

ArcGIS-Based Spot Analysis of Road Accidents On Mc Road From Paranthal to Manthuka

Aswathy S Kumar

Assistant Professor, Department of Civil Engineering
Sree Buddha College of Engineering (Autonomous), Pattoor, Kerala, India

Adithya Chithran, Adithya M A, Bhavana S, Krishna Madhav Nair
UG Scholars, Department of Civil Engineering
Sree Buddha College of Engineering (Autonomous), Pattoor, Kerala, India

Abstract— Road traffic accidents continue to pose a significant challenge to transportation safety and sustainable development, especially in developing countries like India, where mixed traffic flow and inadequate road infrastructure contribute to increasing accident rates. This study employs a Geographic Information System (GIS) based approach to identify and analyze accident prone locations along the MC Road stretch from Paranthal to Manthuka. The analysis integrates spatial and temporal data collected from local police records and field surveys to map and assess blackspots along the selected corridor. Spatial statistical tools such as Kernel Density Estimation (KDE) and spatial autocorrelation were used to determine accident clustering patterns and hotspot intensity. The study highlights the importance of incorporating GIS technology in transportation safety analysis for effective decision making and the prioritization of remedial measures. By identifying and ranking critical accident spots, this research supports evidence based planning, low cost mitigation strategies, and targeted safety interventions aimed at reducing accident rates and enhancing overall road safety along the MC Road corridor.

Further, the study utilizes GIS-based thematic mapping to enhance the analysis of accident patterns. Spatial distribution maps were developed to visualize accident occurrences along the study stretch, while severity-based maps classified accidents into minor, major, and fatal categories. Temporal analysis was carried out to identify peak accident periods during different times of the day. In addition, heatmaps were generated using Kernel Density Estimation (KDE) to identify high-density accident zones and critical blackspots. These visual representations improve the understanding of accident patterns and support effective planning of targeted road safety measures.

Keywords—Road accidents, GIS, Blackspot analysis, MC Road, Kernel Density Estimation, Road safety

I. INTRODUCTION

Road traffic accidents are a major challenge to transportation safety and sustainable development, especially in developing countries like India. Rapid urbanization, increasing vehicle population, mixed traffic conditions, and inadequate road infrastructure have contributed significantly to the rise in accident rates. Understanding the spatial and temporal distribution of accidents is essential for implementing effective road safety measures and reducing accident severity.

Traditional accident analysis methods mainly rely on statistical records and tabular data, which often fail to represent the actual spatial distribution of accidents. In this context, Geographic Information System (GIS) provides an effective platform for accident analysis through visualization, spatial mapping, and hotspot identification. GIS-based techniques help in identifying accident-prone zones, understanding clustering patterns, and supporting evidence-based decision making for transportation planning and safety improvements.

The MC Road stretch from Paranthal to Manthuka in Pathanamthitta district experiences frequent road traffic accidents due to heavy vehicular movement, mixed traffic flow, junction conflicts, and varying road geometry. Several locations along this corridor have emerged as accident hotspots, leading to increased risks for road users. Therefore, a detailed spatial analysis of accidents is necessary to identify blackspots and recommend suitable mitigation measures.

This study focuses on ArcGIS-based spot analysis of road accidents along the selected MC Road corridor. The research integrates accident records, field observations, and GIS-based Kernel Density Estimation (KDE) techniques to identify accident hotspots and analyze spatial-temporal patterns. The study aims to support effective road safety planning and contribute toward reducing accident risks through targeted interventions.



Fig.1 Accident Scene on MC Road Showing Vehicle Collision

II. LITERATURE REVIEW

A literature review provides a structured understanding of the developments and methodologies adopted in a particular research domain. In transportation engineering, accident analysis has evolved from conventional statistical methods to advanced geospatial techniques. The emergence of Geographic Information System (GIS) has significantly transformed the way accident data is processed, analyzed, and visualized.

