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ASSESSMENT OF BLACK SPOTS IN URBAN BHOPAL WITH THE AID OF WEIGHTED SEVERITY INDEX AND KERNAL DENSITY ESTIMATION METHODS

Nishant Singh[1*], Sunil Kumar Katiyar[2]

[1]Department of Civil Engineering, Maulana Azad National Institute of Technology (MANIT), Bhopal, Madhya Pradesh, India. e-mail: nishantsingh135@outlook.com, orcid: https://orcid.org/0009-0007-7752-3503*
[2]Department of Civil Engineering, Maulana Azad National Institute of Technology (MANIT), Bhopal, Madhya Pradesh, India. e-mail: katiyarsk@manit.ac.in, orcid: https://orcid.org/0000-0002-8364-472X

SUMMARY

One step toward lowering traffic accidents is identifying the locations of road accident hotspots and the appropriate assessment technique. This study evaluated the effectiveness of kernel density estimation (KDE) and the weighted severity index (WSI) in locating blackspots using the ArcGIS tool. Finding out accident severity levels is necessary to identify the accident-related blackspots. The formula for the WSI method was applied. This study examines five-year traffic accidents in the Bhopal, Madhya Pradesh, city intersection zone of the roads to envisage the appropriateness for the given technique on the basis of availability, consistency, and type of the data. This study designates five typical road network intersection zones as blackspot sites based on the criterion. This study's general conclusion is that, during the years 2017 to 2019, Govindpura Turning in Bhopal is a highly accident-prone area, and point density estimation is preferable to kernel density estimation for this purpose. Additionally, this study found that between 2015 and 2017, high-traffic accidents in Sukhisewaniya's Balampur Ghati were more likely to occur in intersection zones with a large number of legs. This study suggests that point density estimation be used to investigate high number of traffic accident areas by looking into blackspot locations at the macroscopic level of road networks. Furthermore, it is necessary to evaluate the effectiveness of the designated blackspot site and suggest corrective measures that reduce the number of accidents and their consequences.

Key Words: *blackspots, weighted severity index, kernal density estimation.*

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INTRODUCTION

In recent days, due to the inadequacy of transportation networks to maintain with other areas like industry and rental properties, road traffic accidents have increased worldwide. Accordingly, road accidents are one of the major causes of human death and injury [1]. Around 1.3 million people's lives are impacted each year as a result of a traffic accident. Here, Non-fatal injuries affect an additional 20 to 50 million people, with many of them becoming disabled as a result of a serious accident [42]. As per road traffic accidents, Vehicle accidents are denoted as the eighth greatest cause of mortality globally [3]. Moreover, the accident rate of emerging countries differs from developed countries. If compared, the frequency of road accidents, deaths, and injuries in developing countries is higher than

the developed nations by about 10–60 times [42]. Especially in India, the enormity of road traffic accidents and mortalities is frightening due to the lack of awareness on this hazard. Significantly, there is one death is reported at every 5-minute time interval due to road accident in the street areas [5, 6]. In accordance with road traffic accident analysis, the maximum road accidents occur because of road factors [4].

Numerous factors contribute to road traffic injury, like driver performance, weather, road conditions, road geometrical elements, and so on [7, 8]. Mostly these above-mentioned factors cause the majority of road traffic accidents. In this road, geometrical elements play a major role in the maximum number of road accidents. The road geometrical elements that will affect the safety of roads are shoulder width, lane width, super elevation, median width, gradient, and cross-section reallocation. Here, lane width is the major fundamental factor for blackspot analysis. The lane width analysis has frequently established that less width of road results in fewer variations of the vehicle's lateral position and a speed reduction [9, 10]. In this, increment in opposing traffic density affected a lateral deformation of the vehicle toward the right side of the lane in the four-lane–width factors; the 2.75 m road width had the greatest effect on road accidents. The width of the shoulder available on the roads is also a major geometrical element that can represent a variety of functions, including offering a recovery space for driver errors. Subsequently, shoulder widening had the opposite effect as lane width reduction, because it generates better speed and lateral positions closer to the accident risk [11]. Based on these road geometrical element studies, Safety on the roads is a significant element in the development of analytical methods [12]. Additionally, the action of road safety will successfully diminish the rate of accidents on roads. So, for detecting the road accident location, the blackspot detection technology is studied expansively. For detecting the accident locations many researchers used GIS software for their analysis [13, 14].

