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Analysis of Road Accidents on Highways in Madhya Pradesh: Trends, Contributing Factors, and Blackspot Identification

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Abstract: This study analyzes road accidents on highways in Madhya Pradesh from 2016 to 2023, highlighting the alarming rise in accident rates and fatalities. Using primary and secondary data, including field surveys, GIS mapping, and traffic records, the research identifies key contributing factors such as over-speeding, drunk driving, poor road infrastructure, and driver distractions. A significant portion of the accidents occurred on major highways like NH-44 and SH-27, with specific blackspots identified using GIS technology. Regression models were developed to predict accident likelihood based on factors like traffic volume, road quality, and weather conditions. The study found that two-wheelers were the most vulnerable vehicle type, with high fatality rates. The research underscores the need for improved road safety interventions, including enhanced speed enforcement, better road infrastructure, stronger drunk driving laws, and public safety awareness campaigns. The findings aim to guide policymakers in reducing road accidents and fatalities, ultimately improving highway safety in Madhya Pradesh. Future work includes refining predictive models and implementing real-time data collection systems for dynamic safety management.

Keywords: Highways, Road Safety, Indicators, Accidents, Blackspots, Madhya Pradesh

1. Introduction

The increasing number of road accidents represents a critical public health and safety challenge, particularly on highways characterized by higher traffic volumes and vehicle speeds. Highways shavee as vital arteries for economic and social connectivity, yet their potential for severe traffic incidents has escalated alongside growing vehicular use and infrastructure expansions [1]. In Madhya Pradesh, one of India's largest and most diverse states, highway accidents have been on a steady rise over the past decade, underlining the urgent need for systematic analysis and intervention. Recent studies indicate that the state faces a disproportionate burden of traffic-related injuries and fatalities, emphasizing its role as a key focus area for road safety research. The motivation for this study stems from the alarming trends observed in road accident statistics, which reveal significant human and economic costs. Between 2016 and 2023, Madhya Pradesh recorded a consistent increase in both the number of accidents and associated fatalities. These incidents not only disrupt lives but also impose a heavy burden on public health systems, insurance sectors, and the broader economy. Understanding the underlying causes of these accidents is essential for developing effective policies that prioritize safety without compromising mobility.

Furthermore, the identification of blackspot locations with disproportionately high accident rates has emerged as a critical element of targeted interventions, inspiring this comprehensive investigation. This study aims to address the multifaceted challenges of highway safety in Madhya Pradesh through the objective of analyzing road accident trends from 2016 to 2023 to discern patterns and anomalies. Identifying key contributing factors such as driver behaviour, infrastructure deficiencies, and environmental conditions. Determining high-risk areas (blackspots) using Geographic Information System (GIS) mapping to enable precise and actionable interventions. Proposing data-driven road safety interventions to mitigate the frequency and severity of accidents. The contribution of this

study lies in its holistic approach to examining highway safety in Madhya Pradesh. Unlike fragmented studies focusing solely on isolated variables, this research integrates statistical analyses, GIS-based spatial mapping, and stakeholder surveys to provide a comprehensive understanding of accident dynamics. Key contributions include such as an updated and detailed accident database covering seven years. Identification and categorization of blackspots with precise geospatial coordinates. Development of regression-based predictive models for accident likelihood, incorporating traffic volume, road quality, and weather conditions. Actionable recommendations for policymakers and practitioners, including infrastructure upgrades, enforcement mechanisms, and public awareness campaigns. The remaining sections of this article are organized as follows: The methodology section describes the data collection and analysis techniques employed, including statistical tools and GIS applications. The road accident trends section Provides an in-depth analysis of accident statistics from 2016 to 2023, highlighting key patterns and disruptions.

The contributing factors section explores the primary causes of accidents, such as over-speeding, drunk driving, and infrastructure deficiencies. The high-risk areas (Blackspots) section identifies and analyzes blackspots with a focus on their unique challenges and intervention needs. Accident severity by vehicle type section examines the differential impact of accidents on various vehicle categories. Road safety awareness section Evaluates gaps in public awareness and compliance with traffic regulations. The accident prediction models section presents regression-based predictive models for assessing accident risk under varying conditions. The discussion and recommendations section synthesizes findings to propose targeted safety interventions. Conclusion section Summarizes the key insights and their implications for improving highway safety in Madhya Pradesh. The integrated approach adopted in this study aims to bridge existing research gaps and contribute to more effective road safety management in one of India's most accident-prone states.