Modern studies emphasize the integration of spatial, temporal, and statistical datasets to identify accident-prone locations more accurately. Unlike traditional tabular analysis, GIS enables mapping of accident data, revealing spatial patterns and clustering behavior. This has led to the identification of blackspots or hotspots, which are critical for implementing targeted safety measures.

Furthermore, researchers increasingly focus on combining multiple analytical approaches, such as density-based methods, statistical modeling, and real-time data integration, to improve the reliability of results. These advancements form the foundation for the present study, which applies GIS-based techniques for hotspot identification along the MC Road stretch.

A major portion of the literature focuses on the application of GIS for spatial analysis of road accidents. Researchers have consistently demonstrated that GIS is an effective tool for visualizing accident distribution and identifying high-risk locations. Mahmoud Hammas and Ahmad Al-Modayan (2022), in the Journal of Geographic Information System, found high accident concentration along Central Ring Roads and major arterials. Kernel Density and hotspot analysis identified critical zones such as Medina city center and the Prophet's Mosque area. Raju Bhele et al. (2022), in the Journal of Advanced Transportation Studies, observed that accident rates increased annually, with major (72.4%) and fatal (14.9%) accidents dominating. The highest density was observed in central highway sections such as Banepa Municipality. Raju Bhele et al. (2022), in the Journal of Advanced Transportation Studies, performed spatial and temporal analysis of road traffic accidents and

demonstrated the effectiveness of GIS techniques in identifying accident-prone areas.

In addition to spatial analysis, many studies incorporate temporal factors to better understand accident trends. Researchers have found that accident frequency varies significantly with time of day, season, and weather conditions.

Common observations include higher accident rates during evening peak hours and adverse weather conditions such as rainfall or fog. Seasonal variations, especially during monsoon periods, have also been linked to increased accident occurrences due to reduced visibility and poor road conditions. The integration of temporal analysis with GIS enhances the predictive capability of hotspot identification. Khanh Giang Le, Pei Liu and Liang-Tay Lin (2023), in Geospatial Information Science, identified temporal accident peaks between 14:00–15:00 and 19:00–23:00, particularly during winter months (December–January). The study found that accident hotspots are concentrated along urban arterial roads with heavy traffic and poor signalization. Pawinee Iamtrakul and Sararad Chayphong (2023), in Transportation Research Interdisciplinary Perspectives, reported that accidents in Bangkok are not randomly distributed. Daytime accounted for the highest number of crashes ($\approx 57\%$), whereas nighttime accidents were more severe and fatal ($\approx 62\%$). Wesam Alkhadour et al. (2021), in the International Journal of Advanced Computer Science and Applications, identified strong clustering patterns of accidents in Amman, particularly along major transport corridors such as Abu Alanda Street.

Hongjun Cui et al. (2022), in the Journal of Traffic and Transportation Engineering, found that accident spacing distribution identified high-risk stretches with an average 42 accidents/km, achieving higher accuracy than conventional methods. Laxman Singh Bisht and Geetam Tiwari (2023), in IATSS Research, compared Ordinary Kriging, Kernel Density Estimation (KDE), and Network KDE, concluding that geospatial methods outperform traditional frequency-based models, especially in limited data conditions. Most Suria Khatun et al. (2024), in Heliyon, identified that 35 blackspot zones were concentrated in specific regions, with crash types dominated by collisions (46.7%), trucks (37.9%), and two-wheelers. Additionally, 86.8% of injuries were reported among females.

Most previous studies using Geographic Information Systems mainly focus on large-scale accident hotspot identification using secondary datasets, with limited emphasis on detailed analysis of specific road stretches using local accident records and field observations. Many studies give less attention to detailed analysis of specific road stretches, including field conditions such as road geometry, visibility issues, and junction characteristics. In addition, local accident data and field observations are

often not integrated together for a comprehensive analysis. Therefore, there is a need for a case study-based analysis that combines accident records, GIS mapping, and field observations to better understand accident-prone locations and suggest practical safety improvements.

