A Framework for Identification of Vehicular Traffic Accidents Hotspots in Complex Networks

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***Abstract* - In the recent times, vehicular traffic accidents are considered to be one of the primary societal and economical related issues concerned to traffic accidents in complex networks. In view of this aspect, managing vehicular traffic accidents in complex networks requires a clear understanding of traffic flow patterns, i.e., acumen into what causes accidents, what controls the time and location of vehicular accidents, how does the vehicular traffic accidents propagate through the complex network, etc., are necessary. For this reason, during the past twenty-four years, a wide range of identifying vehicular traffic accident hot spots theories, methods and models have been developed to answer these research questions. This paper presents an overview of some twenty-four years of identifying the vehicular traffic accidents hot spots in complex road networks. A rich selection of approaches developed so far for identification of vehicular traffic accidents hotspots in complex networks will be examined and evaluated. The considered techniques are classified based on the level-of-detail like input features and parameters with which the identification of vehicular traffic accidents hotspots are described. For each of the techniques, issues like accuracy, applicability, generalizability and model calibration and validation are explained.**

***Index Terms* - Vehicular Traffic Accidents, Complex Road Networks, Traffic Flow Patterns, Hotspots, Techniques.**

INTRODUCTION

Accidents have been a major social problem in the developed countries of the world for over fifty years. It was detected that since 2001 there was a growth of 202 per cent of two-wheeler and 286 per cent of four-wheeler vehicles with no road development. Approximately 1.35 million people die each year as a result of road traffic crashes as per the report submitted by World Health Organization (WHO). The 2030 Schedule for Workable Progress has set an ambitious goal of halving the global number of fatalities and injuries from road traffic crashes by 2020. More than half of all road traffic fatalities are among susceptible road users like pedestrians, cyclists, and riders. It is only in the past decade that developing countries like India have begun to experience a significant increase in the number of road accidents taking place and have found it is necessary to institute road safety programs. It is strongly felt that most of the road traffic accidents, being a multi-factor incident, are not only due to drivers fault on account of driver's negligence or ignorance of traffic rules and regulations, but also due to many other related parameters such as changes in road geometrics, flow characteristics, road user's behaviour, environmental conditions, visibility and absence of traffic guidance, control and management devices. The Geographical Information System (GIS) emphasizes on providing services in location-scale, and it merely enables the operators to use spatial information and descriptive data to make plans, tables and diagrams. This system accurately provides search tools; data analysis and results display. GIS is a organization and decision support system that contains graphic data and site maps which is productive for traffic accident information organization. In the management of road safety, road traffic accident hot spot is a place where accidents occur frequently at that location. It may have occurred due to various parameters like poor road geometrics, environmental factors, driver's characteristics, etc. Since few decades treatment of accident black spots was a spine of road safety management. In the current scenario road safety is a major concern. Road safety measures can be adopted by implementing various steps.

Overview on Vehicular Traffic Accident Hot Spot Techniques:
In order to analyse vehicular traffic accident hotspots, various methods have been discussed in this paper

such as Kernel Density Estimation (KDE), Nearest Neighbourhood Hierarchy (NNH), Inverse distance weighted (IDW), KRIGING. Kim and Levine (1996) described the traffic safety GIS prototype, which performed a spatial analysis of traffic accidents that are developed for Honolulu, Hawaii. Many types of spatial analysis methods based on point, segments and zones analyses had been developed. Affum and Taylor (1998) introduced a method for a traffic management, which is based on GIS package for studying accident patterns over time. The different methods / techniques are shown in Table 1.

