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GIS Contribution for Identification of Accident Black Spots –A Review

Umesh M.Raut[1*], Rajesh K.Dhumal[2] , Ajay D.Nagne[3] ,K.V.Kale[4]

[1*,2,3,4]Department of CS & IT, Dr .BAMU University, India

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***Abstract*—** Traffic accidents contributing major death problems due to increase in number of vehicles. Globally, more than 1 million people die each year from traffic crashes and about 25–50 million are injured or permanently wounded. In India, thousands of people are dying due to road accidents. It is a necessary task to reduce accidents by performing analysis and taking pertinent countermeasures.So, identification of accident black spots is an important aspect in accident studies. Accident analysis aim at identification of high rate accidents spots, and safety areas. For proper road accident analysis, use of GIS is important.

Keywords —Accident black spots, Geographic Information System (GIS), Optimized Route, Risk factors

I. INTRODUCTION

Speedy and unplanned urbanization has resulted in a noteworthy revolution in the growth of vehicles world-wide. The mortality and morbidity owing to road traffic incidents over the past few decades. In India, more than 70,000 people get killed due to road accidents every year, and this needs to be recognized as a crucial public health issue [1]. The nonrandom distribution of accidents, both in spot and time, often raises questions about the location and the reasons for that location, so objective is to determine the factors of accidents at those spots and to take actions that will reduce crash frequency. Determining such factors like road user characteristics and roadway features is done through detail study involving a massive accident database [2].

It is observed that proper designing of traffic control devices can reduce occurrence of accidents. Designing these devices completely depend on analysis of accident data at that spot. Due to human carelessness and error the accurate, systematic and reliable data is not available. So accident records need to provide programs of vehicles database &use of engineering technique [3].

Road network provides connectivity between urban and rural areas. The continuous socioeconomic growth increases demand for transport service, so road safety is important for sustainable transportation development strategy. To meet requirement of transport, number of vehicles on road are rapidly increasing. As the increasing rate of vehicles creates burden on the existing system so proposing a proper transportation system is essential to reduce accident [4].

Police database and newspaper gives information about road traffic crashes. To take adequate and accurate data on road accident need road traffic crash surveillance system. It is needed to have a broad understanding of the various aspects of road traffic accident, and the recommendations are needed for strengthening Surveillance so it helps in reducing injuries and fatalities due to road crashes [5].

For reducing frequency of traffic accident the clear and complete accident database is required and depending on that accident prone zones can be identified and if in case accident is happening, we can find an optimized route between accident spot to the hospital to save the life of humans.

II. ROLE OF GIS IN ACCIDENT ANALYSIS

GIS permits users to display accident database information geographically. It can provide a common link between two or more databases. GIS as a management tool having ability to associate spatial objects (street names, route number, route type, etc.) with attribute information regarding roads (speed limits, traffic condition, accidents reasons, etc.) GIS integrates a number of transportation elements. GIS is a common and coordinated database system that will give all aspects of transportation management, such as bridges, road safety, pavement, congestion. GIS can give a traffic management program which improves the reporting and analysis of data through the creation of graphic displays and map [6].

The capability of GIS is providing a scheme for a traffic management system. The geographic referencing scheme provides making data more readily available. Also it provides spatial statistical and statistical analyzes of roadway characteristics such as road safety, bridges, congestion level and roadway patterns.GIS use in transportation include traffic management systems that work with speed limits, optimal vehicle routing .Automated Mapping Facilities Management (AM/FM) used for infrastructure management, drainage management, traffic modeling and accident analysis and displaying any form of tabular data that has a spatial component [7] .GIS has been proven to work well in

addressing transportation problems related to safety. GIS is a tool for analyzing, managing and processing location and related information about accidents. GIS analyzes traffic accidents towards improving the efficiency and effectiveness of traffic accident countermeasures. The Tool offers to update, maintain accident record database and suitable management strategies for traffic regulation. GIS gives advanced location-oriented and area-wide investigation. It provides accuracy in priorities accident location. The advantages of GIS interface that ability to locate locations accurately on a map and toposheet, database setup is economical and capability to find out the accident prone area easily [18].

III. BASIC TERMS AND DEFINATION

1) Data Collection

Collection of the accident database is the compilation of the accident forms in the respective Police station.

2) Computerization

The data input, analysis framework and processing are summarized and adopted as the standard analysis package for analysis accident black spot problems.

3) Prioritization

Prioritization of black spot carried out such as: Nodal Analysis, Number of lanes in each direction, Kilometer-Post Analysis, Ranking by Accident Maps, Ranking by Accident point, Number of vehicles per day, Width of the road, Drainage facilities provided, Surface condition of the pavement[9].