III. METHODOLOGY

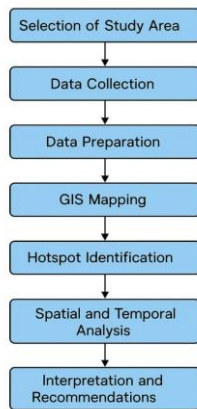


Fig.2 Flowchart

Fig. 2 illustrates the overall methodology adopted for the study. The methodology adopted for this study follows a systematic approach for identifying and analyzing accident hotspots using ArcGIS-based spatial analysis techniques. The study was conducted along the MC Road stretch from Paranthal to Manthuka in Pathanamthitta district, Kerala.

Accident data for the period 2021–2025 was collected from Pandalam Police Station records. The collected data included accident location, date, time, and severity details. Field observations were also carried out to assess road geometry, traffic conditions, visibility issues, junction characteristics, and roadside activities.

The collected accident data was cleaned and organized using Microsoft Excel. Each accident location was assigned geographic coordinates in terms of latitude and longitude. The prepared dataset was then converted into CSV format and imported into ArcGIS software for analysis.

Spatial mapping was performed using OpenStreetMap as the base layer. Accident locations were plotted according to their geographic coordinates, and thematic maps were prepared to visualize accident distribution. Kernel Density Estimation (KDE) was applied to identify accident hotspots and generate weighted heatmaps representing accident intensity across the study corridor.

Temporal analysis was also conducted to examine accident occurrence during different periods of the day. The analysis focused on identifying peak accident hours and understanding the influence of visibility and traffic conditions on accident occurrence.

Finally, hotspot ranking and interpretation were carried out based on accident density and consistency. Suitable road safety recommendations were proposed for major blackspots identified during the analysis.

A. Study Area Selection



Fig. 3 Map of Study Area

The study area selected for this research is the MC Road stretch from Paranthal to Manthuka in Pathanamthitta district, Kerala. This corridor experiences heavy vehicular movement, mixed traffic flow, and recurring road traffic accidents. The stretch includes several junctions, curved sections, and commercial activity zones that contribute to accident occurrence. Due to the presence of frequent accidents and varying road characteristics, the selected corridor is suitable for GIS-based hotspot analysis and road safety assessment.

B. Data Collection

Accident data for the study was collected from Pandalam Police Station records for the period between 2021 and 2025. The collected information included accident location, date, time, and severity details. In addition to police records, field observations were conducted to study road geometry, visibility conditions, traffic flow, roadside activities, and existing safety measures. These observations helped in understanding the physical and environmental factors contributing to accident occurrence.



Fig. 4 Geometric road conditions leading to blind spot formation



Fig. 5 Road bend contributing to increased collision possibility

C. Data Preparation

The collected accident data was cleaned and organized before analysis. Missing values and errors were corrected to improve data accuracy. Each accident record was assigned a unique identification number and categorized according to severity, such as fatal, major injury, and minor injury accidents. Geographic coordinates including latitude and longitude were added to the dataset, and the prepared data was converted into CSV format for easy integration with ArcGIS software.

Table.I Accident Severity Categories and Criteria

Category	Criteria	Description
Fatal	Death reported	Severe Impact, requires urgent mitigation
Major Injury	Hospitalization required	High risk but non-fatal cases
Minor Injury	Simple Injuries	Moderate risk locations
Property Damage Only	No Injuries	Minor road safety concern

D. GIS Mapping

The prepared dataset was imported into ArcGIS software for spatial analysis. OpenStreetMap was used as the base map for plotting accident locations. Accident points were mapped according to their geographic coordinates to visualize their spatial distribution along the study corridor. Various thematic maps, including accident distribution maps and severity-wise maps, were generated to better understand accident patterns and identify areas with high accident concentration.

