International Journal of Scientific Research in Engineering and Management (IJSREM)
Special Edition - Volume 09 ICITES -2025 SJIF Rating: 8.586 ISSN: 2582-3930

Visualization of Road Crash Hot Spots in Kerala using Spatial Statistics

Haznah Nazar[1], Febin Fathima[2], Asiya Abdul Samad[3] , Jose James[4], Chandni J Basu[5]

[1]*St. Joseph's College of Engineering and Technology, Palai*
[2]*St. Joseph's College of Engineering and Technology, Palai*
[3]*St. Joseph's College of Engineering and Technology, Palai*
[4]*St. Joseph's College of Engineering and Technology, Palai*
[5]*Traffic Engineering and Safety Division, NATPAC*

---***---

Abstract - Road crashes have been following an increasing trend in Kerala, leading to a high death toll and financial hardship. It is essential to understand crash trends and identifying crash-prone areas for enhancing road safety. Spatial Statistics methods using Moran's I (Global and Local Moran's) and Getis-Ord Gi* were utilized in this work to analyse the crash data and pinpoint high-risk locations. Significant clustering patterns were revealed in the spatial analysis of road crashes in Kerala, suggesting that crashes especially those involving fatalities and serious injuries, were not dispersed at random. High-risk areas were observed to be clustered with statistically significant clusters at 99% and 95% confidence intervals. Hotspot analysis identified Thiruvananthapuram, Ernakulam, and Kollam districts as high-risk areas, especially along important road corridors such as National Highway 66, MG Road, and Kollam-Ayur Road. The results shows that the minor crashes occur at urban areas with lower vehicle speeds and high crashes occur at major highways, intersections, etc. GIS-based spatial statistics used in this work supports data-driven decision-making aimed at enhancing road safety in Kerala.

***Key Words*:** Spatial Statistics, Road Crash hot spots, Moran's I, GIS, Kerala

1.INTRODUCTION

Since traffic crashes claim millions of lives every year, road safety is a major concern on a global scale. One effective way to address this problem is by using Geographic Information Systems (GIS) in road safety assessments. Spatial analysis of accident data is made possible by GIS technology, which reveals trends, patterns, and connections between crashes and other elements like traffic volume, road infrastructure, and environmental conditions. Hotspot analysis and crash data visualization using GIS technology have become increasingly popular as it effectively saves time and effort. The use of GIS in crash investigations has been documented in numerous research articles.

The scope of the study is limited to Kerala State. The study performed spatial statistical analysis using Moran's I and Getis-Ord Gi* to examine the statistical significance of spatial autocorrelation, and to identify significant cluster locations with High-High (HH) and Low-Low (LL) crash severity values.

OBJECTIVES

- **To perform spatial analysis to identify the trends and patterns**: Through the detection of clusters, outliers, and high-risk areas, spatial analysis aids in the identification of crash trends and patterns.
- **To identify the crash hotspots using Hot Spot Analysis**: Identifies the hotspots where crashes occurred, allowing to plan for safety measures.

2. STUDY AREA

The study area is Kerala, situated on the southwest corner of India with coordinates 10.0°N 76.3°E, spreading over 38,863km^2. Kerala is known for its high population density, with vast road networks and varied terrain. Road safety is impacted by the unique features of each of the state's 14 districts. Districts like Thiruvananthapuram and Ernakulam experience more crashes brought on by heavy traffic and they may also be based on temporal trends such as seasonal variations, time-based pattern, etc. Fig 1 illustrates the study area, highlighting Kerala's diverse road network and population density.

Fig 1: Study area – Kerala

3. METHODOLOGY

The data collection and clustering method for the distribution and clustering of road crashes in Kerala was carried out using Spatial statistical methods. For this purpose data were collected on road crashes from three years (2021–2023), imported in ArcGIS Pro and further by means of spatial analysis methods were applied. After the analysis global Moran I was used to identify overall spatial autocorrelation while local Moran I was used for identifying specific clusters and finally by means of Hotspot Analysis was used to identify high risk crash zones.

