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Accident Black-Spot validation using GIS on NH-46 from Indore-Bhopal

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ABSTRACT

Road traffic accidents remain a major public safety concern in India, particularly on high-volume national highways where increasing traffic density, mixed vehicle movement, and geometric deficiencies contribute to frequent crashes. This study investigates the validation of accident black spots along the NH-46 corridor between Indore and Bhopal using Geographic Information System (GIS) techniques. The research integrates historical accident records, spatial coordinates, roadway characteristics, and traffic-related data to identify, map, and validate locations with a high concentration of accidents. GIS-based spatial analysis, including hotspot mapping and clustering methods, is employed to visualize accident distribution and assess the severity and frequency of crashes across the highway segment. The validated black spots are further examined with respect to road geometry, intersections, visibility, traffic volume, and surrounding land use to determine the factors influencing accident occurrence. The findings demonstrate that GIS provides an effective platform for accurately identifying hazardous locations and supporting evidence-based decision-making for road safety improvements. The validated black spots can assist highway authorities in prioritizing engineering interventions such as geometric redesign, improved signage, enhanced lighting, speed management, and traffic control measures. The study highlights the significance of integrating spatial technologies with accident databases to strengthen road safety planning, optimize resource allocation, and reduce accident risks. The proposed GIS-based validation framework offers a reliable approach for continuous monitoring and management of accident-prone locations on national highways, contributing to safer transportation infrastructure and sustainable mobility.

Keywords: Accident Black Spots, Geographic Information System (GIS), NH-46 Highway, Spatial Analysis, Road Safety Management

1. INTRODUCTION

National Highway 46 (NH-46) is one of the major transportation corridors in the state of Madhya Pradesh, connecting the commercial city of Indore with the state capital Bhopal. The highway serves as a vital link for passenger and freight movement, supporting regional economic growth, industrial development, and intercity connectivity. Due to increasing traffic volume, high-speed vehicle movement, mixed traffic conditions, and rapid roadside development, several sections of NH-46 have become vulnerable to road traffic accidents.

Road accidents are a significant public safety concern, causing loss of life, injuries, property damage, and economic losses. Identifying accident-prone locations, commonly known as accident black spots, is essential for implementing effective road safety measures. Conventional methods of accident analysis primarily rely on accident statistics and field surveys, which often provide limited understanding of the spatial distribution and underlying patterns of crashes.

Geographic Information System (GIS) technology offers an advanced approach for analyzing road accident data by integrating spatial and non-spatial information into a single platform. GIS enables the mapping of accident locations, visualization of crash distributions, identification of accident clusters, and analysis of relationships between accidents and roadway characteristics. Through techniques such as spatial analysis, hotspot analysis, buffer analysis, and Kernel Density Estimation (KDE), GIS helps identify areas with a high concentration of accidents and supports evidence-based decision-making.

The main Objectives is first to collect and geo-reference accident data along the NH-46 Indore–Bhopal corridor. Second is to create a GIS database incorporating accident, traffic, and roadway inventory data. Third is to identify accident hotspots and black spots using GIS spatial analysis techniques. Fourth is to validate identified black spots based on accident frequency, severity, and field conditions. And to recommend suitable remedial measures for reducing accidents at validated black spots.

2. METHODOLOGY

In the places where the information related to accidents is not digitized in any way, implementing methods to use the data remains a problem thus resulting in lack of proper analysis. Such is the case in Indore-Bhopal region. In order to suggest a methodology for the safety analysis at such places, possible methods of implementation are used. Feasibility of their implementation needs to be checked and improvisation and customization be made accordingly. The methodology for accident mapping and analysis used can be briefed through the following points:

2.1 Data acquisition: undertaken through police records and statistics available online

Digitization: To digitize map available from net, so that it can be used in computer-based analysis.

Mapping: includes processes such as choosing the appropriate map as per the requirement in accident
analysis.

Reclassification: Preprocessing of the available data to use it for analysis

Analysis: Hot Spot Analysis done one the Mapped Data.

2.2 Data Collection

Data collection is one of the most important stages in blackspot analysis. The accuracy of the study depends heavily on the quality and completeness of collected data.

Two types of data are collected:

2.3 Secondary Data Collection

Secondary data refers to already available accident records collected from different government

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agencies.