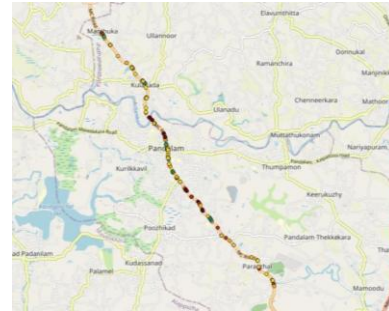


Fig. 6 Severity wise Accident Distribution

E. Hotspot Identification

Kernel Density Estimation (KDE) was used to identify accident hotspots and generate heatmaps representing accident intensity. The technique calculates the density of accident occurrences within a specific area and displays the results using a color gradient ranging from low to high intensity. Areas with higher accident concentration appeared as major hotspots, helping in the identification of critical blackspots requiring immediate safety interventions.

F. Spatial and Temporal Analysis

Spatial and temporal analyses were carried out to study accident distribution based on location and time. Spatial analysis revealed that accidents were mainly concentrated near junctions, curved sections, and areas with mixed traffic conditions. Temporal analysis showed that accidents were more frequent during early morning and late-night hours due to factors such as reduced visibility, driver fatigue, and overspeeding. These analyses helped in understanding accident trends and identifying the major factors influencing accident occurrence along the study corridor.

IV. RESULTS AND DISCUSSION

The analysis revealed that accidents are not uniformly distributed along the study stretch but are concentrated at specific locations. Major accident-prone areas identified during the study include Pandalam Junction, Kulanada Junction, Near Idayadi Pump, and Globe Junction at Manthuka.

A. Year wise Spatial Analysis of Accident Hotspot

Year-wise accident hotspot analysis was conducted using GIS-based heat maps to examine the variation in accident distribution over time. The maps use a color gradient from green (low) to red (high) to represent accident density. The results show that some locations consistently remain as hotspots across multiple years, indicating persistent blackspots, while other locations vary over time due to changes in traffic and road conditions. This analysis helps in identifying critical areas and understanding temporal trends for effective safety planning.

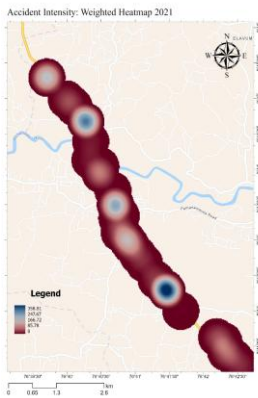


Fig.7. 2021

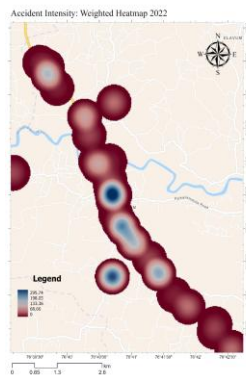


Fig. 8. 2022

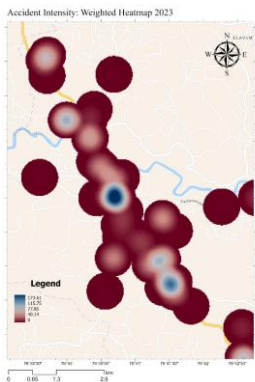


Fig.9. 2023

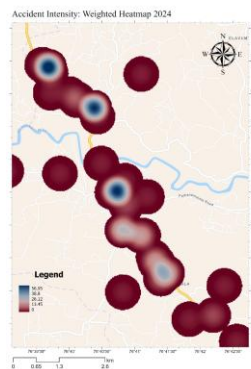


Fig.10. 2024

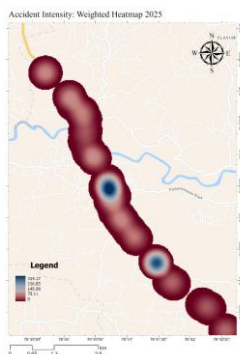


Fig.11. 2025

B. Comparison of Year-wise Hotspot Variation

A comparative analysis of accident intensity from 2021 to 2025 reveals both consistency and variation in hotspot patterns along the study corridor. Key locations such as Pandalam Junction, Kulanada Junction, Idayadi area, and Manthuka region consistently appear as major accident-prone zones throughout the study period, indicating

persistent risk factors related to road geometry and traffic interaction.