3.1 Data Collection

The crash data of Kerala during the years 2021, 2022 and 2023 were collected from the State Crime Records Bureau, Kerala Police. For the analysis, attributes such as crash severity (grievous, death) and total victims were extracted.

3.2 Import data into ArcGIS

The collected data was imported into ArcGIS Pro for analysis which included Moran's I and Hotspot Analysis. The shapefile of Kerala with administrative boundaries was obtained and loaded into ArcGIS pro for the analysis.

3.3 Spatial Analysis

Spatial analysis refers to the process of examining the spatial distribution and patterns in the road crash data. The data was analysed using Moran's I and Hot Spot Analysis from the Spatial Statistic Tools in ArcGIS Pro.

3.4 Global Moran's I

In this approach, the crash data of three years was combined and imported into ArcGIS Pro and spatial autocorrelation was done using Global Moran's I method from the geoprocessing tool. In Global Moran's I, the input feature class given was the crash data and accident severity fields such as grievous and death, and total victims were given as input fields. The result of analysis of each severity field gives a spatial autocorrelation report with values of Moran's Index, Expected Index, variance, z-score and p value where z-scores are standard deviation and p value is the probability.

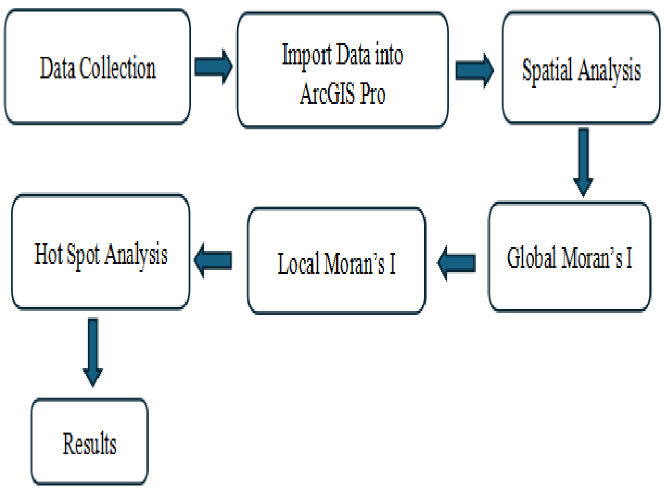


Fig 2 Methodology Flowchart

3.5 Local Moran's I

The tool used was Cluster and Outlier Analysis (Anselin Local Moran's I). For local Moran's I, the results of the input feature class and the input field were undertaken as Global Moran's I. This result indicates that there are spatial clusters of features with high or low values, i.e. High-High and Low-Low clusters.

3.6 Hot Spot Analysis

The result generated from the Local Moran's I analysis was used in the hotspot analysis using the tool Hot Spot Analysis (Getis-Ord Gi*). The results of the analysis give hotspots where crashes are concentrated based on confidence intervals of 90%, 95% and 99%. Fig 2 shows the methodology flowchart.

4. RESULTS AND DISCUSSIONS

4.1 Global Moran's I

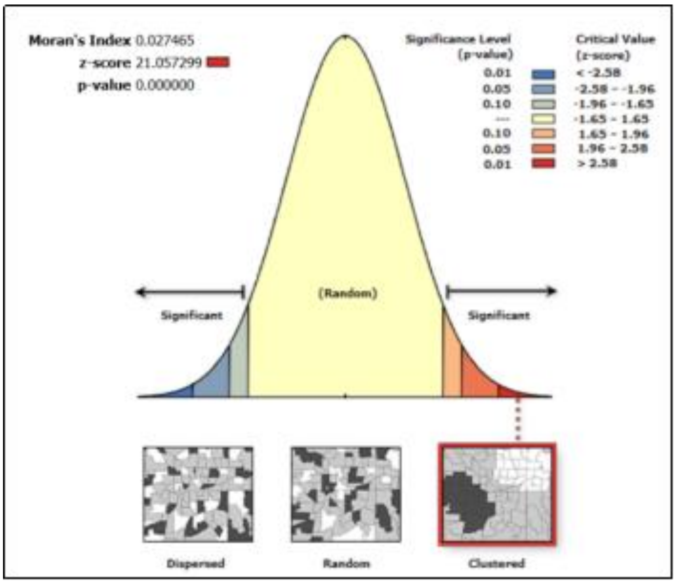
In this approach using a single Moran's I index and statistical test, the Global Moran's I analysis was utilized to investigate the existence of statistically significant spatial autocorrelation between crashes for different severities. This analysis revealed whether similar crash severities were distributed throughout the area or clustered together. Table 1 shows the results of the analysis and Fig 3 shows the Spatial autocorrelation Report for death, grievous and total victims field.