GIS is an effective tool for examining traffic accidents, and it has been widely used in several countries for detecting Accident hotspots [2]. Here, accident locations and attributes are visualized and stored by using GIS and also it indicates that the hazardous spots are effectively shown on a map that is linked to the accident's data sets. Consequently, the impacts of each accident are easy to evaluate by using this software [15, 16]. In this present analysis the accident data was collected with the help of GIS. With the collected data set further analysis are done in the ArcGIS tool. In road accident analysis, ArcGIS is a suitable software and one of ESRI's capabilities is ArcGIS online, which has been made possible by the existence of a GIS-based framework that provides information about traffic [17]. Here, the users will use ArcGIS Network Analyst enthusiastically at any time, including turn limitations, traffic situations, speed limits, and height constraints. Moreover, in transportation planning and traffic engineering, ArcGIS is a most essential, responsive, and time-saving tool. Based on this tool complete accident reports are created as well as traffic impacts are effectively investigated and analyzed [18].

Bhopal is one of the fastest-growing cities in India. Here, more number of traffic accidents were reported between 9a.m to 11a.m and 5p.m to 8p.m i.e., during peak hours. According to the National Crime Records Bureau (NCRB) states that approximately 3000 road accidents are reported every year in Bhopal. The purpose of this study is to identify high-density accident locations in order to improve road safety on highways and also to analyze the road geometrical elements that will affect the road [19, 20]. Furthermore, for the density-based analysis, a widely available Kernel Density Estimation (KDE) method is used for spatial accident detection, which also analysis accident hotspots in roads, and also, it summarizes the point distribution by converting point incidents into a density surface [21, 22]. Thus, the KDE and the Weighted Severity Index (WSI) approach both are evaluated in this present analysis. Because of recent ArcMap improvements, ArcGIS is used to do a spatial traffic accident analysis, therefore for assessing traffic accidents, KDE has proven to be an efficient strategy [23]. In recent days, there have been many researchers analyzed road accidents for reducing road accident injuries. In this present analysis is done by using ArcGIS software, and based on the results some remedial measures are suggested to the road users.

LITERATURE REVIEW

In recent days, Road Safety has been one of the important studies at the worldwide level. This section discusses the past research articles which are executed based on GIS.

In 2020 the impact of accident severity index (SI) was investigated on temporal-spatial patterns by implementing statistical analytic methods based on GIS [24]. The presented work collected the road traffic accident (RTA) data from Hanoi during the time of 2015 to 2017. Moreover, the hotpot which corresponded to the time intervals and seasons was analysed with the help of Kernel density estimation (KDE). Still, the author fails to consider the traffic volume for recognizing the RTA hotspots which was directly related to the frequency of accidents.

The blackspots were analysed, to reduce road accidents by executing spatial statistical methods based on GIS. The presented work collected data from Turkey's General Directorate of Highways during the year 2005 to 2013 [25]. Furthermore, model-based spatial statistical methods could be executed to get a graphical model for identifying the blackspots [26] have investigated the Geographic design of the RTA severity index in Nigeria. Moreover, based on the Federal Road Safety Corps (FRSC) road accident data could be collected. Furthermore, with the help of the exponential smoothing technique, the presented work would predict the historic RTA data. Moreover, the author fails to study the basic factors responsible for the experiential geographic design so that future study is needed. The valuation of road safety was analysed in the Italian urban road network with the help of the DEA-based decision support method. Moreover, to identify the road accident blackspots and wherever road safety was needed to improve were proposed with that method [27]. Further analyses will be carried out in the future to compare the performance of the CCR input-oriented and CCR output-oriented models in order to demonstrate their validity as decision-support instruments and to highlight any discrepancies and application specificities.