The five-year comparison of the MC Road stretch reveals a dynamic shift in accident spatiality, moving from a highly localized southern concentration in 2021 to a widespread, systemic corridor risk by 2025. Initially, the highest accident density was anchored at Pandalam Junction and the Medical Mission Junction, representing urban intersection conflicts, but as the years progressed, the heat migrated northward, establishing Kulanada Junction as a dominant epicenter in 2023 and Globe Junction as a significant emerging blackspot in 2024. While the Idayadi-Kurampala area consistently acted as a moderate-risk "bridge" between these major hubs, the most recent data from 2025 illustrates a bipolar resurgence where the risk has intensified simultaneously at both Pandalam and Kulanada-Globe sectors. This evolution suggests that safety interventions at specific junctions may have inadvertently shifted traffic pressure to adjacent areas, indicating that the stretch has evolved from having isolated blackspots into a continuous high-risk transit corridor requiring holistic traffic safety measures.

C. Hotspot Ranking and Interpretation

Based on the combined analysis of weighted heatmaps from 2021 to 2025, major accident hotspots were identified and ranked according to their intensity and consistency. Pandalam Junction was found to be the most critical hotspot, consistently exhibiting the highest accident intensity throughout the study period. Kulanada Junction is ranked as the second major hotspot due to its consistent accident density across all years. The Idayadi area ranks third and shows a noticeable increase in accident concentration in recent years, indicating emerging risk conditions. Manthuka Globe Junction is identified as the fourth major hotspot, showing relatively stable but moderate accident intensity.

Although Kulanada Junction is ranked as the second major hotspot based on overall accident density, recent year-wise analysis indicates a noticeable increase in accident intensity near the Idayadi area. This suggests that Idayadi is emerging as a critical hotspot and may require increased attention in future safety planning.

TABLE II. Hotspot Ranking Based on Accident Density

Rank	Location	Intensity	Remarks
1	Pandalam Junction	Very High	Major Hotspot
2	Kulanada Jn	High	Junction area
3	Near Idayadi Pumph	Moderate	Less Visibility
4	Manthuka Globe Junction	Moderate-Low	Junction area

D. Temporal Analysis

Temporal analysis was carried out to understand the variation of accident occurrence with respect to time. The

analysis indicates that accidents are more frequent during early morning hours and night-time periods. This trend can be attributed to factors such as reduced visibility, driver fatigue, and overspeeding during low traffic conditions. Night-time accidents are particularly influenced by inadequate street lighting and poor visibility of road features.

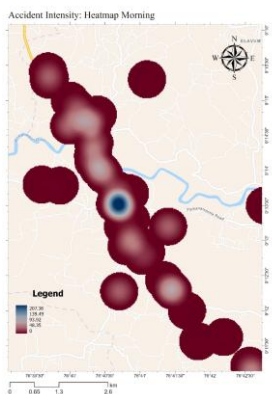


Fig.12 Late Night Hours

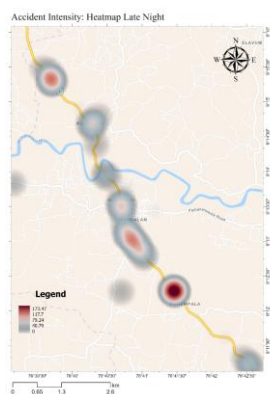


Fig.13 Morning Hours

A comparison between morning and late-night accident patterns reveals distinct differences in their causes and distribution. Morning accidents are primarily associated with high traffic volume, congestion, and increased interaction at junctions, resulting in a continuous spread of accident-prone areas. In contrast, late-night accidents are more localized and are mainly influenced by factors such as overspeeding, reduced visibility, and driver fatigue. The analysis highlights the need for time-specific safety measures, including traffic management during peak hours and improved lighting and enforcement during night-time.

TABLE III. Peak Time of Accidents

The temporal distribution of accidents presented in Table III is further illustrated using spatial heatmaps for different time periods. These maps provide a clearer understanding of how accident intensity varies spatially during morning and late-night hours.