Table 1. Summary of Global Moran's I Analysis Results

Field	**Death**	**Grievous**	**Total Victims**
Moran's Index	0.015682	0.027465	0.023661
Expected Index	-0.000008	-0.000008	-0.000008
Variance	0.000002	0.000002	0.000002
z-score	12.025680	21.057299	18.211740
p-value	0.000000	0.000000	0.000000

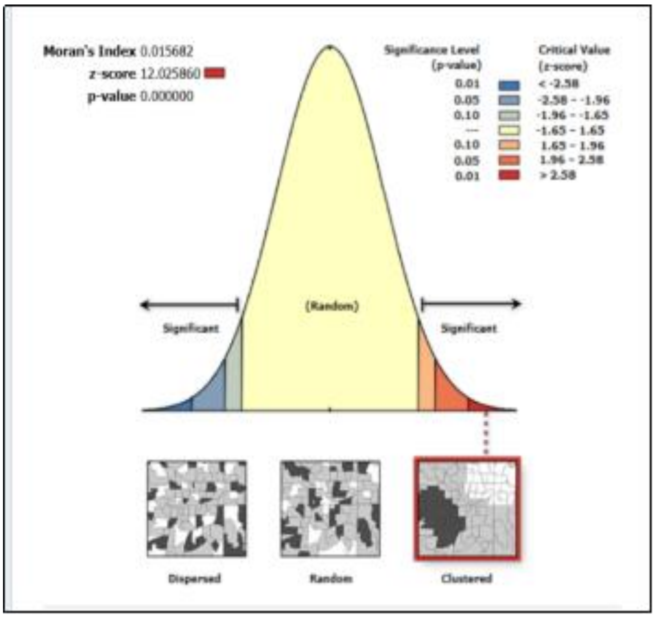
International Journal of Scientific Research in Engineering and Management (IJSREM)
Special Edition - Volume 09 ICITES -2025 SJIF Rating: 8.586 ISSN: 2582-3930

For fatal crash severity in Fig 3 (a), Moran's I value (0.015682) is positive. It indicates that fatal crashes tend to concentrate in specific locations rather than being dispersed randomly. The p-value (0.000000) and the extremely high z-score (12.025680) both attest to the statistical significance of this clustering, signifying that it is not occurring by chance. The number of fatal crashes in Kerala is higher in some districts when compared to others.



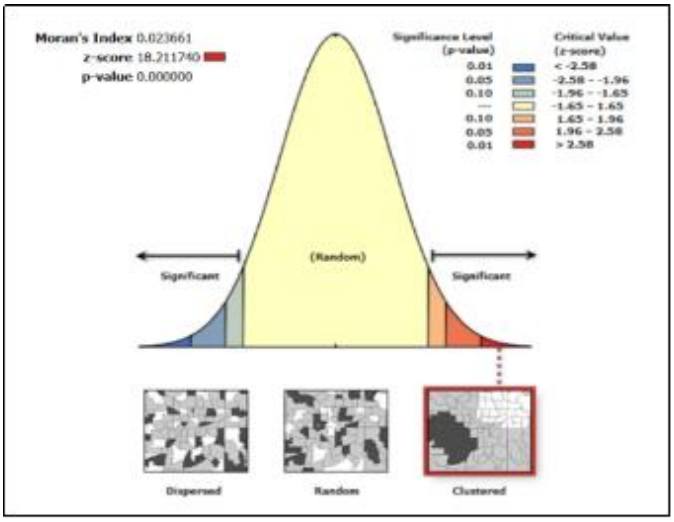
(a) Death

In Fig 3 (b), the Moran's I value for grievous injuries (0.027465) was higher than that of fatal crashes and it clearly indicates that the grievous injury crashes were also concentrated in specific regions. The p-value (0.000000) and the extremely high z-score (21.057299) attest to the statistical significance of these clusters, indicating that they are not occurring by chance. Majority of the crashes in Kerala result in grievous injury when compared to deaths.



