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Identification of Road Accidents Hot Spots in Varanasi using QGIS

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Abstract

Road traffic accident is considered as most negative impact of development of road transportation infrastructure. Road accident is a multi factor event needed to be analysed carefully. As the roadway improvements are meant to be applied to perilous locations or accident hot spots where they have the most vital impact, identification of hot spots is a vital step in safety management. Geographical Information System (GIS) becomes a popular tool amongst researchers for management of accident data records and recognition of accident hot spots on the highways. Accident reports are prepared in form of textual format in Varanasi and it is very difficult to analyze accident and identify hot spots. This study utilized open source GIS software namely QGIS to geocode five years (2009-2013) road accidents locations over the digitized map of Varanasi. To evaluate spatial clustering of accidents and spatial densities, heat map plugin is used. The accident heat map based on Kernel Density Estimation delineates the road stretches as well as isolated zones where accident hot spots are located. Apart from accident counts, severity index based on Belgium system were also employed for analysis and ranking of hot spots. Analysis including severity weighing system considers the effect of severity of accident over the overall result. These heat maps could be effectively utilized by various agencies for optimum planning and management in order to ensure improved traffic conditions and accident reduction.

Keywords: *GIS; Road safety; Traffic accidents; Kernel Density Estimation; Accident severity*

1. Introduction

Road traffic system is considered as most complex and most dangerous system with which people have to deal every day. Road accidents are increasing day by day mainly because the pace of development of transportation infrastructure is somewhat less than that of other sectors such as real estates and industries. India is second most populous country in the world, but it ranked at number 1 spot in the world in terms of total fatalities (World Health Organization, 2013).The probability of occurrence of accidents and their severities can be reduced by the methodical analysis of the incident scenario and by devising appropriate solutions involving suitable roadway design practices, application of proper traffic control devices, and effective traffic police activities. However, the task of proving optimum solutions warrants analysis of spatio-temporal patterns in the zones of traffic accidents, which can be achieved through the application of geospatial technology. This study aims to identify and represent high accident locations or popularly known as accident hot spots in Varanasi city. QGIS is utilized in a proper manner for fast and efficient analysis of traffic accidents and to generate reliable results. The pertinent utilization of spatial analysis technique known as Kernel Density Estimation (KDE) is used to identify the prime vulnerable locations that require remedial measures. This analysis also helps to identify the safe road segments and isolated zones which could efficiently be used as models in development of safer pathways.

2. Feasibility of GIS as road accident data management and analysis tool

Geographic Information System (GIS) is a computer system used for storing, querying, analyzing and displaying geographic data. It could provide relational link between various spatial and non spatial data and model relationships between them. It enables the safety experts to compare accidents along a road way length utilizing various data such as land use data, population data and other demographic data to gain a better perceptive of the relationship of crash incidents with other data to deduce a true picture. There are numerous analyses such as intersection analysis; segment analysis; density analysis; pattern analysis; proximity analysis; spatial query analysis and spatial crash analysis modeling that can be done. Apart from the aforesaid advantages, softwares such as QGIS is known as open source geographical information system can also be acquired at free of cost from many reliable sources. Researchers such as Levine et al (1995), Affum and Taylor (1995) and Ghosh et al. (2004) geo-code accident locations and developed accident pin maps and perform data base queries in transportation safety applications. GIS also have numerous methods of analyzing spatial patterns of accident data as point events, one of the most common methods for hot spots analysis is preparation of crash maps based on Kernel Density Estimation (KDE). It calculates density of crashes in a given search bandwidth also known as its neighborhood. KDE develops continuous surface of density estimates of individual crashes within a search bandwidth thus providing aesthetically and statistically significant results. KDE has been utilized by researchers such as Erdogan et al. (2008), Anderson (2009) and Blazquez and Celis (2013) determine statistically and aesthetically viable results. Truong and Somenahalli (2011), Manepalli et al. (2011) and Rankavat and Tiwari (2013) utilized local measures such as Getis-OrdGi* statistics (Getis and Ord, 1992) and local Moran's I (Anselin, 1995) to detect statistically significant traffic accident hot spots on highways.

