		High-performance vehicle	0.12	29
		Brake failure	0.23	5
		Passenger vehicle	0.82	30
		Cargo vehicle	0.32	26

Table 5: Leading factors.

Characteristics	Factors	Frequency index	Average frequency index	Ranking
Traffic	V/C ratio	0.72	0.720	6
Road geometry	Lack of sight distance	0.75	0.750	3
	Uncontrolled intersection	0.89		
	Bridge approach	0.53		
	Lack of footpath	0.83		
Road characteristics	Skid resistance	0.72	0.730	5
Human factors	Male drivers	0.72	0.861	1
	Drunk and driving	0.943		
	Over speeding	0.92		
Environmental factors	Night time	0.74	0.740	4
Vehicle factors	Passenger vehicle	0.82	0.820	2

6.5. Ranking of Factors. The Statistical Package for the Social Sciences (SPSS) software was utilized to analyze the data collected. The data collected at the accident spot were road geometry, road characteristics, street furniture, human behavior, environmental factors, and vehicle characteristics. The data for the analysis were collected from all 120 accident spots comprising fatal, grievous injury, minor injury, and noninjury for all the identified factors causing accidents in the blackspots. The frequency index (F.I.) was calculated and ranked as shown in the table, and its ranking for each category was calculated for each factor and is given in Table 4. Table 5 shows the leading ten factors causing the accident, covering all groups within each group except the street furniture characteristics. From the observations obtained, it was noted that the features such as human factors stand first as an accident-causing factor, followed by vehicle factors standing second position and geometrical factors in third position.

7. Scope of the Research

This research identifies the most influencing factor causing the accident among the n-number of factors driving the road accident and a limited number of accident spots in the study area; thus, the severity index was obtained in a holistic manner. Hence, it is suggested that intersections and road sections should be examined separately in future studies. Thus, it gives an idea for transport planners to take appropriate action to reduce accidents in the short term and over a long period of time.

8. Limitations of the Study

The following limitations of the study are that the microlevel factors causing the accidents, such as driver behavior, angle of collision, type of collision, volume to capacity ratio, and level of service, are ignored.

9. Conclusion

In the past research, the accident data were analyzed by statistical analysis; machine learning, cluster analysis, and GIS-based have utilized all the factors causing the road crashes, but the highly influenced factors causing road crashes are not identified and ranked. The statistical methods are generalized in nature, where the GIS-based analysis shows the distribution of accidents in specified areas along with the spatial data. This research utilized statistical analysis, which is based on the severity index; the accident studies were carried out in a particular area, the identification of blackspots in that area and the most influencing accident-causing factors, particularly in the blackspots in that area. The 30 accident-causing factors were identified and ranked. The top 10 factors influencing the cause of accidents are volume to capacity ratio, lack of sight distance, uncontrolled intersection, bridge approach, lack of footpath, skid resistance, male drivers, drunk and drive, over speeding, and passenger vehicle. This study reveals that the identification of accident-causing factors is a very complex process in India and requires proactive decisions to reduce accidents on the roads systematically so that road accidents can effectively be drastically reduced in the future.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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