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To Find Accident Prone Zones and Nearest Health Facility by GIS Based Spatial and Network Analysis in Amritsar, Punjab

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ABSTRACT

Context: The use of Geographic Information System (GIS) as a real-time monitoring system for the control and management of accident events is well known as it provides a platform to perform various spatial and network analysis and also in the presentation of descriptive data.

Aim and Objective: This paper presents a GIS-based approach to find out areas prone to road traffic accidents based on spatial analysis and to analyze the spatial accessibility using network analysis

Material and Methods Accident particulars like date, location, time and outcome for the year 2015 were included in the GIS database. Moran's I method of spatial autocorrelation was used for the assessment of spatial clustering of accidents and hotspots spatial densities. The clusters of high and low values of the severity of accidents were obtained using cluster and outlier analysis. Location-allocation was performed as part of network analysis to find the nearest hospital to these high-value clusters.

Results: Spatial autocorrelation showed that there was overall clustering present, cluster and outlier analysis gave clusters of severe accidents at NH-1 and Fortis hospital was the nearest facility to these clusters.

Conclusion: This system is highly useful and provides information about accident locations, accident and service diagnosis and fast delivery of emergency services.

Keywords: Road Traffic Accidents, GIS, Spatial analysis, Network analysis

INTRODUCTION

Road Traffic Accidents (RTA) is one of the most important causes of morbidity and mortality all over the world. This can be attributed to the growing number of vehicles, risky behaviours, and changes in the lifestyle of the general population. World Health Organization has reported five main key risk factors of road traffic accidents such as drinking and driving, speeding, not using motorcycle helmets, seat-belts, and child restraints.[1]

According to a report given by WHO on the global status report on road safety in 2013, 1.24 million road traffic accidents occurred per year which is very high and 97% of the road accidents occur in developing countries, which have only 48% of vehicles.[2] It has been indicated that if the situation is not controlled soon, South Asia will have the most significant increase in road traffic deaths, i.e. 144% which is twice the average rate of increase for other World Bank regions in the near future.[3]

In India, there is a rapid increase in the motor vehicles where 6 million new motor vehicles are sold every year. It is expected to top in the numbers of cars on its roads by 2050. Road traffic accidents related fatality has decreased significantly in the highly motorized and developed countries whereas in India over the past three decades there has been increasing RTI related fatality.[4]

RTA is one of the public health issues which needs to be redressed using a multi-disciplinary approach. Geographical Information System (GIS) is a popular and useful tool for visualization of accident data and analysis of hot spots. Accident analysis aims to identify the high rate of accident locations and safety deficient areas. This is important for implementing precautionary measures and provisions for traffic safety at that hot spot.[5] The Exploration of such risky sites plays a vital role in the provision of emergency services on time. Any error in detecting risky locations might lead to identifying an accident-prone zone as safe or, inversely, the safe locations as hazardous which will result in insufficient allocation of budget and resources.[6]

This study gives an outline about how Spatial Analysis can be used to find out accident-prone areas and the use of network analysis to find out the nearest health care facility to that area. We start with the hypothesis that there is a presence of spatial correlation between the accident spots. As a result this study was conducted with an aim and objective to find out the road traffic accident-prone areas using spatial and network analysis, to determine the clusters of fatal and non-fatal accidents, to identify the hot spots of road traffic accidents and to find the nearest health facility to the hot spot

METHODOLOGY

Study Area: Amritsar city is located in Amritsar district, Punjab with an area of 250 square kilometers. It is located at latitude 31.63°N and longitude 74.87°E with an average elevation of 234 meters (768 ft). According to 2011 census, the population of the city was 1,132,761. Amritsar has a rich history and is one of the major tourist destinations. The rapid growth and development of the city lead to increase in road traffic, which in turn resulted in an increase in number of traffic accidents. Thus, identifying the hot spots can help in finding the possible reason for increase traffic accidents in the area and also to take preventive and emergency measures.

Data Preparation: In this phase the base map of the study area was downloaded from Open Street Map (OSM). The accident data was downloaded from Amritsar city road traffic police website (First Information Report) for the year 2015. The city road network data were downloaded, which had an attribute (meters) to store the length of each road segment in the road network. The data for health care service provider were downloaded from OSM. The data contain an attribute (name) to store the names of each health care provider. The road traffic accident data was entered and compiled in Microsoft Excel with variables such as time and place of the accident, vehicle involved and the outcome of the accident. The severity of the accident was classified according to the outcome of the accident into fatal and non- fatal and was coded accordingly.

Creating Geo-database: Geo database is the fundamental data format used for both editing and management of the data. A personal Geo-database was created that could store, query and manage spatial and non –spatial data. It had data about location of health care providers as point shape file, road network data as line shape file, and location of traffic accidents as point shape file. The attribute regarding the severity of the accidents (severity) was entered in new field in the attribute table for accident locations.