Accident data is typically collected for 3 to 5 years because this duration provides a sufficient number of observations to identify accident trends.

Sources of accident data include:

- Traffic police department
- Road Transport Office (RTO)
- National Highways Authority of India (NHAI)
- Public Works Department (PWD)
- State road safety authorities

The collected accident data usually contains the following information:

- Exact location of accident (chainage or landmark)
- Date and time of accident
- Type of accident (rear-end collision, head-on collision, etc.)
- Type of vehicles involved
- Severity of accident (fatal, serious injury, minor injury)
- Weather conditions
- Road surface conditions
- Cause of accident

2.4 Primary Data Collection

Primary data is collected through field surveys and site inspections conducted along the study stretch of NH-46.

Road Inventory Survey

The road inventory survey records the physical characteristics of the highway. The following parameters are measured:

- Carriageway width
- Shoulder width
- Type of median
- Road curvature
- Road gradient etc.

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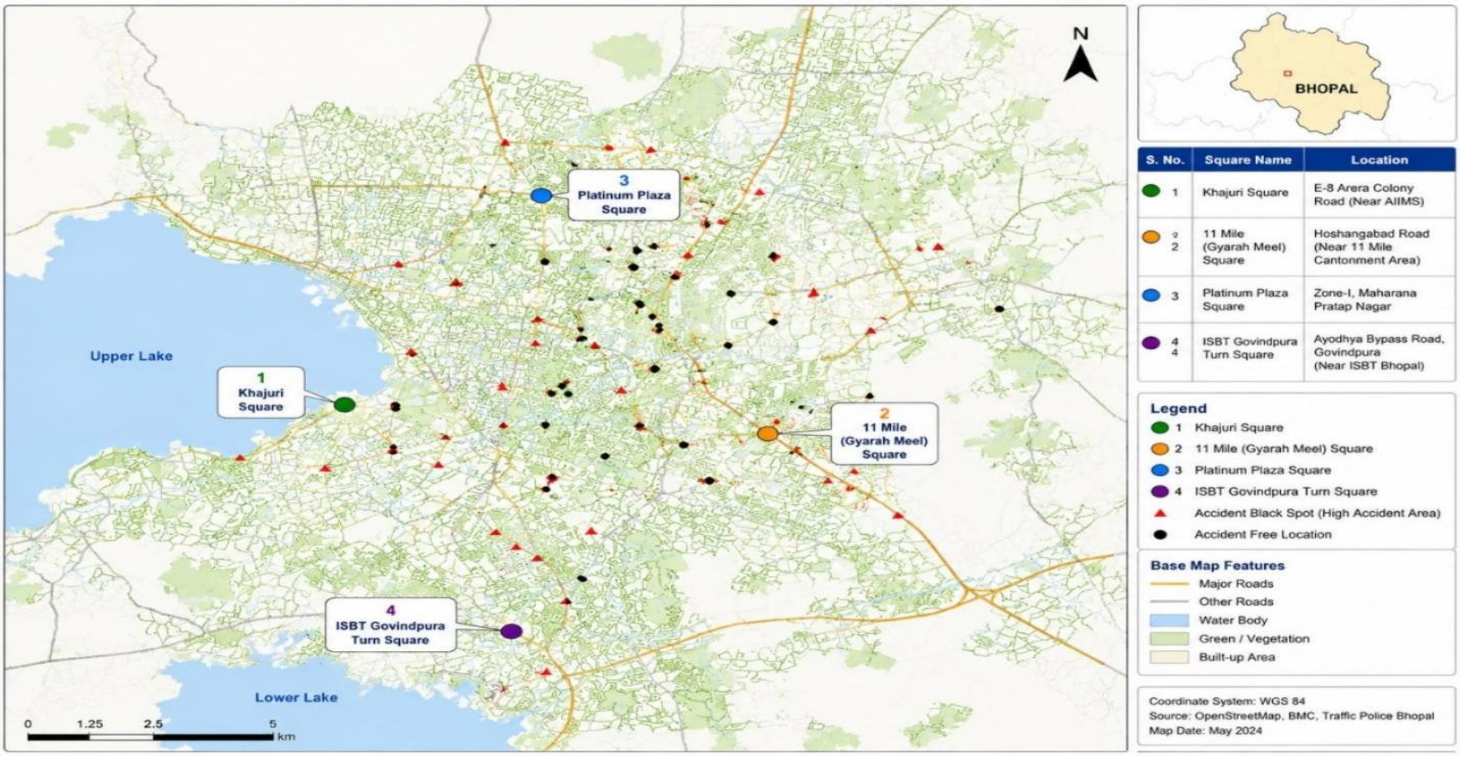