4) Diagnosis and Countermeasure

Diagnosis and Countermeasure are done with site study by capturing the near misses, vehicles, speeds and pedestrian flows and their maneuvers.

5) Geographic Information system

A geographic information system (GIS) is a computer system for capturing, querying, analyzing, storing, and displaying geographic data, GIS is a powerful tool for managing large amounts of heterogeneous data. A GIS can be effectively used to prioritize black spots on the roads.

IV. RELATED WORK

GIS has been widely used to geo-code accident locations, developing pin maps of crashes and database queries as performed by Levine *et al.*(1995); Affum and Taylor (1995); Austin *et al.* (1997); Kim and Levine (1996); Miller (1999). However, some researchers Levine *et al.*(1995); Pulugurtha *et al.*(2007) incorporated some of the powerful analytical tools available in GIS software such as buffer, nearest neighbor method, simple density and kernel density estimation method of crash cluster detection to show the spatial distribution of crashes at the road network level.

Prasannakumar *et al.* (2011) evaluated road accident hot spots in a South Indian city using hotspot analysis (Getis-OrdGi* statistics) in GIS. Anderson (2006) compared spatial methods of GIS for measuring road accident hotspots. Jang *et al.* (2013) used spatial Kernel density estimation method in GIS to measure the concentrated density of pedestrian crashes.

Srinivasan et al. (1987) developed a scientific method for the identification and improvement of accident prone locations NH by identifying black spot. Three methods were used, i.e. i) Quantum of accident method ii) Accident prone index (API) method and iii) WSI method. The study concluded that the method based on WSI was found to be most suitable in identifying black spots [10].

Martin (1993) studied that incorporating GIS in a pavement management program improves the analysis of data through the creation of maps and graphic displays.

Point pattern analyses have been widely examined by scientists and a variety of methods were developed for detecting hotspots. The point pattern methods can be classified broadly into two categories i) methods which examine first-order effects, which measure the variation in the mean value of the process like kernel density estimation, quadrant count analysis etc, and ii) methods which examine second-order effects which measure the spatial dependency of points for spatial patterns like Moran‘s I, Getis-Ord G statistic[25].

A. Faghri and N.Raman (1995) developed a GIS-based traffic accident information system for Kent County. The system included knowledge about the occurrence of Road crashes, such as frequency of incidents, vehicle information, accident type, traffic condition at any given location on a roadway.

Affum and Taylor (1996) developed a safety Evaluation Method for a Local Area Traffic Management (SELATM), which is analyzed accident patterns and the evaluation of the safety by GIS programs. Meyer and Sarasua (1996) enhanced coordinated database system that serve all aspects of transportation management system such as congestion level, pavement, bridges, safety, inter-modal activities.

Binu B Pillai and Dr. Kurian Joseph (2011), in their study of Accidents in Kerala, gives the main causes of road accidents Over speeding and unhealthy competition of vehicles, poor surface conditions, lack of pedestrian crossing facilities, lack of discipline by road users, absence of proper bus bay and shelter, visual acuity of drivers, and protruded lamp post, unscientific check barriers, speed breakers, road cutting, dumping of materials on road, haphazard parking on road side etc [11].

Nagarajan and Cefil (2012) used RS & GIS for identification of black spots and accident analysis for NH-45 starting from Tambaram to Chengalpet. Black spot identified using high resolution satellite map (IKONS) based on the non-spatial data collected from police the department and the field survey conducted in terms of traffic volume and vehicle spot speed by using

GIS[12].
Ziari and Khabiri (2005) presented the development and findings of crash data from police reports (Iran) and how they are being used in GIS. The authors developed a tool that generates a contour map identifying areas of high crash occurrence determined by crash density and clusters of crashes involving pedestrians and bicyclists

From related review, we can conclude that KDE (Kernel Density Estimation) is the most used method for finding the Blackspot and is effectively visualized and helps analyzing the Accident analysis across Geography. Getis-Ord Gi* and IDW are statistical methods for providing the statistical analysis and bar graphs for displaying the statistics of Accident.

V. METHODOLOGY

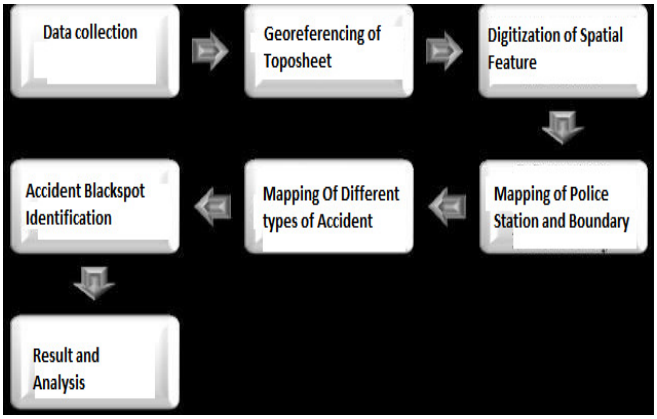

Fig1. Methodology

1) Data Collection
1. Police stations limit map obtained from the office of super indented of police.
2. Survey of India topological map at a scale 1:1, 50,000 [12]

2) Collection of Ground Control Points
The GCPs are collected with the help of the GPS.