Aspatial analysis of RTA in Mashhad, Iran was based on GIS [28]. The combination of spatial-statistical analysis and geo-information technology has been applied to highlight the impact of spatial factors in the present study. Moreover, the study examines the 4 huddling analyses for an improved understanding of traffic accident designs in intricate urban systems. The presented analysis would utilize a combination of methods and techniques including traditional KDE, nearest neighbour analysis, and k-function. The author was analysing the research for the 1-year time period, for the eloquent spatial analysis it was obligatory to extend the study for 3 to 5-year time intervals. [21, 29] have explored GIS-based analysis for finding the blackspot of road accidents. A two-step integrated method was used in the presented study and besides years data was collected during the year of 2011 to 2013 in Sherbrooke, Canada. The presented method was suitable for identifying and ranking the blackspots that need more safety attention [29, 30, 31] have investigated the intensity of RTA over 45km of main roads by implementing spatial statistics techniques based on GIS in Turkey. Moreover, road traffic accident blackspots were stated using the Kernel Density method. Using hot spot statistical analysis, traffic accidents reported over a five-year period are coupled with a geographical dataset for evaluation.

METHODOLOGY

Study Area

Accident data are collected from Bhopal Traffic police. In this study, a GIS-based analysis is used for determining the accident-prone areas. Accident data are collected from Bhopal traffic police for the year 2015 to 2019. Furthermore, for the analysis purpose, 17 black spots of urban Bhopal Figure 1 are taken for the field study, they are Chetak Bridge ISBT road Govindpura, Balampur Ghati Bhopal, Govindpura turning, Board office square, Bhadbhada square, Near steelyard main road, Near Samardha bridge main road, Police control room triangle, Lalghati Square, Karond Square, Anna nagar square Bhopal, Ratnagiri triangle Bhopal, ITI triangle Bhopal, Surendra Palace main road Bhopal, K.N Pradhan triangle Bhopal, Chanchal square Bhopal, Golkhedi square Bhopal. After an on-site survey and reviews from the local public, some preventive measures are given to reduce the

number of accidents at these locations.