3. Study area and data collection

Varanasi is a city on the banks of the Ganges in the Indian state of Uttar Pradesh, 320 kilometres south east of the state capital Lucknow. It is located at 25°16′55″ North Latitude and 82°57′23″ East Longitude. Mixed traffic composition and narrow carriageways in old city area contribute to slow moving traffic. The main accident prone areas are located on highways constituting fast moving vehicular traffic. The study area selected is area encompassing between NH-2 popularly known as Kolkata-Delhi GT road, Varanasi-Kachhanwa SH-74, Varanasi- Sonauli NH-29 and Varanasi-Kanyakumari NH-7.This is because of a large number of accident prone or potential hot spot locations in these areas. These areas also contribute a large amount of traffic flow from outer city to main city, as they are located at the periphery of main city. Police FIR's of five year duration (2009-2013) of various police stations are surveyed and interviews of various police officers are taken. 3 police stations namely Chawk, Laksa and Dashaswamedh have reported to have no accidents because of absence of heavy and fast moving traffic and predominance of pedestrian traffic in vicinity. The data are recorded under following clauses of Indian Penal Court.

Table 1. Various IPC clauses and their significance

IPC Clause	Remarks
IPC 279	Applicable for rash driving
IPC 337	Minor accidents register under this clause
IPC 338	Grievous accidents register under this clause
IPC 304(a)	Fatal accidents register under this clause
IPC 427	Property damage only accidents register under this clause.

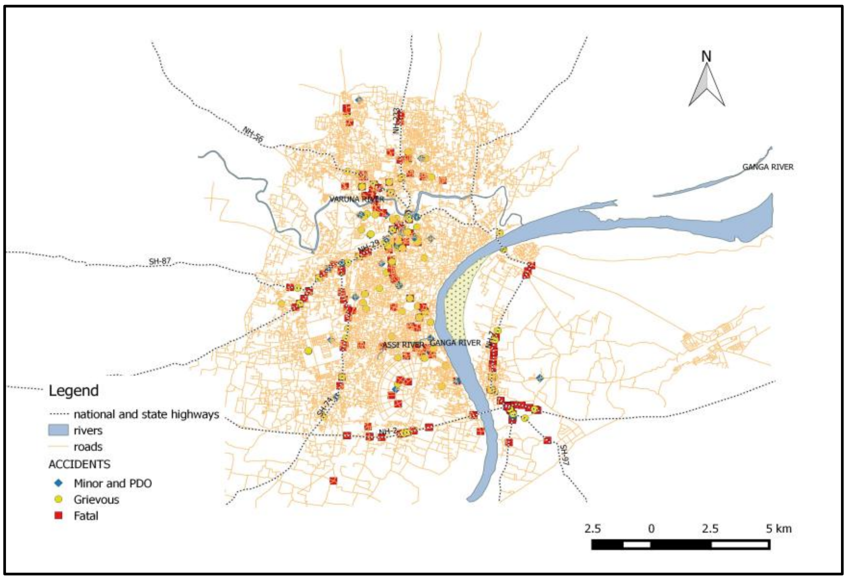

Figure 1. Study area and types of accidents occur in 2009-2013

4. Methodology

4.1 Accident datasets and map preparation

This study utilized QGIS which is an Open Source Geographic Information System for analysis. The digitized map of Varanasi obtained from Google Street map was imported in QGIS and saved as "roads" layer. It was ensured that imported digital map and data frame of QGIS have the same 'projected co-ordinate' system. The co-ordinate system adopted for the present study is WGS 1980 UCS. The 5 years (2009-2013) accidents were geocoded by giving X and Y coordinates to each location. For every geocoded point, an Identity (ID) in a form of whole number is automatically created on QGIS. Every accident location was also attributed with detailed information such as type, landmark, month, date, time, vehicle type etc for further analysis if necessary.

4.2 Incorporation of accident severity in analysis

Studies were performed with and without considering severity of accident incident in analysis for determination of high clustering. For the analysis without taking severity in consideration, ID of each accident should be taken as "1". This will provide equal weight to each accident irrespective of its severity. Some researchers also suggested that, without weighted data, it is very hard to establish whether the observed clustering is true or not. To identify unsafe locations, crashes should be weighted according to severity.

It is a belief that more severe accidents should have greater weights. There is no universally defined optimum accident severity weighing system. The severities of accidents were considered in analysis as per Belgium system. This weighing system was adopted by Belgium government as a part of their official methodology for hot spot detection. As per this system, individual weights of 5, 3 and 1 is provided for fatal, grievous and for minor and PDO type accidents respectively. Severity index for each location can be calculated as per Equation 1:

$SI = 5\times F + 3\times G + M$ (1)

where:

F= total number of fatal accidents

G= total number of grievous accidents

M= total number of minor and property damage only accidents

4.3 Preparation of accident heat map

Heat map in QGIS 2.10 is a tool based on KDE is used to create density map of an input point vector layer. It was utilized to calculate density of accidents within a required search bandwidth. Search bandwidth or kernel bandwidth is distance around an accident point at which influence of a point is felt. Larger bandwidth results in larger and smoother region whereas smaller bandwidth specifies finer details. In this particular study, search bandwidth of 300 meters is considered for analysis. KDE divides the study area into pre-determined number of cells. It utilizes a kernel function to provide a smoothly tapered surface to each accident incident as shown in Figure 2 (Erdogan et al., 2008). The surface value decreases from the highest at incident point to zero when it gets to radial distance from incident point. The value of kernel function is assigned to each cell as individual cell values. The resultant density of every cell is computed by adding its individual cell values. To account accident severity, the weight as per Belgium system is assigned to each accident is represented as its Identification Number (ID). This facilitates counting of every accident according to its weight assigned. Kernel estimator can be defined as in Equation 2.