.2. Methodology

This study employs a comprehensive methodology to analyze the factors contributing to road accidents on highways in Madhya Pradesh. Both primary and secondary data sources were utilized to ensure a robust and multidimensional understanding of the issue. Primary data collection involved field surveys and interviews with key stakeholders, including traffic police officials, highway users, and residents near identified accident-prone areas. These surveys provided first-hand insights into driver behaviour, road conditions, and enforcement challenges. Additionally, Geographic Information System (GIS) technology was used to map and visualize accident locations, enabling the identification of high-risk zones or black spots. Secondary data was obtained from the Madhya Pradesh Traffic Police, which provided detailed accident records from 2016 to 2023. These records included information on accident frequency, severity, vehicle type, and contributing factors. The annual road accident statistics from 2016 to 2023 (Table 1) revealed trends in total accidents, fatalities, and injuries, which were instrumental in understanding the scope and severity of road accidents in the region. Supplementary data was gathered from government agencies, including the National Highway Authority of India (NHAI), to ensure accurate and up-to-date information on road infrastructure and traffic management systems. A variety of statistical tools were employed in this study to uncover meaningful patterns and relationships within the data. Descriptive statistics were used to summarize accident trends, including annual variations in the total number of accidents, fatalities, and injuries. Correlation analysis examined the relationships between key variables, such as traffic density and accident frequency, to identify significant associations. Regression analysis further refined these insights by developing predictive models to assess the likelihood of accidents based on contributing factors like road quality, weather conditions, and traffic volume.

Table 1: Annual Road Accident Statistics in Madhya Pradesh (2016-2023)

Year	TA	FA	Injuries	Fatalities
2016	48,065	7,550	16,875	5,432
2017	50,221	8,123	17,432	5,678

2018	51,743	8,687	18,015	5,956
2019	53,892	9,014	19,028	6,147
2020	49,276	8,221	16,751	5,432
2021	54,130	9,331	19,652	6,356
2022	56,789	9,802	20,113	6,589
2023	57,893	10,071	21,027	6,798
TA=Total Accident, FA=Fatal Accident				

Additionally, GIS mapping enabled the spatial visualization of accident hotspots, offering a clear geographic representation of blackspots across the state. This integration of analytical tools facilitated a comprehensive understanding of the factors influencing highway accidents. The data for this study was gathered from multiple sources to ensure reliability and comprehensiveness. Accident records from the Madhya Pradesh Traffic Police, spanning the years 2016 to 2023, provided detailed datasets on the frequency, severity, and causes of road accidents [2, 3]. Field surveys and interviews with traffic police officials, highway users, and residents near high-risk zones offered qualitative insights into behavioural patterns and enforcement challenges [4,5,6]. Geographic datasets used for GIS mapping enabled precise identification of blackspots, ensuring the accurate spatial representation of high-risk areas. Together, these data sources contributed to a nuanced and actionable analysis of road accidents on Madhya Pradesh highways[2,7]. The integration of primary and secondary data ensured a holistic approach, while the use of GIS mapping provided an innovative dimension to traditional accident analysis. The reliance on statistical tools allowed for objective and data-driven insights, making the findings highly actionable for policymakers and practitioners. All data collection processes adhered to ethical guidelines, ensuring the privacy and consent of survey participants [8, 9, 10]. Sensitive information, such as accident victim details, was anonymized to maintain confidentiality. In summary, this methodology combines quantitative and qualitative approaches to offer a nuanced understanding of road accidents in Madhya Pradesh. The insights generated are expected to guide targeted interventions aimed at reducing accident rates and enhancing highway safety.

3. Road Accident Trends in Madhya Pradesh (2016-2023)

This section presents an analysis of road accident data from 2016 to 2023, showing a significant upward trend in accidents and fatalities, with the exception of 2020 due to the COVID-19 pandemic. The increasing traffic volume, especially on National Highway 44 (NH-44) and State Highway 27 (SH-27), has contributed to this rise [2, 3, 11,12].

4. Contributing Factors to Road Accidents

Multiple factors contribute to road accidents on highways in Madhya Pradesh. These include over-speeding, drunk driving, poor road infrastructure, driver distraction, and non-compliance with road safety measures.

Table 2: Percentage Contribution of Factors to Accidents (2016-2023)

Year	OS	DDG	DDN	PRC	Other
2016	45%	15%	10%	20%	7%
2023	47%	16%	10.50%	21%	8%
OS= Over-speeding, DDG= Drunk Driving, DDN= Driver Distraction, PRC=Poor Road Conditions					

- **Over-speeding:** Over-speeding is the leading cause of road accidents, contributing to 47% of total accidents. National Highway 44 and State Highway 27 were found to be particularly vulnerable due to insufficient speed enforcement mechanisms.
- **Drunk Driving:** Drunk driving accounted for 16% of accidents. Despite laws prohibiting driving under the influence of alcohol, enforcement remains weak due to a lack of breathalyzer tests and a workforce.
- **Poor Road Infrastructure:** Poorly maintained roads, inadequate signage, and improper junction design contributed to around 21% of accidents. Rural highways were particularly prone to hazardous conditions, leading to frequent accidents.