3) Map Scanning
The Survey of India topographical map at a scale of 1:50000 were scanned and taken as raster input [8].

4) Georeferencing
The Scanned map does not contain information as to where the area represented on the map fits on the surface of the earth. To create the relationship between an image coordinate system and a map (x, y) coordinates system need to georeference the raster data [6][17].

5) Digitizing
Digitizing is the process of converting analog information into a digital representation. The road network of the study area was digitized as line features and accident locations are digitized as point features. The spatial data prepared in feature class and personal geodatabase[1][18].

VI. DIFFERENT TECHNIQUES FOR DETECTION OF BLACKSPOT

The black Spot methods in Accident analysis can be broadly classified into three categories, namely Spatial Analysis Methods, Interpolation Methods and Mapping Cluster or Spatial Interpolation Methods. Different Methods used for Black spot detection are as follows: [24]

1) Spatial Analysis Methods:
   a) Kernel Density Estimation

2) Interpolation Methods:
   a) Inverse distance weighted (IDW) interpolation
   b) Kriging
   c) Spline
   d) Natural Neighbor

3) Mapping Cluster
   a) Cluster and Outlier Analysis
   b) Getis-Ord Gi*

6.1) Spatial Analysis Method
Spatial Analysis is the process of checking the locations, attributes, and connection of features in spatial data among overlay and other analytical techniques, which is used for acquiring knowledge that can be used in different aspect. Spatial analysis creates or extracts different new information from spatial data [20]. Different techniques under this category are Kernel Density Estimation (KDE) [21] [22], Point Density [22], Line Density.

6.2) Interpolation Methods
Interpolation is the process of using points with better-known values to propose values at alternate unknown points. It is often used for unknown values in any geographic point data, which can be used in the field of rainfall, noise levels, chemical concentrations, elevation, or other spatially based phenomena. It is the approximate judgment of surface values at the points which are un-sampled based on the surface values of surrounding points which are known. Interpolation is usually used as a raster operation, but using a TIN (Triangulated Irregular Networks) surface model it can be used as vector operation [20] [23]. There are several well-known interpolation techniques such as Inverse Distance Weighted (IDW), Kriging, Spline, and Natural Neighbor.

6.3) Mapping Cluster
Mapping Cluster also known as Spatial Autocorrelation is

an amount of the degree to which a set of spatial features and the data values associated with it. It can be clustered together in Space (positive spatial autocorrelation) or Scatter Widely (negative spatial autocorrelation) [20]. Different methods under Mapping Cluster or Spatial Autocorrelation is Anselin Local Moran's I [19] [21] and Getis-Ord Gi*.

Sr. No.	Technique	Formula	Purpose
1.	Kernel Density Estimation	$\hat{f}(x) = \frac{3}{nh^2\pi}\sum_{i=1}^{n}\left\{1-\frac{1}{h^2}[(x-x_i)^2+(y-y_i)^2]\right\}^2$	For smoothing effect within particular radius and cell size
2.	Point Density	$\hat{f}(x) = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{h}w\left(\frac{x-X_i}{h}\right)$	Calculates magnitude per unit area using neighborhood operation for given cell size
3.	Line Density	$\hat{f}(x) = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{h}w\left(\frac{x-X_i}{h}\right)$	Calculates magnitude per unit area for radius of the cell size
4.	IDW Interpolation	$z_0 = \frac{\sum_{i=1}^{s} z_i \frac{1}{d_i^k}}{\sum_{i=1}^{s}\frac{1}{d_i^k}}$	For classifying within max and min value
5.	Kriging	$\hat{f}(x^*) = \sum_{i=1}^{n}\lambda_i(x^*)f(x_i)$	For assuming spatial variation of attribute
6.	Spline	$Q(x,y) = \sum A_i d_i^2 \log d_i + a + bx + cy$	For smoothing effect
7.	Morans I	$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{s^2\sum_{i=1}^{n}\sum_{j=1}^{m} w_{ij}}$	For detecting the presence of the clustering of similar values
8.	Getis-Ord Gi*	$G(d) = \frac{\sum\sum w_{ij}(d)x_i x_j}{\sum\sum x_i x_j}, i \neq j$	For separating the clusters of high and low values

Table 1. Different Techniques for Accident analysis

VII. BLACK SPOT IDENTIFICATION

Black spots identification required to determine the highest rate accident locations and the cause of these accidents. It issued to develop a model to prioritize hazardous locations by comparison of real time data with records available in the police station.

