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Spatial and Temporal Analysis of road accidents using GIS

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Abstract – *Traffic accidents are a critical public safety concern, resulting in loss of life, property damage and economic cost worldwide. Analyzing the pattern and factors contributing to accidents can help identifying high-risk areas and understanding causes. Geographic Information System (GIS) technology, particularly using ArcGIS software offers powerful tools for spatial analysis and visualization of accident data and enabling more precise and targeted interventions. This project aims to analyze traffic accident data using ArcGIS Pro to identify accident hotspots and visualize accident patterns in State Highway (SH-1) in Muvattupuzha region. Accident trends can be visualized by mapping accident locations and applying spatial analysis techniques like hotspot analysis and Kernal Density Estimation.*

Key Words: **Traffic accidents, Geographic Information System, ArcGIS Software, Spatial analysis, Kernal Density Estimation**

1.INTRODUCTION

Road accidents are a significant global hazard, posing a critical public safety challenge. The primary cause of road accidents often include speeding and driving of vehicles under the influence of alcohol. These factors contribute to an alarming number of fatalities worldwide, with an estimated 1.3 million people losing their lives annually due to road traffic crashes, equating to approximately 3000 deaths day.

Various factors contributing to collision includes vehicle design, operational speed, road layout, weather conditions, road environment and driver behavior. The lack of safe and adequate road infrastructure is a primary cause of road traffic crashes. Accident analysis helps identifying the causes of accidents, whether single or multiple, with a goal of preventing future accidents of similar nature.

Geographic Information System software offers powerful tool for analyzing accident data. GIS technology allows for the integration of spatial analysis with statistical methods, providing valuable insights into accident trends and patterns. By mapping accident locations ,GIS software can identify areas with high concentration of accident referred to as "accident hotspots". Further analysis of these hotspots helps researchers and policy makers understand the underlying causes of accidents in specific locations. ArcGIS, a widely used GIS software, will be applied to conduct traffic accident analysis. ArcGIS provides tools for mapping, analyzing and visualizing spatial data, making it possible to identify accident patterns. Through ArcGIS, we aim to enhance our understating of accident hotspots.

2.LITERATURE REVIEW

Khaled Aati (2024) explores how urban density affects road traffic accidents, using advanced spatial and statistical tools like Geotech Transport and ArcGIS. The study highlights the unique traffic challenges in densely populated cities, where high vehicle and pedestrian volumes, limited road space, and complex layouts contribute to accident risks. Previous research points to urbanization, infrastructure quality, and traffic flow as key factors influencing accident rates. The paper emphasizes the importance of spatial analysis tools in identifying accident hotspots and understanding traffic patterns. By leveraging GIS technology, urban planners can make data-driven decisions to create safer and more efficient road networks, ultimately reducing accidents and improving city resilience.

K. Athiappan (2022) highlighted that severe road crashes are a major public health concern. To reduce these incidents, both immediate and long-term countermeasures are necessary. A statistical analysis of accidents in Toronto revealed that fatal crashes often result from harsh driving, lack of focus, and speeding. The study used cluster analysis to identify key factors contributing to accidents and collected data from 2012 to 2015. By utilizing GIS-based analysis, accident-prone areas and blackspots were mapped, helping to focus preventive efforts on the most critical causes to reduce future crashes.

Md Izharul Haque et al. (2022) conducted a study on traffic safety along NH-76, covering a 93.5 km stretch from Udaipur to Chittorgarh in Rajasthan, India. The research aimed to identify the key factors contributing to road accidents by analyzing data from police records between 2017 and 2019. Various aspects, such as time of occurrence, accident type, and frequency, were examined. The study also pinpointed accident-prone areas (black spots) and suggested safety improvements, including better pavement maintenance, proper zebra crossings, and enhanced road signs near intersections. The goal was to address design flaws and improve overall road safety for users.

3.METHODOLOGY

The process begins with selecting a suitable study area, followed by collecting relevant data. After gathering the

necessary information, a preliminary survey is conducted to assess the situation. The collected accident data is then analyzed using GIS technology to identify patterns and risk factors. Finally, appropriate accident control measures are implemented based on the analysis to enhance road safety.