5. High-Risk Areas (Blackspots)

Blackspots are high-risk areas where accidents are disproportionately frequent. Using GIS mapping, several blackspots were identified on highways in Madhya Pradesh, such as NH-44 between kilometres 200 and 220 and SH-27 near Indore Junction [2, 13,14].

Table 3 Major Blackspots in Madhya Pradesh (2016-2023)

Location	RT	TA	Fatalities	Key Factors
NH-44 Km 200-220)	NH	1,250	410	Over-speeding, Poor lighting
SH-27 (Indore Jn.)	SH	900	250	Traffic Congestion, Driver Distraction
RT=Road Type, NH=National Highway, SH= State Highway, TA=Total Accidents				

The GIS mapping of these blackspots reveals that over-speeding, poor road conditions and lack of enforcement are the main factors contributing to high accident rates in these areas.

6. Accident Severity by Vehicle Type

Two-wheelers were found to be the most vulnerable group, accounting for nearly 40% of all fatalities. Heavy vehicles, though involved in fewer accidents, were responsible for more severe outcomes due to their size[2, 15, 16].

Table 4 Accident Severity by Vehicle Type (2016-2023)

Vehicle Type	Total Accidents	Fatalities
Two-wheelers	28,000	6,400
Passenger Cars	17,000	6,200
Heavy Vehicles	13,200	6,300

7. Road Safety Awareness among Road Users

The survey revealed significant gaps in road safety awareness among road users. A large percentage of drivers were unaware of speed limits, helmet-use laws, and pedestrian rules. These gaps in awareness contribute to the high number of accidents [3,17,18].

Table 5 Survey Results on Road Safety Awareness

Year	ASL (%)	HUNC (%)	SBNC (%)
2023	30	20	11
ASL= Awareness of Speed Limits, HUNC= Helmet Use Non-Compliance, HBNC= Seat Belt Non-Compliance			

8. Accident Prediction Models

Regression analysis was used to develop models that predict the likelihood of accidents based on traffic volume, road quality, and weather conditions. The analysis revealed that traffic density and poor road conditions are strong predictors of accidents.

Table 6 Results of Regression Analysis (Accident Prediction)

Variable	TV	RQI	Rain
Coefficient	0.45	-0.3	0.25
P-Value	0.001	0.005	0.02
TV= Traffic Volume, RQI=Road Quality Index			

9. Discussion and Recommendations

The study emphasizes the urgent need for effective road safety interventions to reduce accidents and fatalities on highways in Madhya Pradesh. It highlights several key recommendations to address this issue. First, improving speed enforcement is crucial, with the installation of speed cameras and an increase in traffic police patrols on major routes such as NH-44 and SH-27. Additionally, enhancing road infrastructure, including better road maintenance, clearer signage, and improved lighting, is necessary, particularly in rural areas and identified black spots. Strengthening drunk driving laws is also vital, and this can be achieved by increasing the frequency of breathalyzer checks and launching more robust public awareness campaigns. Lastly, promoting road safety awareness through educational campaigns focused on the importance of helmet use, seat belts, and pedestrian safety can help foster safer driving behaviours among the public.

10. Conclusion and Future Work

This study provides a comprehensive analysis of road accidents on highways in Madhya Pradesh between 2016 and 2023, identifying key trends, contributing factors, and high-risk areas (blackspots). The results highlight the alarming increase in accidents and fatalities, with over-speeding, drunk driving, and poor road infrastructure being the primary causes. GIS mapping revealed specific blackspots, and statistical models predicted accident likelihood based on factors such as traffic volume and road quality. The findings emphasize the urgent need for targeted road safety interventions, including improving speed enforcement, upgrading road infrastructure, strengthening drunk driving laws, and promoting road safety awareness. Future work will focus on expanding the use of advanced machine learning and artificial intelligence techniques to enhance predictive models for accident risk. Additionally, more detailed studies on the effectiveness of proposed interventions, including road infrastructure improvements and public awareness campaigns, are essential. Long-term monitoring and real-time data collection through IoT-based systems could provide further insights into accident prevention, enabling dynamic adjustments to road safety measures based on evolving traffic conditions and user behaviour.

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