S. No	Technique	Formula	Purpose
1.	KDE	f(x) = $\frac{3}{nh^2\pi}\sum_{i=1}^{n}\{1-\frac{1}{h^2}[(x-x_i)^2+(y-y_i)^2]\}^2$	For smoothing effect within particular radius and cell size
2.	Point Density	f(x) = $\frac{1}{n}\sum_{i=1}^{n}\frac{1}{h}w(\frac{x-x_i}{h})$	Calculates magnitude per unit area using Neighborhood operation for given cell size
3.	Line Density	f(x) = $\frac{1}{n}\sum_{i=1}^{n}\frac{1}{h}w(\frac{x-x_i}{h})$	Calculates magnitude per unit area for radius of the cell size
4.	IDW	$z=\frac{\sum_{i=1}^{s} z_i \frac{1}{d_i^k}}{\sum_{i=1}^{s}\frac{1}{d_i^k}}$	For classifying within max and min value
5.	Kriging	$f(x)=\sum_{i=1}^{n}\surd_i(x^*)f(x_i)$	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 = $\frac{\sum_{i=1}^{n}\sum_{i=1}^{n} w_{ij}(x_i-x)(x_j-x)}{s^2\sum_{i=1}^{n}\sum_{i=1}^{n} w_{ij}}$	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.

Kernel Density Estimation:

Kernel density estimation is one of the significant spatial analysis tools in commercially available GIS software package. K divides the entire study area into a pre-determined number of cells. It uses a quadratic kernel function to fit a smoothly elongated surface to each accident location. The surface value reduces from the highest at incident location point to zero when it reaches radial distance from incident location point. The value of kernel function is assigned to every cell as individual cell values. The resultant density of every cell is computed by adding its i cell values individually. To account the road accident severity, the weight of each accident is represented as its Identification Number (ID). This facilitates the counting of each accident according to its weight assigned. In case of no injury or severity, according to incident points, the population field is selected as "None". Kernel function can be defined as stated in equation 1.

$$f(x) = \frac{3}{nh^2\pi}\sum_{i=1}^{n}\{1-\frac{1}{h^2}[(x-x_i)^2+(y-y_i)^2]\}^2 \quad \text{Equation (1)}$$

where: h is termed as bandwidth, K is kernel, f is estimator of probability density function, π is a constant, and are the deviation in x-, y-coordinates between point and known point that is within the bandwidth, n is the number of known points. The kernel estimator depends upon choice of bandwidth (h), hence suitable bandwidth should be determined according to purpose of study. Density values in the raster are predicted values rather than probabilities. It generally gives a smoother surface than the normal estimation method.

K- Means Clustering:

These hotspots are then classified using the clustering process and are organised into classes (or clusters) based on similar attributes. These clusters are then arranged into groups, based on the similarity of the clusters. This hierarchical process allows spatial classification based on the similarity of either characteristic of the accidents within the hotspots or the environmental factors. When determining the database used to build the classification, it is essential to assess the type of data which would be collected and would have the potential of having an impact on accident density.

Point Density Method:

The Point Density tool estimates the density of point features around each output raster cell. Neighborhood can be shown around each raster cell centre, and the number of points which comes within it, is totalled, and divided by the area of the Neighborhood. If other than NONE is used in Population field setting, the item's value determines the number of times to count the point. For instance, an item with a value of 3 would cause the point to be counted as three points. The values can be floating-point or integer. If a unit is selected with in the area, then the estimated density for the cell is multiplied by the suitable factor before it is written to the output raster. Although more points will fall inside the broader Neighborhood, this number will be divided by a more extensive area when calculating density. It can be evaluated using the equation as given below:

$f(x) = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{h}w(\frac{x-x_i}{h})$..................Equation (2)

The main consequence of a larger radius is that density is calculated considering additional number of points, which can be farther away from the raster cell. This results in a more generalised output raster as stated in equation 2. Where: h is termed as bandwidth, w is weight, n is number of known points.

Line Density Method:

In this method magnitude/unit area from polyline features that lies within a radius around each cell are evaluated. The portion of a line within the Neighborhood is considered only when calculating the density. If no lines lie near the Neighborhood at a specific cell, that cell is assigned No Data. Larger values of the radius parameter produce a more comprehensive density raster as stated in equation 3. Lesser values obtained shows a raster which have more detail. The output raster values on the will always be floating point.