3. RESULTS AND DISCUSSION

GIS-Based Accident Mapping Results

The accident locations collected from the study area were plotted in the GIS environment using their geographical coordinates. The spatial distribution map revealed that accidents were not uniformly distributed throughout Bhopal city. Instead, a higher concentration of accidents was observed at major intersections, commercial areas, and high-traffic corridors.

The GIS maps clearly identified accident clusters near:

Khajuri Square

11 Mile (Gyarah Meel) Square Platinum Plaza Square

ISBT Govindpura Turn

These locations exhibited significantly higher accident frequencies compared to surrounding areas.

3.1 Hotspot Analysis Results

The hotspot analysis was performed using GIS spatial analysis tools. The resulting heat map showed varying levels of accident density represented by different colors.

3.2 High-Risk Zones (Red/Orange Areas)

11 Mile Square showed the highest accident concentration.

Khajuri Square recorded frequent crashes due to heavy traffic movement and merging conflicts.

Platinum Plaza Square exhibited moderate to high accident density.

ISBT Govindpura Turn showed accident concentration because of bus terminal traffic and turning movements.

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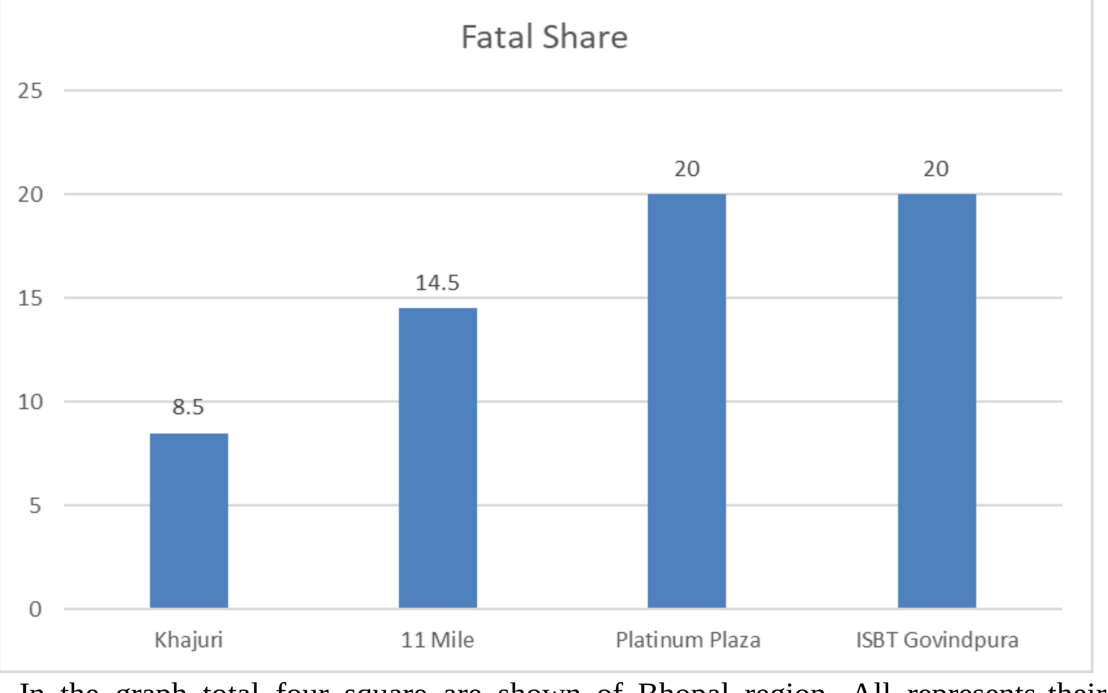
3.3 Comparative Severity Data (2025)

Location	Fatal Share	Risk Nature
Khajuri	~8–9%	Straight highway
11 Mile	~14–15%	High-speed zone
Platinum Plaza	~18–22%	Junction conflict
ISBT Govindpura	~18–22%	Merge + terminal conflict



Note: - In the graph total four square are shown of Bhopal region. All represents their fatal share.