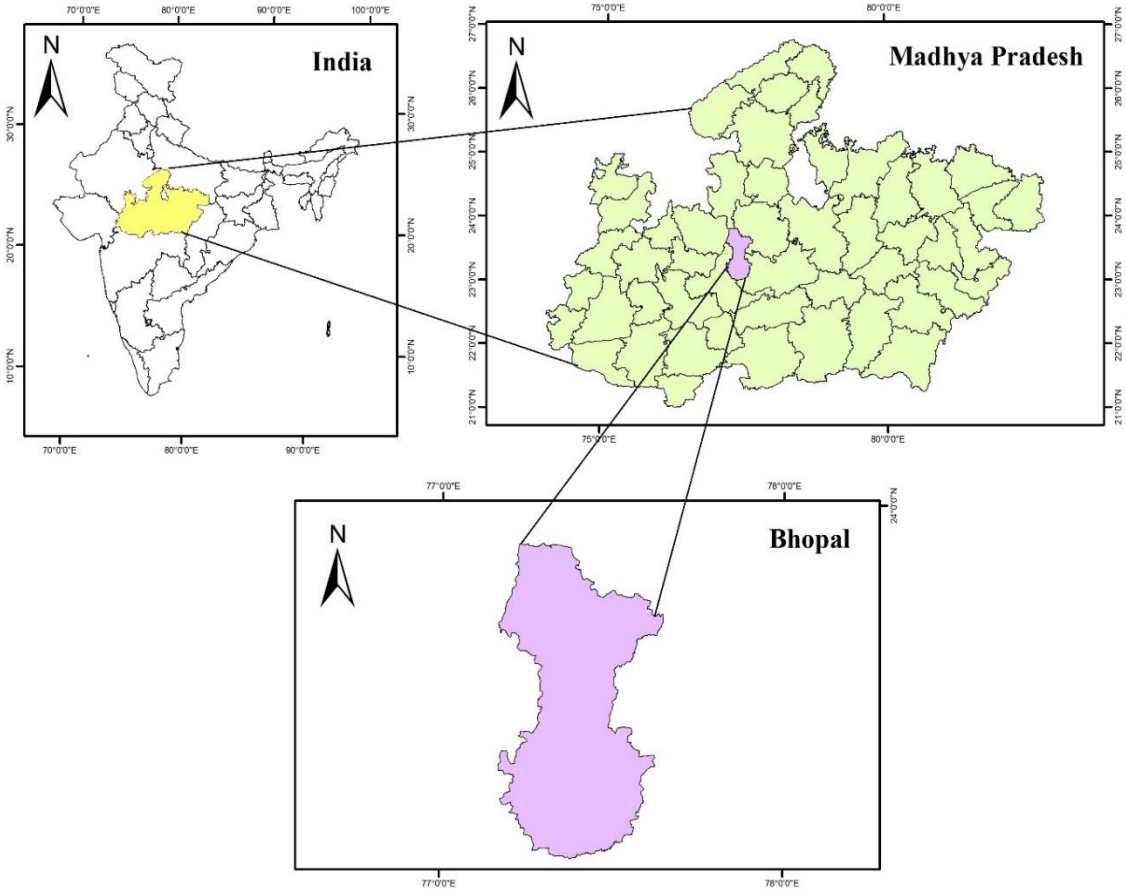


Figure 1. Study area information map

Analysis

Now a days Road Accident is one of the major causes of the human death. The death rate of road accidents has gradually increased with the development of technology and population growth. Therefore, for the reduction purpose of death rate and injury rate based on road accidents, it is necessary to analyses the road accident locations and factors affecting the road accident. The main objective of this paper is to reduce the rate of accidents through the identification of blackspots by using Geographic Information System (GIS) based analysis in urban Bhopal. GIS affords maps that are accommodating for identifying the locations of blackspots. Blackspot analysis will be used to avoid and reduce road accidents with the gathered information and to make a decision that will be helpful. In this presented work the accident data such as road type, location of blackspot, high accident zone, number of accidents, and number of deaths are collected with the help of GIS.

Spatial Analyst Tool

Spatial analysis is one of the geographical analysis methods that gives the spatial expression in the mathematical and geometry form called location analysis. Spatial analysis is also called spatial statistics it contains different analysis methods in different research fields, so finding the classification of spatial analysis is difficult. Moreover, spatial analysis permits people to solve location-related problems and also it allows for a better understanding of the field. Moreover, spatial analysis advances new outlooks people for making a decision. Some of the spatial analysis methods are SANET-KDE, Kernel Density Estimation, Getis-Ord Gi, and Moran's I statistic. In this present study, we are using WSI and KDE methods.

Kernel Density

Kernel density analysis is one of the most effective methods for this road accident analysis. It is a spatial analysis method. Kernel Density is used to determine the density of road accidents at a particular radius, spread risk of accidents, and magnitude per unit area [32, 33, 34]. The Kernel Density Estimation situates a symmetric surface over all points and then based on the mathematical function from the point