$f(x) = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{h}w\left(\frac{x-x_i}{h}\right)$…………..…Equation (3)

Where: h is termed as bandwidth, w is weight, n is number of known points.

Interpolation Method:

It is the process in which points with known values are used to estimate values at other unknown points. Interpolation can estimate the accident locations without recorded data by using known accident points at nearby surrounding areas. This type of interpolation is also called as statistical surface. It is the approximate judgment of surface values at the points which are unsampled 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 a vector operation. High cost and limited resources lead to limited number of selected point locations within that area. In GIS, spatial interpolation of these points can be useful to create a raster surface with estimates made for all raster cells. The output of the interpolation analysis can be used for analyses and modelling of entire area. There are many techniques within the interpolation method which can be used such as Inverse Distance Weighted (IDW), Kriging, Spline, and Natural Neighbor.

$z = \frac{\sum_{i=1}^{s} z_i \frac{1}{d_i^k}}{\sum_{i=1}^{s} \frac{1}{d_i^k}}$ ……………………….... Equation (4)

Where z_o is the estimated value at point 0, $z_i$is the value at known point i, d_i is the distance between point i and point 0, s is the number of known points used in estimation, and k is the specified power as stated in equation 4. It is also noticed that this method has some drawbacks like quality of the interpolation result can decrease if the distribution of sample data points is uneven, only higher and lower values in that surface can occur at sample data points.

Kriging Method:

Kriging involves an interactive investigation of the spatial behaviour unlike interpolation methods that includes phenomenon characterized by the values, before selecting the best method of estimation for generating the output surface. The distance or direction between points which reflects a spatial correlation were used to describe the difference in the surface. It is a tool which performs mathematical function to a specified number of points, or all points within a specified radius, to evaluate the output value for each location. This process includes multiple steps, statistical analysis of the data, modelling, creating the surface, and exploring a variance surface. Kriging is most appropriate when you know there is a spatially correlated distance or directional bias in the data can be simply computed from the observed values, their variance, and the kernel matrix derived from the prior. The formula is given as stated in equation 5.

$f(x) = \sum_{i=1}^{n}\sqrt{\lambda_i(x^*)}f(x_i)$……………Equation (5)

In Kriging, the weight λ_i, depends on a fitted model to the measured points, distance and the spatial relationships among the calculated values around the locations.

Spline Method:

This converts the raster data that allows for local change, gives similar results as a increasing order polynomial transformation and is also suitable for scanned imagery. It requires only one GCP. This method is generally preferred over other methods because the interpolation error can be made small even when using lower degree polynomials. This method avoids the problem of Runge's phenomenon. The approximation of Thin-plate Splines is of the form as stated in equation 6.

Q (x, y) = $\sum A_i d_i^2 log d_i + a + bx + cy$…Equation (6)

where x and y are the x-coordinate and y-coordinate of the point to be interpolated, di2 = (x-xi2)2+ (y-yi2)2and xi and yi are the x, y-coordinates of control point.

Natural Neighborhood Method:

This method is developed by Robin Sibson. This method shows a discrete set of spatial points. Unlike other methods of interpolation this is simple method of multivariate interpolation in one or more dimensions. This method selects value of algorithm of the nearest point and does not consider the values of Neighboring points at all. To select colour values for a textured surface an algorithm is used in real-time 3D rendering.

Mapping Cluster:

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 Widely Scattered or Spaced together. Different methods under Mapping Cluster or Spatial Autocorrelation are Anselin Local Moran's I and Getis-Ord Gi*.