A. BLACK SPOT

Black spot is used to tackle the problem of location and length of problematic road taking into account the contiguity structure of the basic individual spatial units. A black zone is a set of contiguous spatial units taken together and characterized by a high number of accidents [15].

The distribution of traffic accidents in the road space is decentralized and intensive. Decentralized distribution of accidents is concerned with the unsafe behavior of the drivers of different vehicles. But intensive distribution of accidents is more related to the road level, accident category, conditions of traffic facilities and the traffic environment [14].

B. BLACK SPOT SAFETY WORK

Black spot safety work can be described for improving road safety through analyzing of the geometrical, statistical and environmental characteristics of the accident prone sites in the existing road network by focusing on the study of intersections and road sections with a large number of accidents.

Vistisen (2002) explains that this work may be divided into three phases.

1. Targeting hotspots on the road network.
2. Prioritizing the hot spots to treat with safety, improving measures.
3. Before and after effects of treatment.

Here are four basic approaches to reducing road crashes by applying engineering treatments or countermeasures.

1. Black spots-treating as a problematic site.
2. Area-wide action-applying several treatments over a wide area.
3. Route action-applying known remedies on a route with an abnormally high crash rate.
4. Applying a known remedy to locations with common crash problems [13].

C. PROFILING ACCIDENT BLACK SPOTS

The Road accidents are related with a number of features, which may be considered in analyzing the occurrences of accident on various locations.

1) The severity of the accident, e.g. fatal, nonfatal, serious, injury.

2) Factors of accident, e.g. traffic volume, weather condition, obstacles on road, school zones, roadwork, and area types.

3) The accident category, e.g. left-angle, rear-end, head-on, left-turn, right turn and various run-off-road collisions [13].

D. PROFILING RISK FACTORS

The Risk factors explain accident involvement and severity. Risk factors play following two roles in accident model.

1. Improve overall model and reduce the amount of unexplained variation. Important is that this model does not include any unnecessary variables.
2. Gives effectiveness of safety measures.

The following risk factors have been elaborately adopted in the literature for the explaining accident scenario. A more detailed description of these risk factors can be found as,

- Course of the accident: vehicle type, driver action, accident circumstances.
- Traffic conditions: traffic volume, traffic curve, speed limits.
- Environmental conditions: type of area, weather condition, road surface condition, road geometry, road curves, light condition.
- Human conditions: physical condition, Psychological condition, vision problems, lack of knowledge of rules of the road, seating position, driver condition (alcohol drink, fatigue, illness), seat belt use.
- Vehicle conditions: vehicle mass, vehicle size, vehicle type (light or heavy vehicles)[13].

An association algorithm is used to identify accident factors of prone accident locations. Furthermore, these patterns are analyzed and compared with frequently occurring accident characteristics at low frequency accident locations. This approach resulted in the identification of relevant variables so better understanding of accident circumstances and descriptive accident patterns results in profiling black zones [16].

VIII. OPTIMIZED ROUTE FROM AN ACCIDENT SPOT TO HOSPITAL

Network analysis in GIS provides good decision support to find out shortest or optimal route, finding the nearest facility and determines the service area. The optimal path is an important function in Network Analysis available in GIS. The accident spot is the origin and the nearest hospital is the destination. Correct landmark identification such as building, towers, road junctions, area name, etc. have to be identified and locating along each road so easy to reach the accident spot. The place of the accident must be related to the nearest landmark in the road network. GIS able to put graphically highlighting the route that to be traversed indicating the direction of accident spot to the hospital location. In order to highlight route we can give description such as the starting point of the road, the roads to be traversed, turns to left or right and distance of travel along that road [1].

CONCLUSION

GIS is a good tool for analyzing the multifaceted nature of accidents. The Geographic Information System is an effective tool to display different type of spatial accident distribution on the digital road network.

Accident Mapping and Analysis can effectively provide the understanding of where and why accident activity takes place Different methods are classified based on the input feature. and the input parameters. The methods can also be used as per the requirement of the problem. KDE and Thin-plate Spline provide the smoothing surface, while IDW can be used when we require having a specific range of maximum and minimum values. Moran's I can be used for both point and polygon features and can detect the presence of the clustering of similar values, whereas Getis-Ord Gi* can separate the clusters of high and low values and can be applied for point and polygon features. The Moran's I and Gi* both also calculate the value for the analysis purpose.

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