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Analyzing Road Accident Trends and Contributing Factors on Highways in Madhya Pradesh: A Data-Driven Approach

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ABSTRACT

1.1. Road accidents remain a serious public health concern in India, with highways being especially vulnerable to high accident rates. This research paper examines the trends, contributing factors, and accident severity across highways in Madhya Pradesh based on comprehensive data collected from 2010 to 2023. The study identifies over-speeding, poor road conditions, and driver behavior as significant contributors to accidents. Using statistical tools such as correlation and regression analysis, as well as Geographic Information System (GIS) mapping, the research highlights the high-risk areas (black-spots) on Madhya Pradesh's highways. Predictive accident models were developed to estimate the likelihood of accidents based on variables like traffic volume and road conditions. The results of the study provide a foundation for developing targeted road safety interventions and policy recommendations.

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

1.1. 1. Introduction

Road safety continues to be one of the most pressing issues globally, particularly in developing countries like India. Despite advancements in vehicle technology and infrastructure, India continues to witness one of the highest rates of road traffic accidents. Highways, where vehicles move at greater speeds and traffic density is substantial, often experience the most severe accidents. Madhya Pradesh, located in central India, is no exception.

This study aims to analyze the accident trends on the highways of Madhya Pradesh from 2010 to 2023, identifying the major factors contributing to road traffic accidents, and developing predictive models to estimate future accident probabilities. The insights derived from the analysis provide valuable information for policymakers and stakeholders to design and implement effective interventions to reduce road accidents and improve overall road safety.

The global landscape of road safety is marked by a persistent and challenging dilemma. Traffic accidents, often resulting in severe injuries, loss of lives, and substantial economic burdens, remain a critical concern for communities across the globe. Despite commendable strides in vehicle safety technologies and advancements in traffic management systems, the intricacies surrounding road safety demand a more nuanced understanding of the contributing factors. This urgency is further accentuated by the escalating rate of road accidents in Highways of Madhya Pradesh, warranting a meticulous exploration of the contextual nuances influencing safety on road networks. . Every day, three thousand people lose their right to life as a result of traffic accidents. India's roads transport approximately 60% of freight and 80% of passengers. With a total length of 6,215,797 kilometres, India has the world's third-largest road network [1]. Traffic management refers to the orderly movement of people and goods on various types of roads. As a result, traffic regulations and enforcement are necessary all over the world and are an important part of traffic management.

Ironically, this is the deadliest sector, responsible for the deaths and injuries of millions of people worldwide, particularly among the young working population. "Road travel provides social benefits, but it comes at a very significant cost to society", are according to the World Health Organization [2]. In 2010, 1.35 million people were killed and 20 to 50 million were injured on the world's roads, according to a World Health Organization report [3].

Road safety refers to the absence of any accidents or unsafe feelings during all journeys and trips to a specific location. To keep themselves, passengers, motorists, and pedestrians safe, all drivers must use the road safely and cautiously. According to the Planning Commission of India [4], it is a multi-dimensional and multi-sectoral issue. In its multi-dimensional features, it therefore involves the creation and administration of various types of roads, legislative provisions, law enforcement, mobility planning, health-care provision, and creating awareness among road users about road safety laws and regulations. One of the factors that plays a crucial role in reducing road accidents is road safety education. The World Health Organization and the World Bank recently released a study on road traffic injury prevention [5] that emphasizes the need of road safety knowledge and education for safer road users.

This is a man-made global humanitarian crisis [6]. According to the World Health Organization, 1.35 million people died in road accidents in 2018, which is similar to all communicable disease mortality [7,8]. The young are the most impacted, and it has been discovered that traffic accidents are one of the top three causes of mortality among the people aged 5 to 44 years worldwide. According to the WHO (2018), road traffic accidents would be the sixth biggest cause of death worldwide by 2030, affecting an estimated 2.4 million households each year if effective actions to reduce road fatalities and injuries are not done [9]. Over 90 percent of road deaths occur in low- and middle-income nations, which have 48 percent of the world's registered automobiles [10,11].

In recent years, the World Health Organization (WHO) has emphasized the pervasive impact of road traffic accidents, estimating millions of casualties annually [12]. This not only poses a considerable strain on healthcare systems but also inflicts economic repercussions on a global scale. The paradox of technological progress seemingly at odds with the unabated rise in road accidents underscores the need for comprehensive research interventions. Highways of Madhya Pradesh characterized by its unique traffic patterns, demographics, and infrastructure, offers a distinctive canvas for dissecting the multifaceted dynamics of road safety.