to reference location, distance can be determined. Then the summation can be determined by adding each surface from the reference location. To make the analysis less complicated the bandwidth value- 1000 m and cell size- 100 m were examined to interpret the blackspots. By adding the individuals kernel gives the density of accident points. And the KDE equation (1) is given by,

$$g(a,b) = \frac{1}{mk^2}\sum_{j=1}^{m} Q\binom{e_j}{k} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 1)}$$

Where,

$g(a,b)$- the estimate of distance at the location (a,b),

m - the number of observations,

k - kernel size,

Q - kernel function,

e_j -distance between the location (a,b).

Moreover, Kernel density analysis is one of the most effective method for the road accident analysis. This present study is made by using ArcGIS tool. In ArcGIS kernel density is the spatial analysis tool. The risk spread of accidents can be detected by using Kernel Density. Generally, the area surrounding the cluster where the risk of an accident may grow is called risk spread [35]. The Kernel Density analysis gives the output in the form of raster. Furthermore, GIS acts as a management system for identifying the blackspots with kernel density as well as for the analysis of accidents with kernel density estimation.

Weighted Severity Index

Weighted Severity Index (WSI) is the method, applicable for the spatial analysis of road accidents. In this research, the WSI method is used to differentiate and rank the Road Traffic Accident (RTA) locations [36, 37, 38]. The WSI is calculated based on the types of accidents such as death, major injuries and minor injuries. The analysis of WSI is done manually in this presented work.

$$\text{Weighted Severity Index (WSI)} = N_a W_a + N_b W_b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 2)}$$

Where,

N_a = Number of accidents,

W_a = weight assigned to accidents = 6,

N_b = Number of deaths,

W_b = weight assigned to deaths = 4.

RESULTS AND DISCUSSION

After the whole assessment from the Weight Severity Index (WSI) and Kernel density test some observations are figured out in this section. The Kernel density test is performed by using ArcGIS. The obtained results are discussed in the following sections.