(b)Grievous

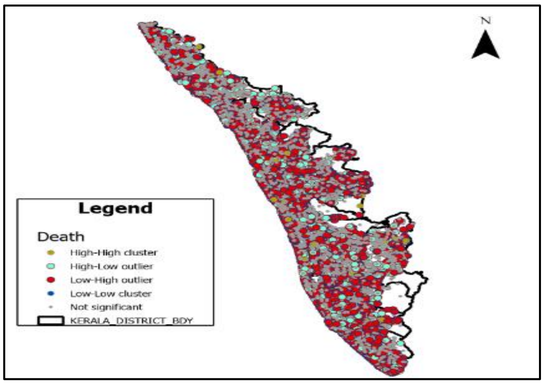
For total victims in Fig 3 (c), the Moran's I value was positive (0.023661), indicating that crashes with multiple casualties prefer to cluster in particular locations rather than disperse randomly. The p-value (0.000000) and the extremely high z-score (18.211740) both attest to the statistical significance of this clustering, indicating that it is not occurring by chance.



(c) Total Victims

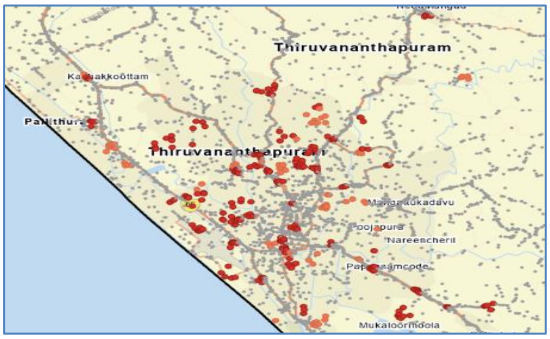
4.2 Local Moran's I

The map in Fig 4 (a) displays the Local Moran's I clusters for crashes with Grievous Injury in Kerala. High-High clusters show areas of severe crashes with frequent grievous injuries that may be due to unsafe road conditions and Low-Low clusters show areas with fewer grievous injuries. Low-High clusters indicate areas with fewer grievous injuries surrounded by areas with higher number of grievous injuries and High-Low clusters show areas with higher number of grievous injuries surrounded by areas with lower number of grievous injuries.



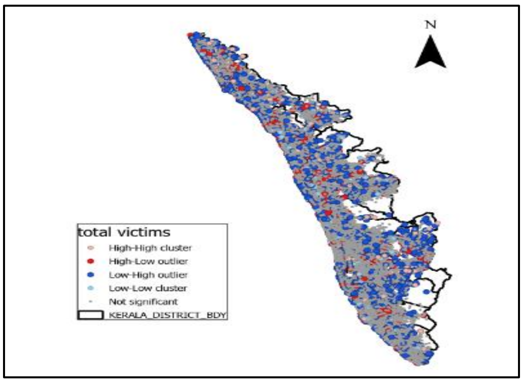
(a) Grievous Injury

Fig 4 (b) represents result of the Local Moran's Clusters of Death field where Low High outliers are highly concentrated. Low-High Outliers are regions with fewer accident fatalities that are surrounded by areas with higher number of fatalities.



(b) Death

Fig 4 (c) represents the result when the input field is total victims involved in the crashes. Here, High-Low and Low-High clusters are more which indicates that despite being surrounded by places with relatively lower accident severity, these locations still have a high number of crash victims. This suggests an isolated crash hotspot that needs focused intervention since it shows the existence of a localized high-risk zone inside an otherwise safer area.