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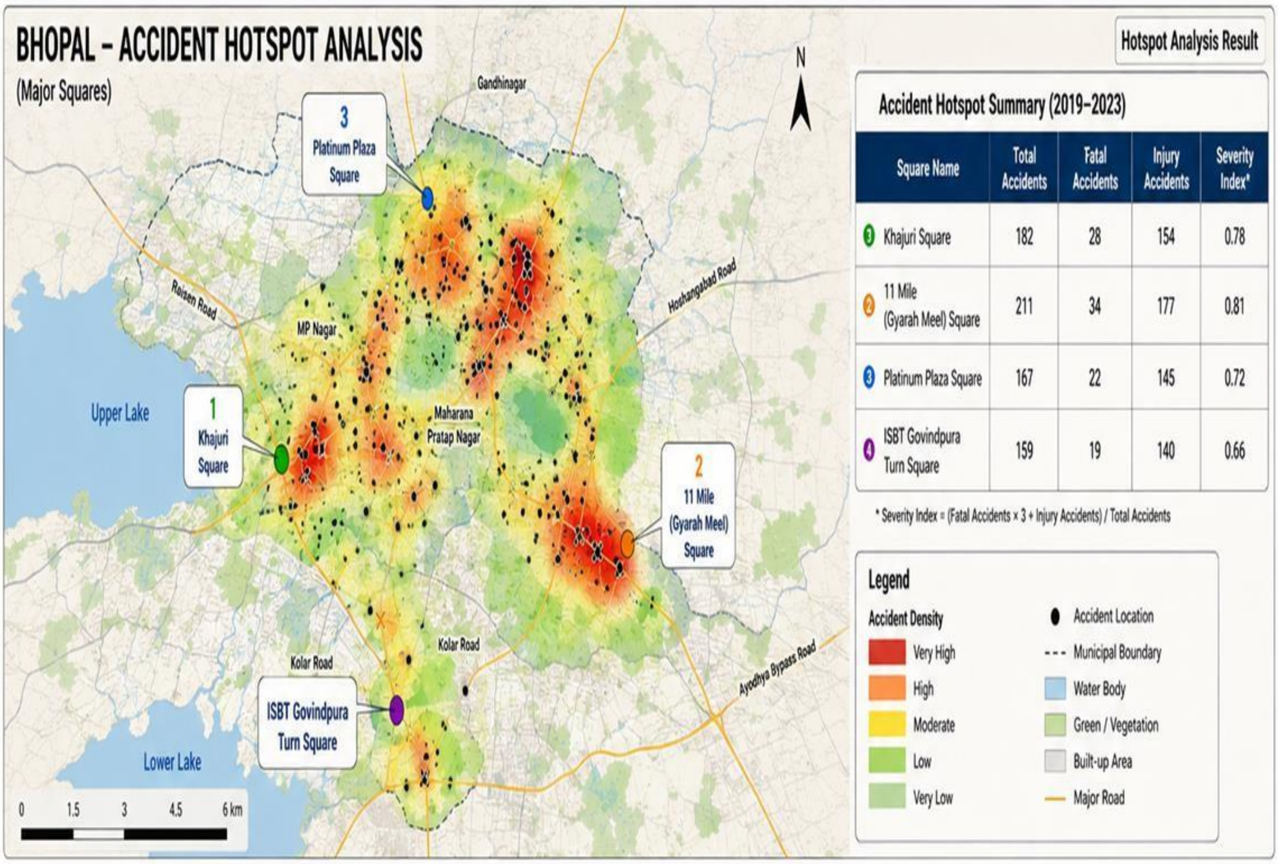
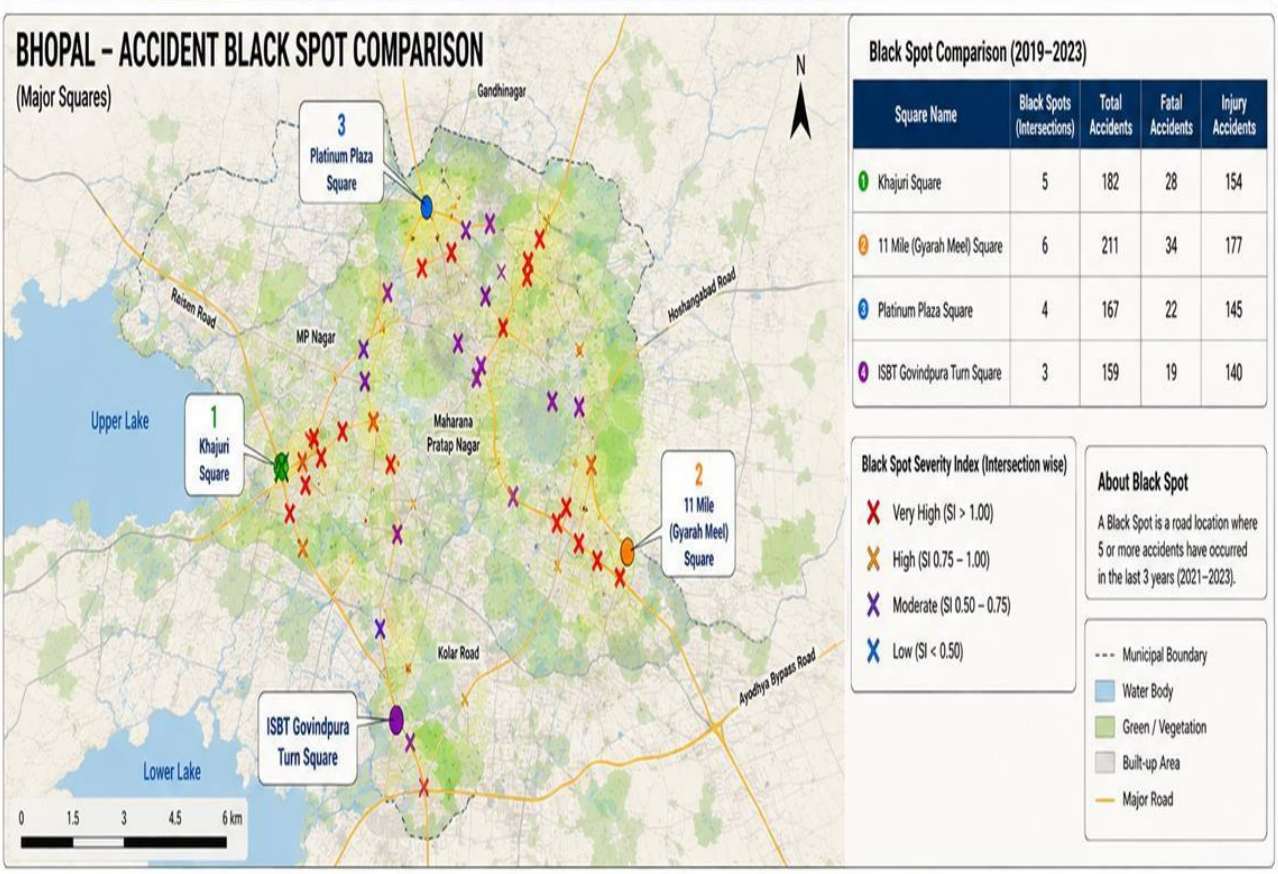