Weighted Severity Index

For both locations Equation 2 was applied and WSI was calculated. The hotspots were then ranked based on the weighted severity values obtained.

During the study year, Govindpura turning had more severity than other locations. And secondly, more severity occurs in the Balampur Ghati of Sukhisewaniya followed by the Police Control Room. The maximum number of accidents occur in the location of Govindpura Turning Bhopal. In these 15 locations are taken for the analysis. Based on the weightage severity index values the ranking was arranged. Below Table 1 and Figure 2 clearly show where the maximum WSI value occurs and where the accident rates are increased.

Table 1. Shows WSI value and ranking of blackspots at bhopal

S.No.	Police Station Name	Blackspot Location	WSI	Rank
1	Govindpura	Govindpura Turning Bhopal	88	1
2	Sukhisewaniya	Balampur Ghati Bhopal	82	2
3	Jahangirabad	Police Control Room Triangle	72	3
4	Kohefiza	Lalghati Square Bhopal	68	4
5	Nishatpura	Karond square Bhopal	64	5
6	Misrod	NearSamardha BridgeMain RoadBhopal	62	6
7	Kamla Nagar	Bhadbhada Square Bhopal	58	7
8	Sukhisewaniya	NearSteelyard Main Road Bhopal	58	7
9	MP Nagar	Board office square Bhopal	54	8
10	Piplani	Ratnagiri Triangle Bhopal	52	9
11	Jahangirabad	K. N Pradhan Triangle Bhopal	52	9
12	Govindpura	Anna Nagar square Bhopal	46	10
13	Bagsewaniyan	Surendra Palace Main Road Bhopal	46	10
14	Eetkhedi	Golkhedi square Bhopal	46	10
15	Bairagarh	Chanchal square Bhopal	42	11

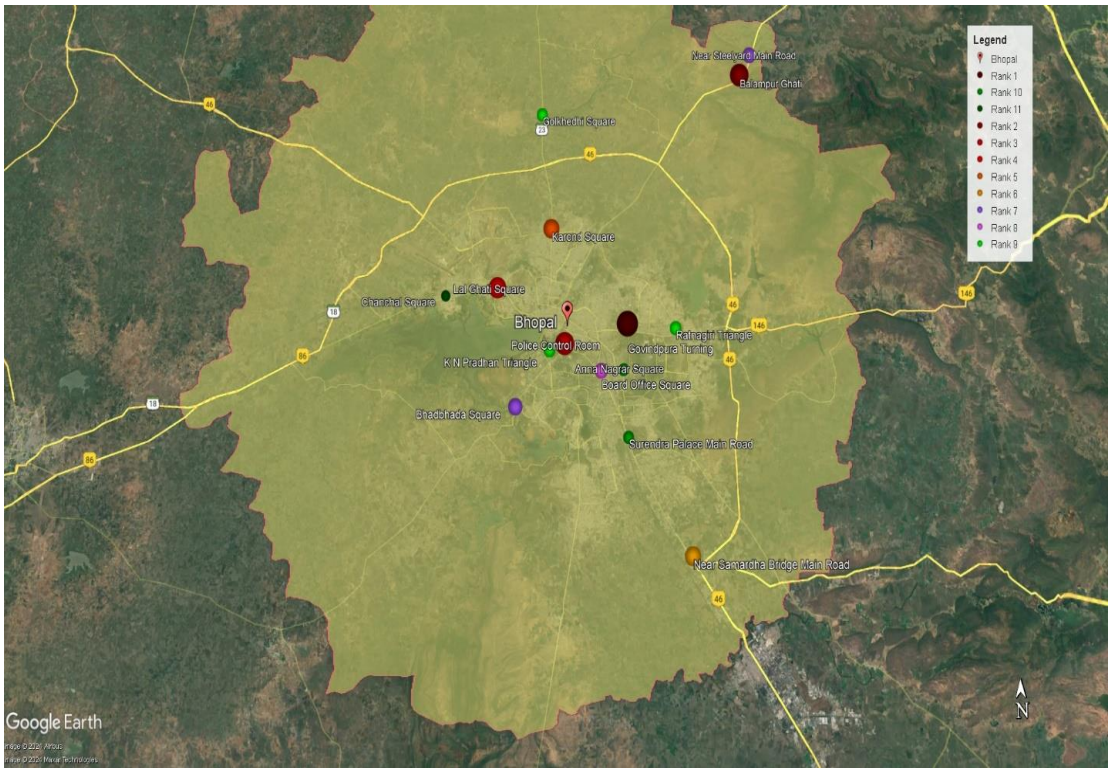
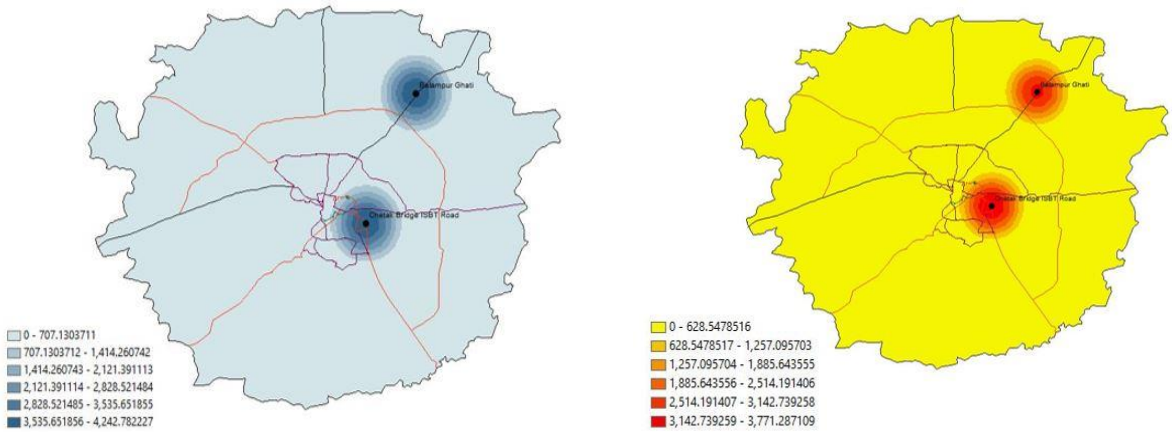