3.1 STUDY AREA

The study area is under Muvattupuzha police station. Muvattupuzha police station is situated at Thottumkalpeedika,3 km east of Muvattupuzha Town. The area has number of educational institutions, textile shops, retail stores, markets, hospitals etc, causing traffic flow in the city. The study area consists of Paipra Panchayat and Muvattupuzha municipality. Study area is divided into 3 regions. Study Area 1 - Pezhakkapiiy, Study Area 2 - Vazhappilly and study area 3- Velloorkunnam. The total area found to be 43.23 sq.km. It includes one grama panchayat and one municipality. The study area lies between 9°59' 21.85362616" N and 10° 00' 38.26377323" N latitudes and 076° 33' 35.43168408"E and76° 36' 18.07850385" E longitudes.

The map showing study area is shown in Fig [1].

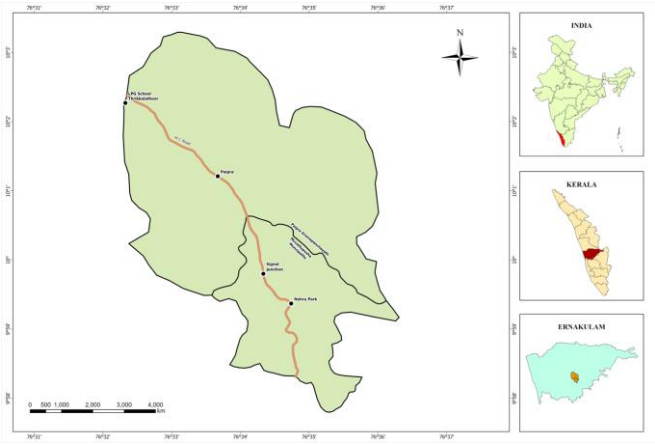

Fig –1: Study Area

3.2 DATA COLLECTION

The goal of collecting crash data is to support the blackspot investigation team in understanding the causes and patterns of road accidents, helping them improve safety and prevent future incidents. Accident data of study area 1,study area 2 and study area 3 for the 5 years 2020,2021,2022,2023 and 2024 were collected from the police station. The data collected are:

- Date and time of accident
- Type of vehicle involved
- Location
- Classification of accidents: fatal/major/minor
- Number of people involved

4. PRELIMINARY SURVEY

A preliminary assessment was carried out to evaluate the current road conditions in the study area. A survey was carried out to gather responses from participants regarding various road-related issues, their locations, and supporting photographic evidence. The goal of this assessment was to identify potential safety concerns and areas needing improvement.

Table -1: Site observations

Site	Observations
 Study Area 1	Pedestrian crossings are faded, and there is a shortage of parking spaces, making it challenging for both pedestrians and drivers.
	The drainage systems along the road are damaged and in poor condition, leading to potential water accumulation.
 Study Area 2	The road surface has noticeable irregularities, which could impact driving comfort and safety.
 Study Area 3	Faded lane markings create safety risks, particularly in high-traffic zone

Poorly marked pedestrian crossings, along with worn-out lane markings, make navigation difficult for road users. Furthermore, inadequate drainage in certain sections increases the risk of waterlogging, affecting both motorists and pedestrians. Regular maintenance and timely repairs are necessary to enhance road safety and ensure smoother traffic flow.

3.1 TRAFFIC VOLUME STUDY

Traffic volume study is conducted at study area 1(starting point of study area) and study area 3 (Ending point of study area). The study is conducted at 8:30 AM- 10:00 AM (Peak hour) and 1:30 PM – 3:00 PM (off peak hour). The results of traffic volume study shows that traffic volume of study area 3 is higher than that of study area 1.

Table -2: Traffic composition of study area

Study Area	Traffic composition of vehicles				
	% of Car	% of 2 - Wheeler	% of 3 - Wheeler	% of Bus	% of Truck
Study Area 1	46	30	11	3	10
Study Area 3	43	31	12	4	10

4. ACCIDENT DATA ANALYSIS

The accident data are analyzed by Kernal Density Estimation method in ArcGIS Pro. For Kernal Density Estimation, location coordinates of each accident locations were obtained. All the coordinates are plotted in study area are shown in [2]