Moran's I Method:

Moran's I is one of the oldest global spatial autocorrelation indicators which evaluates whether the spatial pattern is clustered, random or dispersed. It works on both feature locations and features values simultaneously as stated in equation 7.

$$I = \frac{\sum_{i=1}^{n}\sum_{i=1}^{n} w_{ij}(x_i - x)(x_j - x)}{s^2 \sum_{i=1}^{n}\sum_{i=1}^{n} w_{ij}} \text{………… Equation (7)}$$

Where x_i is the value at point is the value at point i, x_j is the value at point j, w_{ij} is a coefficient, n is the number of points, and s^2 is the variance of x values with a mean of $\bar{x}$. The coefficient w_{ij} is defined as the inverse of the distance (d) between points i and j or 1/d_{ij}.

Getis-Ord GI* Method:

This method involves identification of desired hot spots, collection of events and mapping of clustering using spatial data base function as stated in the equation 8.

$$G(d) = \frac{\sum\sum w_{ij}(d) x_i x_j}{\sum\sum x_i x_j}, i \neq j \text{……...……Equation (8)}$$

Where x_i is the value at location i, x_j is the value at location j, and if j is within d of I, and w_{ij} (d) is the spatial weight. The weight can be calculated based upon some weighted distance. There are distinctions between these methods; a method uses the actual location of an accident (point in GIS) and one that uses the number or density of accidents for a small geographical area such as grid cell or zone. Getis-Ord Gi* is a tool used for performing Hot Spot Analysis. The resultant z-scores and p-values tell you where spatial features lie with either high or low values cluster. This application works by looking at each feature within the context of Neighboring features. A feature with a high value is exciting but may not be a significant hot spot as shown in Figure 1.

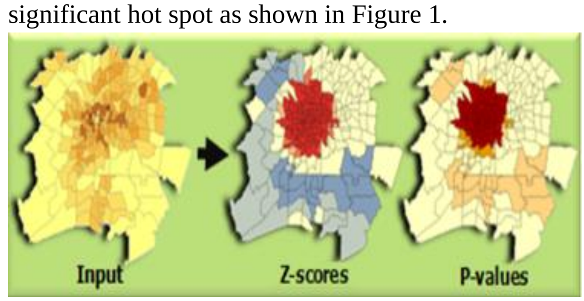

*Figure 1: Output of Getis-Ord GI**

A feature will have a high value and are surrounded by other features with high values. The sum of feature and its neighbours are compared correspondingly to the sum of all features; when the local sum is very different from the expected local sum, and when that difference is too high to be the result of random chance, statistically significant z-score results. After performing FDR correction is applied and eventually statistical significance is adjusted to account for multiple testing and spatial dependency. This method also helps in identifying statistically significant spatial clusters of high values called as hot spots and low values called as cold spots. For each feature in the Input Feature Class it creates an Output Feature Class with a z-score, p-value, and confidence level bin field known as Gi Bin.The Gi-Bin field identifies statistically noteworthy hot and cold spots irrespective of whether or not the FDR correction is applied. A higher z-score and lower p-value for a feature indicate a spatial clustering of high values. A low negative z-score and small p-value indicate a spatial clustering of lower values. The higher the z-score, clustering is found to be stronger. A z-score near zero shows no apparent spatial clustering. The z-score is based on the randomization null hypothesis calculation. Getis-Ord Gi* is used to add statistical significance to hotspot analysis and for predicting where accidents occurs.

Earlier Studies:

Anderson et al. [2006] presented a methodology based on Kernel Density Estimation using Geographical Information Systems to study the spatial patterns of injury related road accidents. Study area was London, UK and clustering methodology was used including environmental data. Results created a classification of road accident hotspots and environmental data was then added to the hotspot cells and using K-means clustering, an outcome of similar hotspots was interpreted. According to the cluster's robustness and potential uses in road safety were assessed and discussed.

Chand M et al. [2007] has researched on accident risk index and accident severity index for different states in India. An index was formed by combining all indices using set of accident indicators. Values of these two indices have been computed and compared across the states of India.