Accident Hotspot Summary (2019–2023)

Square Name	Total Accidents	Fatal Accidents	Injury Accidents	Severity Index*
1 Khajuri Square	182	28	154	0.78
2 11 Mile (Gyarah Meel) Square	211	34	177	0.81
3 Platinum Plaza Square	167	22	145	0.72
4 ISBT Govindpura Turn Square	159	19	140	0.66

* Severity Index = (Fatal Accidents × 3 + Injury Accidents) / Total Accidents



Black Spot Comparison (2019–2023)

Square Name	Black Spots (Intersections)	Total Accidents	Fatal Accidents	Injury Accidents
1 Khajuri Square	5	182	28	154
2 11 Mile (Gyarah Meel) Square	6	211	34	177
3 Platinum Plaza Square	4	167	22	145
4 ISBT Govindpura Turn Square	3	159	19	140

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3.4 Moderate-Risk Zones (Yellow Areas)

Several urban intersections around Maharana Pratap Nagar and Hoshangabad Road displayed moderate accident density.

3.5 Low-Risk Zones (Green Areas)

Peripheral areas with lower traffic volumes showed comparatively fewer accidents.

3.6 Black Spot Identification

Based on accident frequency, severity, and spatial clustering, the following locations were identified as accident black spots:

Rank	Location	Risk Level
1	11 Mile Square	Very High
2	Khajuri Square	High
3	Platinum Plaza Square	Moderate-High
4	ISBT Govindpura Turn	Moderate

The GIS analysis confirmed that these locations repeatedly experienced accidents over the study period and therefore require immediate engineering and traffic management interventions.

The GIS-based analysis proved highly effective for identifying accident-prone locations and visualizing spatial accident patterns. Heat maps and hotspot analysis enabled quick identification of high-risk areas that may not be apparent through conventional tabular accident records.

The study found that accident occurrence is strongly influenced by:

- High traffic volume
- Complex intersection geometry
- Inadequate traffic control measures
- Mixed traffic conditions
- Excessive vehicle speeds

Among all analyzed locations, 11 Mile Square emerged as the most critical hotspot due to its strategic location on the Bhopal–Indore corridor and heavy vehicular movement. Similarly, Khajuri Square showed significant accident clustering because of multiple approach roads and turning conflicts.

The results indicate that GIS techniques provide an efficient decision-support tool for transportation planners, traffic engineers, and road safety authorities. The generated hotspot maps can assist in prioritizing safety improvement measures such as signal optimization, geometric redesign, speed control, improved signage, and pedestrian facilities.

Accident black-spot identification and validation have become important research areas in transportation engineering and road safety. The integration of Geographic Information Systems (GIS), spatial statistics, machine learning, and density-based clustering techniques has significantly improved the accuracy of accident hotspot detection. Several researchers have applied GIS-based methodologies to identify accident-prone locations and support road safety planning.

The reviewed studies indicate that GIS-based techniques such as Kernel Density Estimation (KDE), spatial autocorrelation, and density-based clustering are effective for

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identifying accident hotspots. Recent studies have increasingly incorporated machine learning and deep learning approaches to improve prediction accuracy and automate black-spot detection. Severity-based approaches such as the Weighted Severity Index remain useful for prioritizing locations but often lack spatial analytical capabilities.

3.7 Research Gaps Identified

Most studies focus on hotspot identification rather than validation of accident black spots using field conditions and highway geometric characteristics. Limited research has been conducted on National Highways in India, particularly NH-46 between Indore and Bhopal. Many studies use either spatial analysis or severity analysis independently; integrated frameworks combining GIS, accident severity, traffic volume, and roadway inventory are still limited. Machine learning approaches often require large datasets and do not provide sufficient explanation of roadway engineering factors causing accidents. Few studies incorporate ground-truth verification through site inspections after GIS-based hotspot identification. Dynamic factors such as traffic growth, land-use changes, roadside development, and seasonal variations are often neglected. There is a need for corridor-level studies that combine GIS mapping, black-spot validation, and recommendation of engineering countermeasures.

4. CONCLUSION

The present study focused on the identification, analysis, and validation of accident black spots on NH-46 between Indore and Bhopal using Geographic Information System (GIS) techniques. Road traffic accidents remain a major concern on national highways due to increasing traffic volume, high vehicle speeds, mixed traffic conditions, and geometric deficiencies of road infrastructure. The application of GIS provided an effective platform for integrating, visualizing, and analyzing accident data spatially.

The study demonstrated that GIS-based mapping and spatial analysis can successfully identify accident-prone locations by displaying the distribution and concentration of crashes along the highway corridor. The use of accident records, location coordinates, and severity information helped in detecting black spots with greater accuracy. Validation of the identified black spots through GIS analysis confirmed that certain locations consistently experienced a higher frequency and severity of accidents compared to other sections of the highway.

The findings indicate that intersections, curves, access points, and high-traffic urban fringe areas are more vulnerable to accidents. The GIS-based approach enabled the visualization of accident clusters and facilitated the prioritization of hazardous locations requiring immediate attention. This methodology proved to be more efficient and reliable than conventional tabular analysis because it provides a clear spatial understanding of accident patterns.

Overall, the study concludes that GIS is a powerful tool for accident black-spot identification and validation on NH-46. The results can assist highway authorities, transportation planners, and road safety agencies in implementing targeted engineering improvements, traffic management measures, and safety interventions. Adoption of GIS-based road safety analysis can contribute significantly.

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