$f(\mathrm{x}) = \frac{1}{nh}\sum_{i=1}^{n} K(\frac{x-x_i}{h})$ (2)

where:
h is termed as search bandwidth, search radius or smoothing factor; K is kernel and *f* is estimator of probability density function.

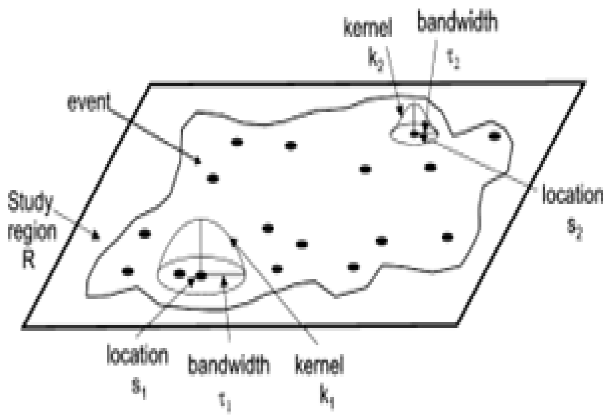

Figure 2. Principle of kernel density (Erdogan et al., 2008)

4.4 Categorization of hot spots

In case of analysis using KDE, since there is no index associated with statistical significance, hot spots were categorized using equal intervals. In this study, the categorization was done in five categories i.e. Very low, low, medium, high and very high priorities based on their associated accident densitie