Kowtanapanich [2007] analyzed accident statistical methods that were used to identify hazardous road locations on the highways in three different countries Thailand, India and Turkey. Statistical methods include frequency of accident, accident rate, severity index, quality control and combined method.

Xie and Yan [2008] used and compared planar and network KDE in terms of pixel size (linear pixel, same as raster cell but it is in a network), bandwidth and density visualization while identifying accident hot spots. However, results shows that KDE network is more appropriate than planar KDE in terms of estimating density estimation for road traffic accidents as planar KDE estimates density beyond accident data context.

Kim et al. [2009] in his study he has proposed Models which can predict road and traffic circumstances, environmental conditions, and driver behaviors during motor vehicle accidents. Accident prediction models attempt to identify potentially dangerous locations of high frequency motor vehicle accidents on roads. Qualitative measures for road user risk are described as a function of road user characteristics, traffic control devices, and road geometric parameters.

Deepthi et al. [2010] has studied “Density” function technique which is available in the Arc GIS software package to identify the accident-prone areas in the selected study area. Simple and Kernel densities both were applied in identifying the accident patterns. The road geometric parameters were considered in the accident-prone areas to find out the reasons for the road traffic accident. Suggestions were provided based on the result, to reduce the road accidents in the future.

Hadayeghi et al. [2010] developed Accident models can illustrate the relationship between accident frequency and a variety of additional variables such as traffic volume, roadway characteristics, or socioeconomic and demographic features.

Wang C [2010] made an attempt to establish the relationship between traffic congestion and road accidents by using an econometric and GIS approach. The data used was between 2003 to 2007 data from the M25 motorway and its adjacent roads. UK adopt speed limit in roadway for reducing traffic congestion and accidents this also prospers a new map- matching technique for road segments and accident frequently then identify the hazardous accident hotspots for road safety and control measures.

Dai et al. [2010] has researched on Geographical Information System (GIS) which is one of the tools used to analyze crashes for which crash information has to be converted meaningfully for the spatial mapping. Information regarding the number of crashes, time of crashes and locations weretaken. By using this information, crash data was analyzed spatially using GIS, the high crash risk areas (hotspots) and the times that most crashes occurred were found by this method.

Steen Berghen et al. [2010] has researched on Geographical Information System (GIS) which is one of the tools used to analyze crashes for which crash information has to be converted meaningfully for the spatial mapping. For such a conversion, information regarding the number of crashes, time of crashes and locations are needed. By using this information, crash data can be analyzed spatially using GIS.

Prasanna Kumar et al. [2011] has researched on road accident hot spots in a South Indian city. Road traffic accidents and hotspots spatial densities was carried out using Moran's I method of spatial autocorrelation, Getis-Ord Gi statistics and point Kernel density functions. The traffic accidents shows a clustered nature while the comparing with Spatio-temporal break ups and shows random distribution in certain modules. The results of hotspot analysis can be estimated using Kernel density which delineates the road stretches as well as isolated zones where the hotspots are concentrated.

Plug et al. [2011] has researched on Geographical Information System (GIS) is one of the tools used to analyze crashes for which crash information has to be converted meaningfully for the spatial mapping. These methods can provide us with the high crash risk areas (hotspots) and the times that most crashes occurred. To identify clusters of various road traffic incidents, a number of studies successfully implemented GIS techniques.

Rodzi et al. [2011] has researched on how to reduce the amount of road accident specially in Malaysia since it could be a big threat to this country. Due to lack of a complete road traffic accidents recording and analysis system, can be effective in these kinds of difficulties. By making use of IRAS system, the traffic police would be able to control and manage whole traffic accidents as a real-time monitoring system. For road traffic analysis and management, GIS-based solution can be used for a comprehensive intelligent.

Chih Tang et al. [2011] proposed a Fuzzy K-Means Clustering Algorithm by extending the K-Means Clustering Algorithm with Fuzzy Rules. In their model, the authors used center displacement for making cluster decisions. However, the distance-based clustering methods perform better than clustering using center displacement. Therefore, it is necessary to propose a Fuzzy Clustering Algorithm based on distance.