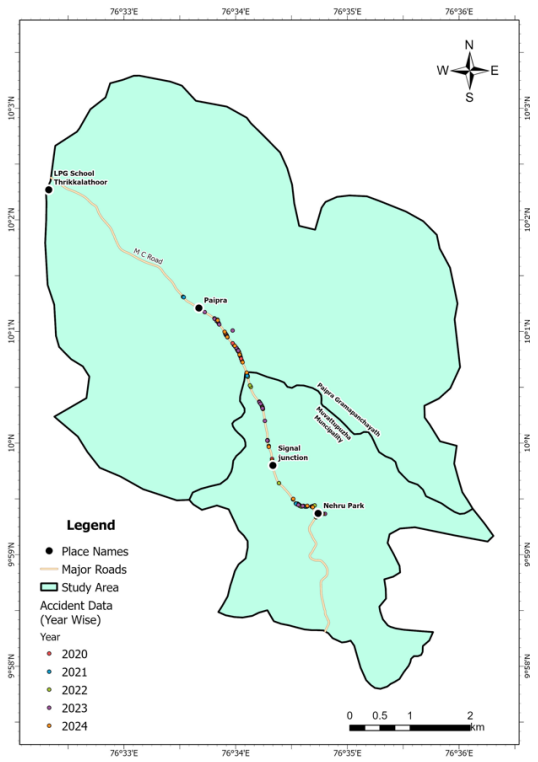

Fig –2: Locations of the accidents reported

4.1 KERNAL DENSITY ESTIMATION

The Kernel Density Estimation (KDE) analysis of the study area reveals notable shifts in accident concentration over time. The darkest tones in the KDE maps represent accident hotspots, highlighting areas with the highest frequency of incidents. The analysis examines KDE separately for 2020 and 2024, as well as a cumulative assessment spanning 2020 to 2024. Figures [2], [3], and [4] illustrate the spatial and temporal distribution of accident-prone zones. The KDE results indicate that in 2020, the majority of accidents occurred in Study Area 1. By 2024, the distribution of accidents became more balanced between Study Area 1 and Study Area 3. The overall KDE analysis from 2020 to 2024 identifies Study Area 3 as the primary accident-prone region. Additionally, the most hazardous road sections within the study area are depicted in Figure [5].

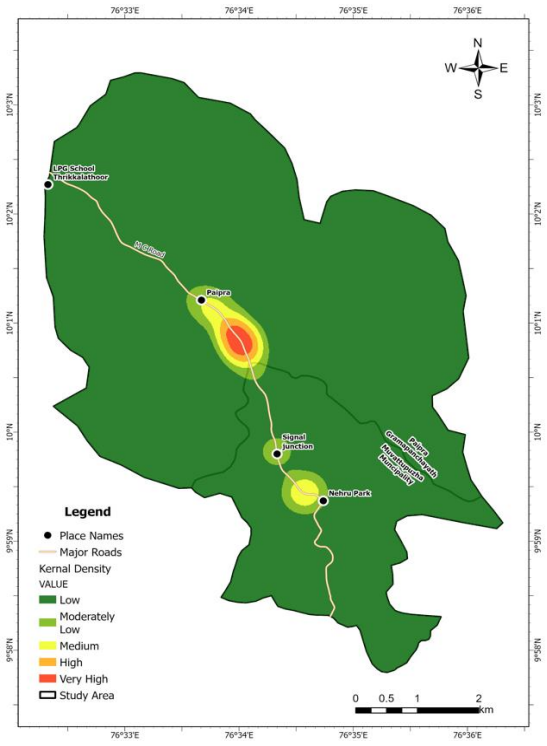

Fig –2: Spatial and temporal distribution of accidents

(2020)

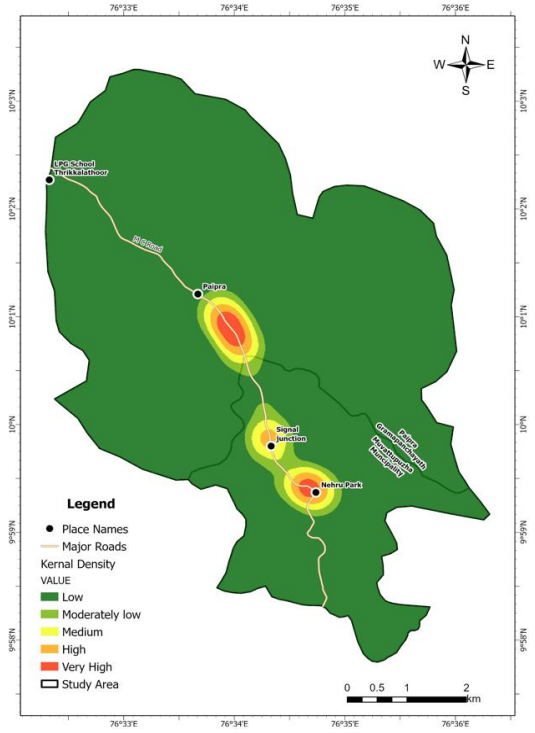

Fig- 3: Spatial and temporal distribution of accidents (2020)