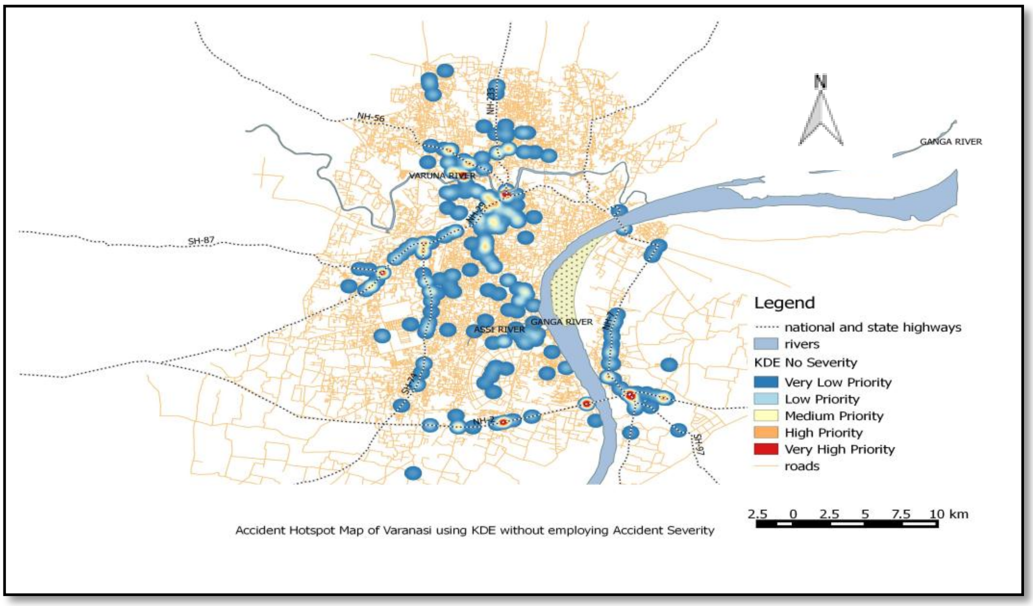

Figure 3. Accident hotspot map of Varanasi using KDE without accident severity

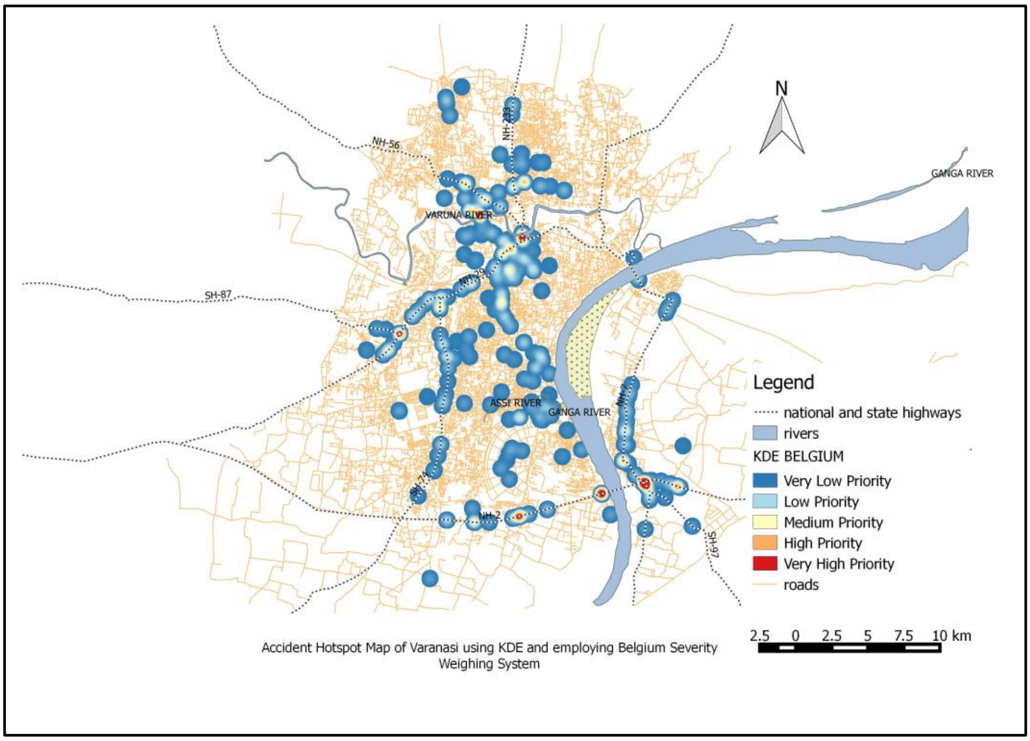

Figure 4. Accident hotspot map of Varanasi using KDE and employing Belgium severity weighing system

5. Results and discussions

No accidents were found in police records of old city area near Ganga's Ghats, particularly near the old Kashi Vishwanath temple. This was attributed to absence of high speed vehicles, high proportion of pedestrian traffic and presence of police check posts in the area. Police records revealed that the majority of accident registered in Varanasi were either fatal (45.52 %) or grievous (40.75%). Obviously there was negligence of people towards the filing of complaints for accidents of minor and property damage only type which accounted for 8.15% and 5.56% respectively of total accidents. The majority of hot spots are located on national and state highways; this is due large proportion of accident caused due to fast moving vehicles on the highways.

Table 2. Ranking of top identified hot spots

Severity weighing system / Hot Spots Identified	Rankings of major hot spots based on KDE	
	Based on Incident Points	Based on Belgium severity weighing system
Tengra Intersection	2	1
Chawkaghat	1	2
Harsevanand Intersection	3	3
Varuna Bridge	5	4
Toll Plaza Dafhi	4	5

The results of hot spot identification done with the help of KDE, with and without consideration of accident severity are shown in Figures 3 and 4. They divulge locations of high priority hot spots within the study area of Varanasi.Both analyses identified identical hot spots, although their relative rankings are different. These hot spot locations are specified in Table 2 along with their respective rankings. These rankings were made according to accident densities associated with each location obtained using KDE. After the analysis of ranking, the effect of severity of accidents over the results can be easily observed. Chawkaghat intersection has the highest number of accidents and is the most significant hot spot when analyzed without severity. But after considering severity according to Belgium system, Tengra intersection emerges as most significant hot spot. Similar situation can be observed in the case Toll plaza. This is due to larger percentage of fatal and grievous accidents in these locations which shows their impact over the result.

6. Conclusions

The present work has illustrated use of GIS for processing of accident data and performing spatial analysis using KDE for hot spot identification. This study is first of its kind in Indian traffic conditions which employed QGIS in analysis and taking severity of accidents in consideration. This method identified accurate and distinctive hot spots for given mixed traffic conditions.

Although the scope of the study is limited to identification of hot spots but it can also be employed for identification of cold spots. This analysis would have more accurate, easier, reliable and descriptive if accident records were more detailed and properly formatted. GPS should be provided to every police station to facilitate accurate recording of X and Y coordinates of each accident location. The accident severity weighing systems employed were adopted from countries having diverse traffic and demographic conditions than India. Future research aspires at development and employment of an optimum severity weighing for hot spot identification as per Indian traffic and demographic conditions.

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