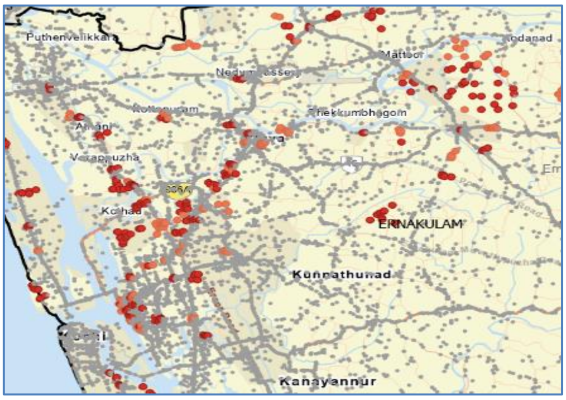
(c)Total victims

Fig 4: Results of Local Moran's I for crashes with grievous injuries, deaths and total victims

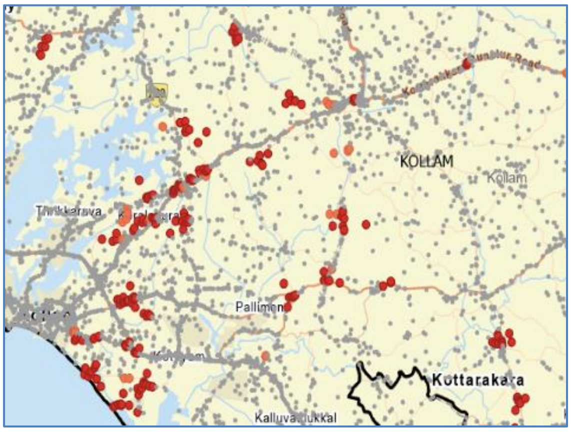
4.3 Hot Spot Analysis

Fig 5 represents the districts with higher number of critical hotspots where the accident density was high with a 99% confidence interval. Crashes were more in areas such as Kazhakootam and MG road of Thiruvananthapuram district, Kalamassery Road and Pullepady of Ernakulam district and Kollam-Ayur Road and Chadayamangalam of Kollam district.

(a) Thiruvanathapuram



(b) Ernakulam

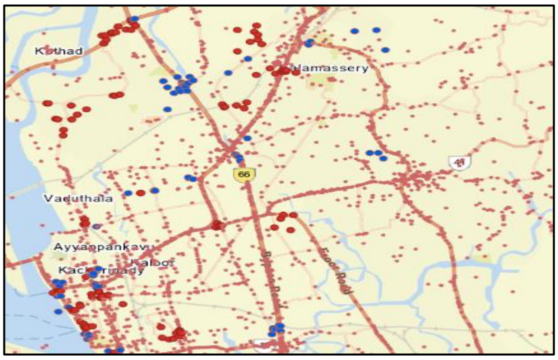


(c) Kollam

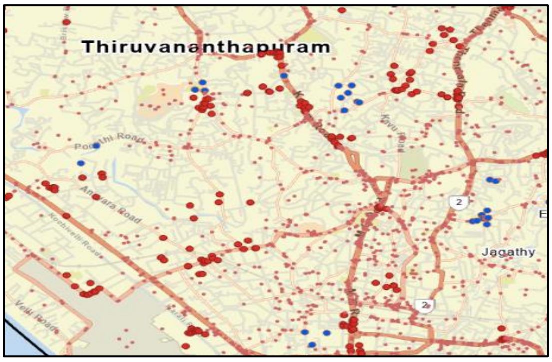
Fig 5: Hotspot areas with 99% confidence interval of Grievous Injury

Fig 6 represents the hotspot areas when Death was given as the input field. Ernakulam and Thiruvananthapuram districts tend to have high risk crash zones among the districts. They are statistically significant hotspots with 99% confidence interval which means that the results are extremely reliable and not due to random variations in crash frequency. The blue-colored ones are the hotspots with 95% confidence interval. Although not quite as severe as the 99% confidence hotspots, these crash clusters are statistically significant as well.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Special Edition - Volume 09 ICITES -2025 SJIF Rating: 8.586 ISSN: 2582-3930



(a) Hotspots of Ernakulam



(b) Hotspots of Thiruvanathapuram

Fig 6: Hotspot areas with 99% confidence interval of Deaths

Fig 7 represents the districts with higher number of hotspots for total victims involved in the crashes. The red coloured spots show the hotspots with 99% confidence interval, with high statistical certainty for accident prone locations. Orange coloured spots show the hotspots with 95% confidence interval. Fig 8 shows the crash statistics for 2021, 2022 and 2023.