Network Analysis: Network topology was used to get a good and accurate network analysis. It was necessary to discover the errors that were there in the network topology and correcting them. Rules to correct network topology were applied such that there were no dangles in the road network, and there was no overlapping or intersection of the roads. The network analyst extension was enabled, and a new network dataset was created after correcting the errors.[7]

Location allocation analysis is part of the network analysis. It was done to identify the nearest hospital facility to the hot spot. The goal of location-allocation was to identify the facilities that supply the demand points most efficiently. It simultaneously located facilities which were the nearest hospital and allocated demand points (hot spot) to those facilities.

Spatial Analysis: Spatial statistic maps are essential to realize the locations of accident-prone zones. The collection of such statistics helps to describe and model the spatial and temporal data. Spatial analysis was conducted in the following steps:

Spatial autocorrelation (Global statistics) has been used to identify clustering. This tool returns five values: the Moran's I Index, Variance, Expected Index, z-score, and p-value. It evaluates whether the pattern of distribution of cases is clustered, dispersed, or random. A positive Moran's I index value (-1 to +1) indicates that there is a tendency of clustering, whereas a negative Moran's I index value indicates a tendency towards dispersion. A value of 0 for Moran's I show no apparent spatial clustering.[8]

Incremental spatial autocorrelation will create a line graph which indicates spatial autocorrelation for a series of distances with their corresponding z-scores. The spatial clustering in the data is reflected by statistically significant peak and z-scores, which indicate distances where spatial processes that promote clustering are most evident. Usually, when there is more than one statistically significant peak, the first significant peak is selected.[9]

Cluster and Outlier analysis (Anselin Local Moran's I) indicates that the spatial clustering of both high or low values and a spatial outlier is more evident than expected in a random distribution. It uses a local statistic to identify defined areas with features and attribute values, then cluster the features sharing a common attribute. The measures of statistical significance, z-scores and p-values tell you whether or not to reject the null hypothesis, feature by feature.[9]

Hot spot analysis helps to identify spatial clusters of high values (hot spots) and low values (cold spots) which are statistically significant. It gives an output feature class with a z-score, p-value, and confidence level bin. Measures of statistical significance which are the z- scores and p- values tell you whether or not to reject the null hypothesis.[10]

RESULTS AND DISCUSSION

After performing network and spatial analysis for road traffic accidents in Amritsar city, the following results were obtained.

The output of spatial autocorrelation, as given in figure 1, shows that there is a statistically significant overall clustering present in the data. The value of Moran's I was positive and closer to 1, proving the hypothesis of the presence of spatial clustering of road traffic accidents correct. Given the z score of 2.681532, there was less than 1% likelihood that this clustered pattern could have occurred by random chance with p-value <0.05.

The incremental spatial autocorrelation output figure 2 demonstrate a statistically significant peak at a distance of 1300 meters. This was the maximum peak value indicating the range where maximum clustering occurred. The beginning distance used was 400 meters with an increment of 300 meters between each feature. The number of distance bands used was 10.

The Cluster and Outlier analysis output, as shown in figure 3, show spatial clustering of both high and low values and spatial outliers with defined areas. The figure shows High-High (HH) for a statistically significant cluster of high values which were fatal accidents and Low-Low (LL) for a statistically significant cluster of low values which were non-fatal accidents. High-Low (HL) and Low-High (LH), also known as spatial outliers, show areas where high values were surrounded by features with low values and vice versa. The Grand Trunk road, which is the National Highway 1 (NH-1), was prone to severe road traffic accidents having HH clustering.