Figure 2. WSI-based ranking of blackspot sites in Bhopal

Kernel Density

This section discusses the obtained results from the KDE and the results are illustrated in Figure 3. KDE has discovered five important hotspots. The diagram Figure 3 depicts the major accident hotspots in Bhopal. The hotspots depict the number of accidents and deaths from 2015 to 2017 in Figure 3(a) and Figure 3(b). Fig. 3(c) and 3(d) depict blackspots from 2016 to 2018 accident and death rates. Figure 3(e) and 3(f) show that the accident and death rates increased from 2017 to 2019.



(a) (b)

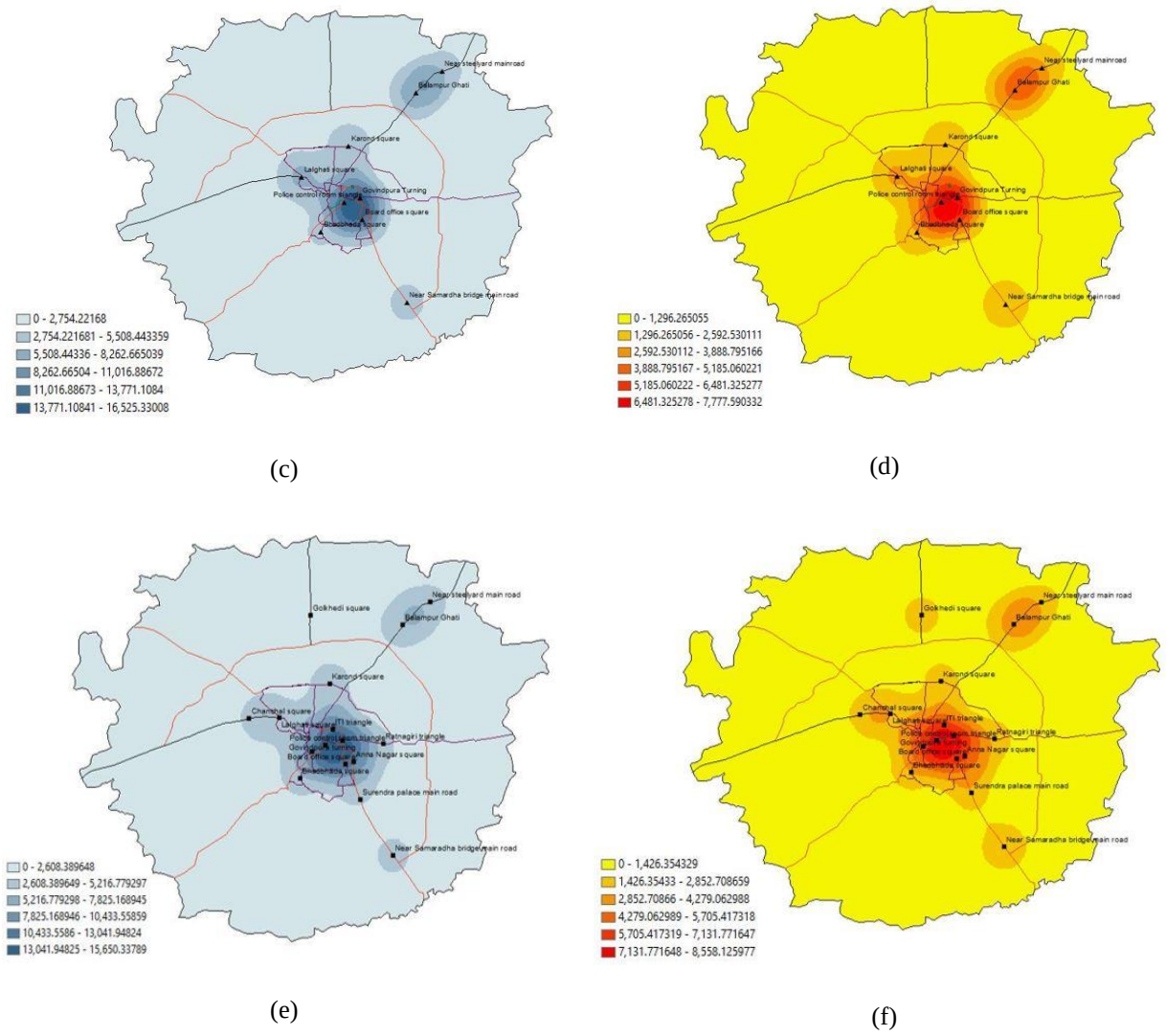


Figure 3: Kernel density analysis (a) No. of accidents in 2015 to 2017, (b) No. of Deaths in 2015 to 2017, (c) No. of accidents in 2016 to 2018, (d) No. of Deaths in 2016 to 2018, (e) No. of accidents in 2017 to 2019, (f) No. of Deaths in 2017 to 2019

The top-ranked hotspots in Bhopal are calculated by location using Moram's I Index, Hotspot Analysis and KDE results as shown below: Govindpura Turning, Police Control Room Triangle, Balampur Ghati, Lalghati Square, Bhadbhada Square, Near Samardha Bridge Main Road, Naear Steel Yard Main Road, K. N. Pradhan Triangle, Ratnagiri Triangle, Chanchal Square, Board Office Square, Anna Nagar Square, Golkhedhi Square, and Surendra Palace Main Road Figure 4.