(a)Hotspots of Ernakulam

Fig 7 Hotspots of Total Victims field

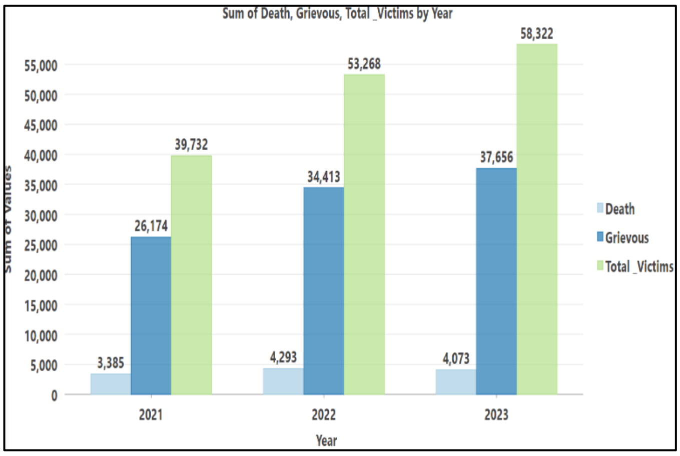


Fig 8: Sum of crashes with Deaths, Grievous Injuries and Total Victims by year

5.CONCLUSION

The purpose of this study was to use spatial statistics, such as Global Moran's I, Local Moran's I, and Hotspot Analysis, to examine the spatial distribution of traffic crashes in Kerala. The findings offer a comprehension of crash clustering and aids in locating high-risk regions that need prompt attention. A statistically significant spatial autocorrelation among crashes in Kerala was validated by the Global Moran's I analysis, suggesting that crashes are not dispersed randomly but rather tend to cluster in specific areas. This implies that crash occurrences may be influenced by outside variables like road conditions, driving behaviour, traffic volume or enforcement levels.

Significant clustering patterns were revealed in the spatial analysis of road crashes in Kerala, suggesting that crashes especially those involving fatalities and serious injuries, were not dispersed at random. High-risk areas were observed to be clustered with statistically significant clusters at 99% and 95% confidence intervals. Hotspot analysis identified Thiruvananthapuram, Ernakulam, and Kollam districts as high-risk areas, especially along important road corridors such as National Highway 66, MG Road, and Kollam-Ayur Road. The results shows that the minor crashes occur at urban areas with lower vehicle speeds and high crashes occur at major highways, intersections, etc. GIS-based spatial statistics used in this work supports data-driven decision-making aimed at enhancing road safety in Kerala.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Kerala Police for sharing the crash data for undertaking the study. The authors also acknowledge Mr. Ebin Sam, Scientist, National Transportation Planning and Research Centre (NATPAC) for facilitating and providing technical guidance for the study.

REFERENCES

1. Wondwossen Taddesse Gedamu , Uwe Plank-Wiedenbeck , Bikila Teklu Wodajo, A spatial autocorrelation analysis of road traffic crash by severity using Moran's I spatial statistics: A comparative study of Addis Ababa and Berlin cities, Accident analysis and Prevention, Volume 200, June 2024, 107535
2. Deepika Munasinghe, Spatial Analysis of Urban Road Traffic Accidents Using GIS, December 2023, British Journal of Multidisciplinary and Advanced Studies 4(6):70-83
3. Nishant Singh, Sunil Kumar Katiyar, Application of GIS in Reducing Accident Black Spots and Planning Safe Urban Road Network, Ecological Informatics Volume 66, December 2021, 101436
4. Sandeep Gupta, Pradeep Kumar Garg, Sanjay Kumar Ghosh, Analysis of Road Accidents Using GIS, SSRG International Journal of Civil Engineering, 1 September 2022
5. Raju Bhele, Sameer Dhungana, Dikshit Chimoriya, Aabhushan Sapkota, Sujan Ghorasaini, Spatial and Temporal Analysis of Road Traffic Accidents Using GIS, International Journal on Engineering Technology (InJET)Volume 2, issue no. 1, Dec 2024