Parasanna Kumar et al. [2011] has researched on clustering analysis with respect to accident type and occurrence time, using Moran's I Index to perform spatial autocorrelation. Clustering analysis was performed using KDE and Getis-Ord GI* statistics. Road traffic accident hot and cold spots were determined by using clustering analysis method. From this study, high speed was found as an indicator factor of single vehicle crashes (run-off crash).

Eckley and Curtin [2012] has researched on clustering of traffic accidents on a road network using Sanet software and studied road traffic accident clusters within the boundary of selected study area. Traffic accident were determined for different seasons, days and time periods. KDE, K-means clustering and NNH clustering are used to show road traffic accident hot spots. Zones with hotspots were identified according to seasons, day and time periods in terms of incidence. Due to the lack of data, only South Anatolian Motorway was analyzed in detail numerically. In the study area, most accident types identified were rear-end, colliding with stationary object and run-off.

Nagarajan et al. [2012] has researched on use of remote sensing (RS) & GIS for identification of black spots and accident analysis for a particular stretch of NH - 45 starting from Tambaram to Chengalpet. There are eleven traffic accident locations were identified in this study using using Arc GIS software a high-resolution satellite map was developed based on the data collected from traffic police department, field survey conducted for traffic volume, vehicle spot speed, plotting of the study area.

Rakesh Kumar Singh et al. [2012] has developed accident prediction of model and studied the effect of traffic volume on road accident rate and to develop an accident prediction model based on AADT and road condition. NH-77 was selected as study area which passes through cities of Hajipur and Muzaffarpur and data was collected using statistical methods for prediction of road traffic accidents. The estimated values from the accident prediction model remained tested by Chi square test.

Apparao et al. [2013] has researched on accident analysis statistical methods (accident frequency, accident rate, severity index, quality control and combined method) were used to identify hazardous road locations on the highways in Thailand.

Liyamol et al. [2013] has researched on use GIS for identification of accident black spots. fAccident can occur at any instance of time with multi factors depending on the situation including parameters like driver characteristics, road user characteristics and environmental characteristics. The study carried out by the Kerala Road Safety Authority found that, the maximum numbers of accident-prone stretches or the black spots are in the districts of Alappuzha and Ernakulam.

Blazquez CA et al. [2013] has researched on Moran's I Index test which is used to identify a positive spatial autocorrelation on accident contributing factors, times of day, straight road sections and intersections.

Alkesh Kumar et al. [2014] conducted accident analysis and identification of black spot its objective was analysis of road traffic accident data and identify black spot. Finally, they concluded the following estimations from accident analysis: Estimates maximum number of accidents occurs due to head collision there was no facility median on center of lane. In this study they concluded that the maximum number of road accidents are occurring in month of March and April. Majority of accidents are occurring in summer season.

Patel Savan Kumar et al. [2014] carried out analysis of road accident its aim was to analyze the traffic accidents occurring in a selected stretch because of vast number of road user incidences of clients, specially four wheelers were a concern. Road traffic accident data was collected from the department of police of the study area. The collected data are analyzed according to the Parameters such as yearly variation of accident, classified according to month, according day, according collision type, according accident spot, etc. and concludes their study by proposing safety measures.

Gupta et al. [2014] made an attempt to study accident blackspot validation using GIS in Chandigarh. The promising idea of this research is that the utilization of GIS tools for the study. The use of ArcGIS tools for accident mapping facilitated the easy recognition of accident spots. The spatial autocorrelation tools aided to derive more accurate results in identifying the significant hot spots termed as black spots which are the major risk zones that seeks immediate attention on mitigation measures to prevent frequent accidents.