E. Blackspot Analysis

The GIS-based hotspot analysis identified major accident-prone locations along the MC Road stretch from Paranthal to Manthuka. The primary blackspots identified were Pandalam Junction, Kulanada Junction, Near Idayadi Pump, and Globe Junction at Manthuka. These locations showed high accident concentration due to heavy traffic interaction, junction conflicts, roadside activities, and poor visibility conditions.

Pandalam Junction recorded the highest accident intensity because of traffic congestion, frequent turning movements, and complex junction geometry. Kulanada Junction also exhibited significant accident density due to mixed traffic flow, inadequate traffic control, and speeding. Near Idayadi Pump, accidents were mainly influenced by roadside fuel station activities and reduced visibility, especially during night-time. Globe Junction at Manthuka showed moderate accident clustering associated with congestion, pedestrian movement, and roadside commercial activities.

The analysis indicates that road geometry, visibility issues, traffic conditions, and human factors collectively contribute to accident occurrence. The identified blackspots require targeted safety measures such as improved traffic management, speed control, better lighting, and pedestrian facilities to reduce accident risk and improve overall road safety.



Location	Peak Time
Pandalam Junction	Morning
Kulanada Jn	Early Morning
Near Idayadi Pump	Early Morning
Manthuka Globe Jn	Early Morning

Fig.14 Field Photographs of Identified Blackspots

F. Interpretation of Results

The GIS-based analysis clearly showed that accidents are concentrated at specific locations rather than being randomly distributed along the study stretch. Major accident hotspots were identified at Pandalam Junction, Kulanada Junction, Near Idayadi Pump, and Globe Junction. These locations experience high traffic interaction, turning conflicts, mixed traffic flow, and

visibility issues, which increase accident occurrence. Temporal analysis indicated that accidents are more frequent during early morning and night-time periods due to reduced visibility, driver fatigue, and overspeeding. The study also revealed that road geometry, inadequate traffic control measures, and lack of pedestrian facilities significantly contribute to accident risk.

G. Recommendations

Based on the identified issues, several safety improvement measures are recommended for the study corridor. At Pandalam Junction, improvements such as flyover construction, pedestrian crossing facilities, speed control measures, and signal synchronization are necessary to reduce congestion and conflicts. Kulanada Junction requires proper traffic control systems, pedestrian sidewalks, regulated parking facilities, and speed regulation measures. Near Idayadi Pump, warning signs, convex mirrors, improved street lighting, and rumble strips can help reduce accidents caused by poor visibility and roadside activities. At Globe Junction, road widening, pedestrian pathways, improved lighting, and traffic regulation during peak hours are recommended to improve overall road safety.

V. CONCLUSION

The present study successfully analyzed road traffic accidents along the MC Road stretch from Paranthal to Manthuka using ArcGIS-based spatial analysis techniques. The integration of GIS tools and Kernel Density Estimation enabled effective identification of accident hotspots and visualization of accident distribution patterns.

The study identified Pandalam Junction, Kulanada Junction, Near Idayadi Pump, and Globe Junction as major accident-prone locations along the corridor. Spatial and temporal analyses revealed that accident occurrence is strongly influenced by factors such as road geometry, traffic congestion, visibility conditions, roadside activities, and human behavior.

The findings indicate that accidents are more concentrated near junctions and curved road sections where vehicle interaction and conflict points are higher. Temporal analysis further showed that early morning and late-night periods experience increased accident frequency due to reduced visibility, driver fatigue, and overspeeding.

The study demonstrates the practical applicability of GIS tools in transportation safety analysis and highlights the importance of data-driven decision making for accident prevention. The proposed safety recommendations, including improved traffic control, enhanced street lighting, pedestrian facilities, speed regulation measures, and junction improvements, can significantly reduce accident occurrence along the study corridor.

Overall, the research provides a reliable framework for accident hotspot identification and road safety assessment that can be extended to other accident-prone corridors for future transportation planning and safety management.

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