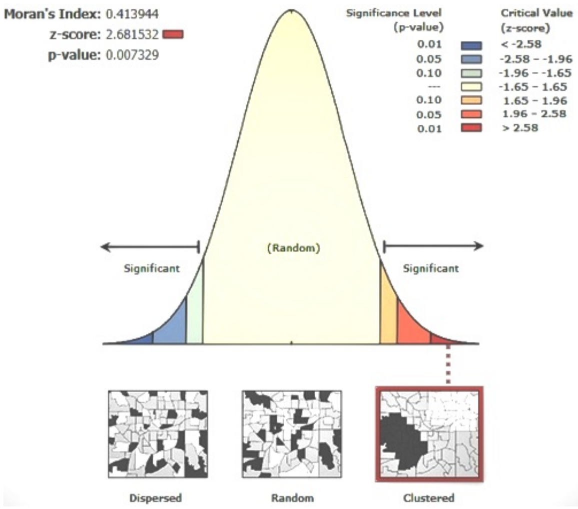

Fig. 1- Spatial Autocorrelation Report

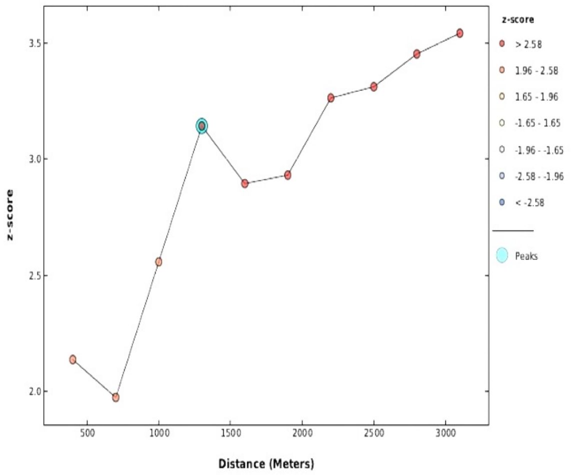

Fig. 2-Incremental spatial autocorrelation output

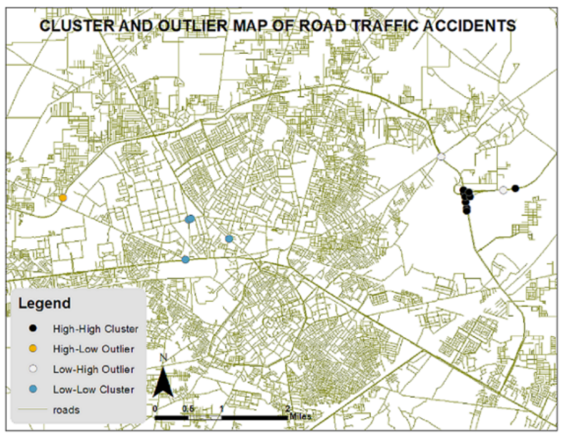

Fig. 3-Cluster and Outlier analysis output

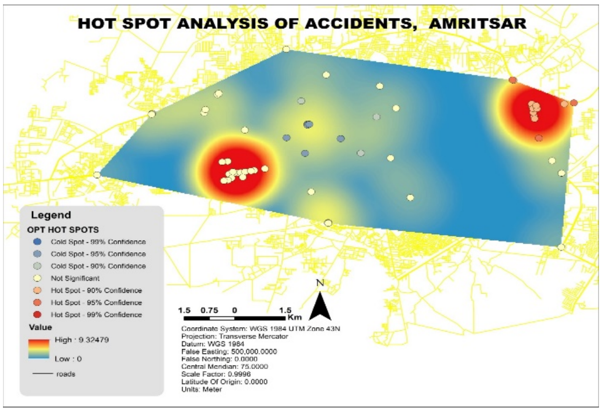

Fig. 4-Hot Spot analysis output

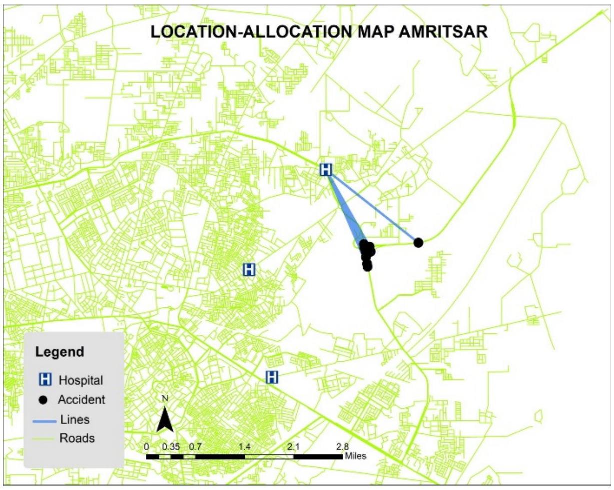

Fig. 5-Location-allocation output

Hot spot analysis output, in figure 4, shows significant spatial clusters of high values (hot spots) and low values (cold spots). The hot spots which are in red, show fatal accidents and cold spots which are in blue colour show non-fatal accidents. The white spots show no significant clustering. The density map as a base map shown in red colour around the points represents the density of the points in that area irrespective of the attribute value.

Location allocation analysis output in figure 5 shows that Fortis Hospital is the nearest facility that supplies the demand point, which is the HH spot. These spots were the areas of fatal road accidents.

LIMITATIONS

The accident data used in this study is only from those recorded by the police. There might have been more information on the accident that the police could not have registered as a response was arrived much earlier. While using network analysis, we did not include travel impedances such as traffic data within the city. Global Positioning System (GPS) devices were not used by the police for data collection, so the accuracy of the location of the road accidents is doubtful.

CONCLUSION

The use of GIS to capture accurate geographical locations and mapping of the accident areas as well as visually analyzing the data is significantly important these days. Road traffic accidents are increasing in number, so there is a need to build strong emergency services in accident-prone areas. Geospatial techniques of GIS with supplementation of GPS are recommended to improve the current system on data collection, storage, manipulation and analysis of accident data. This can aid in decision making, analytical processing and visualizations for future accident related researches.

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