Saleh et al. [2014] has done a Geographical Information System based researched to identify road traffic accident black spots in Federal capital territory of Nigeria. A complete database of road traffic and accident data and other relevant information was developed, which will be needful and useful for Nigeria Police, Federal Road Safety Commission and Road Traffic Services and other stakeholders.

Vyas, P.R. et al. [2014] made an effort on State Highway, Karnataka to identify the significant hotspots i.e., where occurs frequent accidents which is also termed as black spots

Kumar et al. [2014] has researched on a case study on Vishakhapatnam city, his work was intended to identify accident spots in the study area by using collected police record data and optimum route was identified between accidents spot to hospitals using Arc GIS-10.2 analysis tool.

Yakar [2015] carried out research on road traffic accidents and studied about the parameters related to the road and environment and that future traffic accidents will occur under the same conditions as past traffic accidents. This study investigates the use of frequency ratio method in the determination of accident-prone road stretch. In this research developed a relationship between accident number and environmental properties of road sections and also identified accident-prone road sections.

Sorate et al. [2015] has studied on National Highway 4 (from Katraj Tunnel to Chandni Chowk) for identification of black spots on the selected stretch as a potential blackspot. This study included several analytical methods to identify the blackspots such as ranking method and severity index, density method, weighted severity index to process the primary and secondary data. A GIS based Weighted Severity Index method was used in this study to identify such blackspots.

Subba Reddy et al. [2015] have studied the accident black spots using mixed traffic sheets in developed cities. The authors also suggested suitable remedial measures to develop an accident prediction model which can reduce the life losses and injuries in the study area.

Bobade et al. [2015] attempted a study on black spots identification on National Highways and Expressways and stated that around 13 people die per day due to road traffic accidents. In this study an experimental investigation was undertaken on the past accident data and compared the data with the data recorded in Police records. Finally, they derived 10 parameters and used a ranking method to identify the accident black spots.

Lalita Thakali et al. [2015] researched on identification of crashspots on a road network. This study aimed at comparison of two geostatistical-based methods named as kernel density estimation and kriging.It was found that, based on the PAI measure, the kriging method outperformed as compared to KDE method in detection of accident hotspots, with respect to the groups of crash data with different times of day. It was found that the results were completely different in both methods, hence signifying the importance of selection of right geostatistical method for identification of road accident hotspots.
Anitha et al. [2016] has researched on present state of traffic accident information on NH-47 from Gandhipuram to Avinashi, Coimbatore District and also discussed the Identification of high-rate accident Locations by using GIS tool and lack of safety on selected study areas on the highway. Remedial measures and provisions for traffic safety were suggested for reducing the risk of accidents in blackspots.
Benjamin Romano et al. [2017] has studied on numerous techniques to identify spatial accident hotspots on the road network using kernel density-estimation, and significant linear route detection, but the time dimension and temporal dynamics of hotspots are not considered. Limitations were demonstrated using existing methods, both a new method called Spatial-Temporal Network Kernel Density Estimation that involves these features.
Chandrashekar Reddy et al. [2017] has researched on identification of black spots (high risk accident locations accident-prone locations) on Puttur to Ramagiri stretch. Accident data consisted of time of incidence, kind of collision, type of vehicles, persons died, persons injured. Using the data ten black spots were identified and engineering surveys were conducted to know the road characteristics. Parameters such as width of the road, alignment of the road, number of aspect roads and traffic volume were considered.
Sarifah et al. [2018] has researched on suitable techniques for determination of the hotspot on Malaysian highways. This study uses spatial analysis techniques namely, Nearest Neighborhood Hierarchical Clustering and Spatial Temporal Clustering, using Crime Stat and visualizing in ArcGIS™ tool to estimate the concentration of the traffic incidents. Results were compared based on their accuracies, identified numerous hotspots and presented that they varied in number with places, depending on the parameters. Further analysis showed that Spatial Temporal Clustering has a higher accuracy index compared to Nearest Neighbor Hierarchical Clustering (NNH) on the selected stretch.
H. Ebru Colak et al. [2018] identified intensity of traffic accidents (hot-spot regions) using spatial statistics techniques. Geographical Information Systems (GIS) tool was used to examine the hot spots for traffic safety. This study used analysis based on network spatial weights to identify black spots. Hot Spot Analysis was carried out using Getis-Ord Gi* and road accident data was used to generate network spatial weights. Then, Kernel Density method was used to define traffic accident black spots.
Faheem et al. [2019] has identified the accident black spots in Hyderabad city and to develop an accident prediction model using multiple linear regression method. They have developed the prediction models by considering the various accident-causing parameters. QGIS software has been used for the study which included collection of spatial data and non-spatial data for identification of traffic accident blackspots. The required data was then collected (zone wise) which comprised of accidents caused due to various factors. Different equations were developed for different zone which helps in prediction of accidents. They suggested to make necessary improvements to be made at the black spot locations to reduce the traffic accidents.