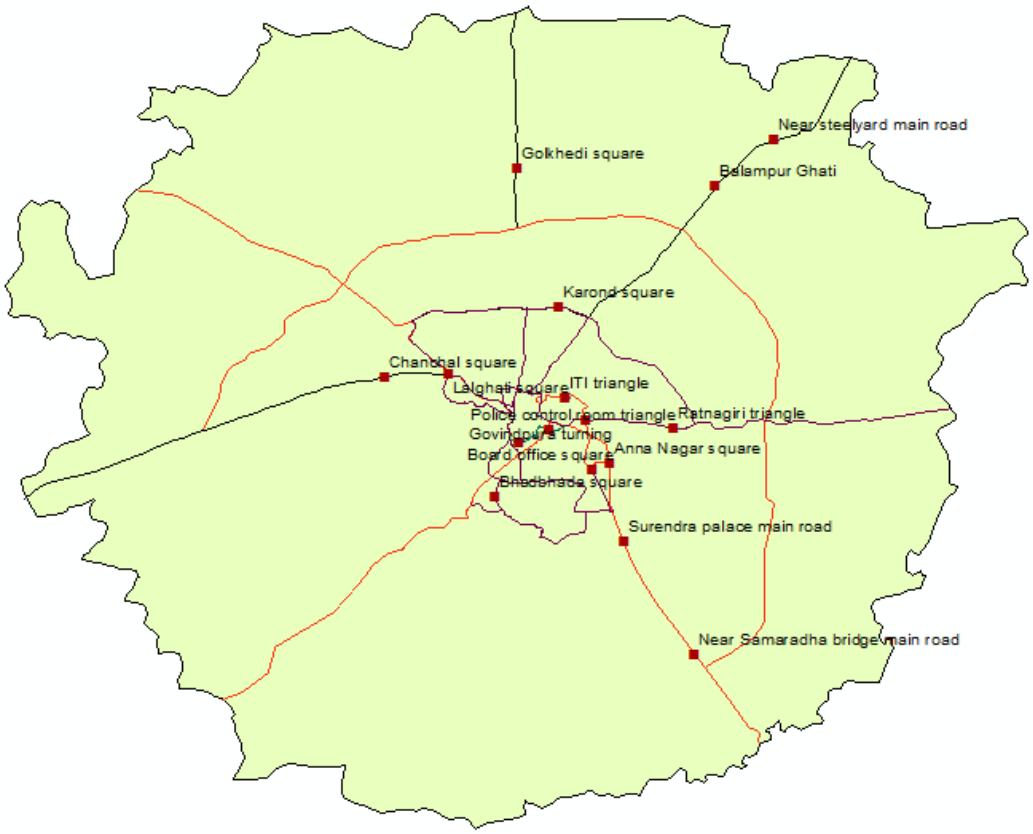


Figure 4. Map of urban bhopal with major accident blackspots

After the above observations, it is found that KDE provides a more accurate and better understanding of blackspots and the probability of providing the count for the intersection zone of road networks is also higher through this method [39]. On the other side,for the specific location's blackspot analysis, the WSI is the most preferable method [37]. So, for the assessment of blackspots in the Bhopal traffic area, WSI is the most suitable procedure.

Bhopal as a capital since inception has been developed as an administrative centre for the state and mainly focused on needs of the service class. Initially, it was not one of the goals to develop Bhopal as business centre for IT companies or MNC's rather Indore was setup as a commercial city in Madhya Pradesh. It was only after 2010 that focus was directed towards modernisation of infrastruture in Bhopal. Especially after 2014 aggressive infrastructure development and commercialisation of city started. This changed the demographic dividend of the city which resulted in increase of traffic volume and change in traffic pattern of Bhopal [40].

Main commercial centres of Bhopal which saw exponential growth of businesses were – M.P Nagar, Govindpura Industrial Area, Bairagarh market area, New Market, etc. Thus increased volume of traffic at peak hours in such areas consequently exposed many Blackspots all over Bhopal. This condition further has put pressure on certain selective roads and squares for which they were not initially designed or planned. So the accident Data from 2015 – 2019 depicts broader trends of accident proneness around crowded commercial areas of Bhopal [41]. Also, this data represents the need for safety measures to be implemented in such areas especially in aspiring cities which are on the path of commercial development. Thus these implications not only stands true for Bhopal but can also be used for such cities on which the Government is planning to focus in near future [42].

CONCLUSION

According to the findings, the study region is located between rural and urban areas. This method was used in the urban areas of Bhopal Madhya Pradesh with high-traffic transportation. Studies on road

traffic accidents often focus on the characteristics of the accidents, but the ultimate goal of this research work is to identify the cause of accidents through the above methods. After the observation that was found during the whole work, concluded that some potential factors that may contribute to road accidents in Bhopal include poor road conditions, inadequate traffic control measures, driver error or impairment, and vehicle malfunction. By analyzing the data and identifying the specific factors that are most commonly associated with accidents in Bhopal, it will be possible to develop targeted interventions to address these issues.

Overall, the use of the GIS system and the implantation of various strategies can help the Madhya Pradesh transportation department to better understand the elements contributing to traffic accidents in the state and take appropriate action to reduce the risk of future incidents.

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