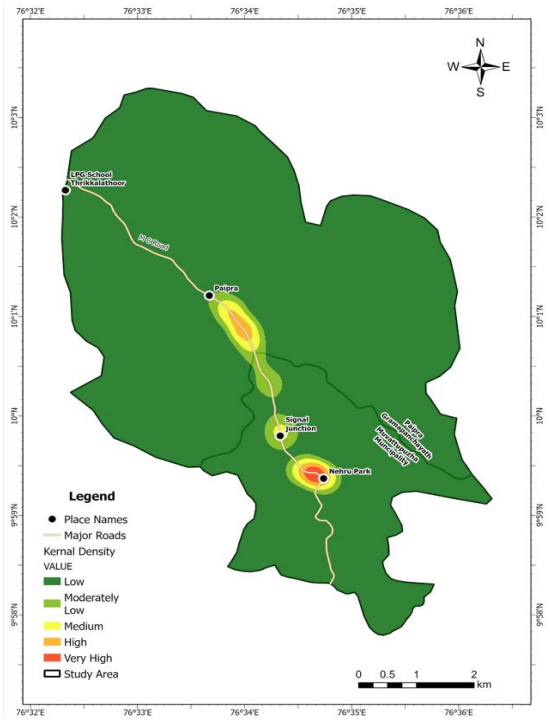

Fig -4: Spatial and temporal distribution of accidents (2020-2024)

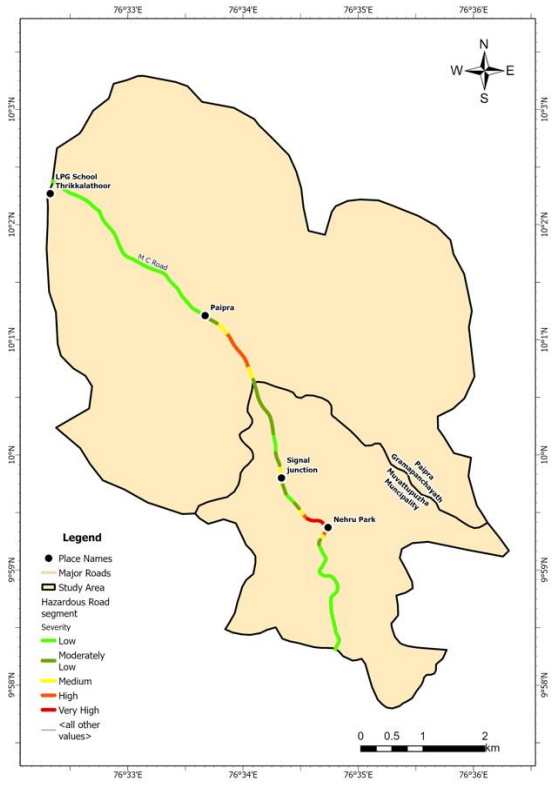

Fig-5: Hazardous road segment in the study area

5. CONCLUSIONS

The project identified the spatial-temporal patterns of road accidents between the years 2020 and 2024 under Muvattupuzha police station, Kerala. Initial preliminary survey was carried out within the study area to identify present road conditions. Using Kernal Density Estimation, the major vulnerable road segment found as Study Area 3 - Velloorkunnam. The two major accident-prone road segment observed in the study area are Pezhakkappilly road from paipra junction to 0.9 km distance. In Veloorkunnam road, from signal junction to Nehru park. These hotspots are depicted by the darkest shade (Red), in fig. [5], indicating high concentration of accidents in those locations. Furthermore, other road segments in the study area also has high Kernal Density, which means that, this road segment may also be considered while treating an hazardous road segment. The length of segments identified with very high kernal density are .39km and the segments with high kernal density are 0.9km. There are also several road networks with low, moderately low and medium kernal density. Based on the value of kernal density all the accident prone road segments were identified.

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