Research Directions:

The majority of the existing works carried on identification of vehicular traffic accident hotspots methods considered the road traffic parameters individually or in combination. This paper provides a framework of different methods on identification of vehicular traffic accident hotspots. Many authors developed different models out of which maximum work has been carried out on KDE, Kriging and NNH methods whereas minimum work has been carried out on spline, point density, line density, IDW and Moran's I methods. After studying different methods stated above, it is found that least work has been carried out on Getis-Ord Gi* Method.

Research Framework:

Research Framework for identification of vehicular traffic accident hotspots in complex networks as shown in the figure 2.

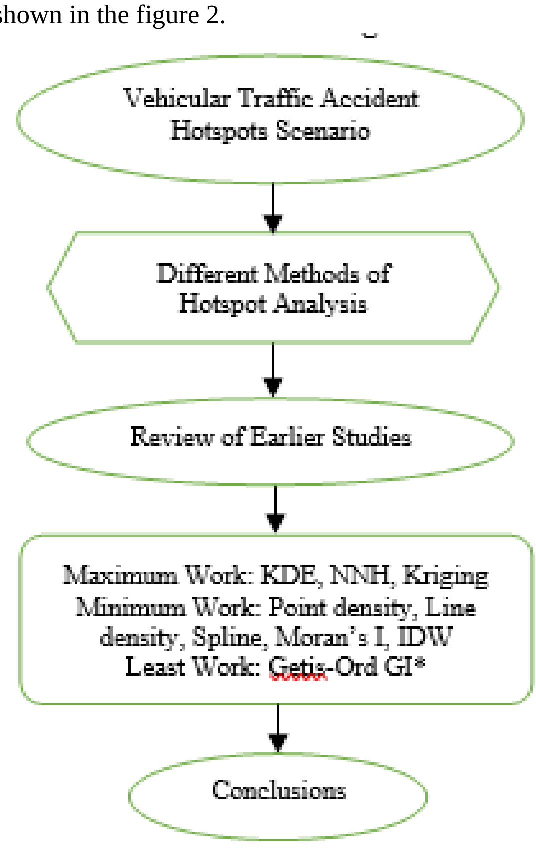

Figure 2: Research Framework for Identification of Vehicular Road Traffic Accident Hotspots

This paper attempts to explore the future research trend with respect to the literature survey done so far which characterized as the aim and objective of the study, to separate the clusters of high and low values and to apply for point and polygon features using Getis-Ord Gi*, to limit the traffic congestion and ease the number of accidents by investigating into the chronology of the accidents using GIS methods, to provide recommendation for ensuring the road user's safety.

CONCLUSIONS

This paper attempts to study united different researchers view on the identifying of vehicular road accident hot spots. This research allocates a lot in perceptive the conditions and source of the road accident in the light of qualitative and quantitative traffic parameters. This research establishes to be precious in a large quantity of identifying of vehicular road accident hot spots. GIS method shall be employed to evaluate the vehicular road accident in complex networks.

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