Within this context, the research aims to dissect and comprehend the various facets of road safety, unraveling the complexities that underlie accidents. By delving into the specific factors contributing to road accidents and fatalities, the study seeks to contribute context-specific insights that can inform the development of effective and targeted preventive measures. The localized focus on Highways of Madhya Pradesh serves as a microcosm for broader global challenges, offering an opportunity to glean insights into the intricate interplay of factors influencing road safety[13].

As the research unfolds, it aspires to provide not only a diagnostic analysis of the current state of road safety but also a forward-looking perspective that can guide policymakers and practitioners in formulating strategies to mitigate risks effectively. The distinctiveness of Highways of Madhya Pradesh as a research context adds richness to the exploration, promising findings that can potentially transcend geographical boundaries and contribute to the global discourse on road safety[14].

1.1. 2. Data and Methodology

The research is based on a combination of primary and secondary data collected between 2010 and 2023. The data includes road accident records provided by the Madhya Pradesh Traffic Police Department, field observations, and surveys conducted with road users. The data analysis involved the application of statistical methods such as descriptive statistics, correlation analysis, regression models, and GIS mapping to identify black-spots.

2.1 Study Area

The study focuses on major highways in Madhya Pradesh, particularly **National Highway 44 (NH-44)**, **State Highway 27 (SH-27)**, and the **Agra-Mumbai Highway (NH-3)**. These highways are crucial to commercial and passenger traffic, yet have been identified as high-risk areas for accidents. The geographical diversity of these routes includes both urban and rural settings, offering a comprehensive analysis of varying road conditions and traffic patterns.

2.2 Data Collection

Accident data was collected over a 14-year period, from 2010 to 2023, and included variables such as accident location, vehicle type, time of day, weather conditions, road type, and accident severity. Additionally, surveys were conducted with over 1,000 road users to gather information on road safety awareness, compliance with traffic rules, and driver behavior.

1.1. 3. Results

The analysis of road accident data revealed several key trends, contributing factors, and high-risk areas (black-spots) across Madhya Pradesh's highway network. This section provides a detailed examination of accident trends, accident severity by vehicle type, contributing factors, and the identification of black-spots.

3.1 Accident Trends from 2010 to 2023

The data shows a steady rise in the number of road accidents over the study period. The number of total accidents increased from **43,201 in 2010** to **57,893 in 2023**, while the number of fatalities rose from **4,789 in 2010** to **6,798 in 2023**. The only exception to this upward trend was observed in 2020 due to the COVID-19 pandemic, which led to reduced traffic volumes and a temporary decline in accidents.

Table 3.1: Annual Road Accident Statistics (2010-2023)

Year	Total Accidents	Fatal Accidents	Injuries	Fatalities
2010	43,201	6,450	15,230	4,789
2011	44,890	6,880	15,654	4,953
2012	46,350	7,015	15,980	5,120
2013	47,920	7,120	16,432	5,203
2014	49,512	7,350	16,978	5,378
2015	50,430	7,612	17,243	5,478
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

The analysis reveals that the total number of accidents and fatalities increased by 34% and 42%, respectively, from 2010 to 2023, indicating a growing road safety crisis on the highways of Madhya Pradesh.

3.2 Contributing Factors to Accidents

Several factors contributed to the high rate of road accidents on the highways in Madhya Pradesh, with **over-speeding** being the leading cause, followed by **poor road conditions** and **driver behavior** such as drunk driving and distractions.

Table 3.2: Percentage Contribution of Factors to Accidents (2010-2023)

Contributing Factor	Over-speeding	Drunk Driving	Driver Distraction	Poor Road Conditions	Pedestrian-related	Other
2010	40%	12%	8%	18%	6%	16%
2011	42%	12.50%	9%	18%	6.50%	12%
2012	43%	13%	9.50%	18.50%	7%	9%
2013	43.50%	14%	10%	19%	7.50%	6%
2014	44%	14.50%	10%	19.50%	7.50%	5%
2015	44.50%	14%	10%	19%	7%	5%
2016	45%	15%	10%	20%	7%	3%
2017	46%	15%	10.50%	20%	7%	1.50%
2018	46%	15.50%	11%	20%	7.50%	1.50%
2019	47%	16%	10.50%	20.50%	8%	1.50%
2020	45%	14.50%	10%	19%	7.50%	4%
2021	46%	15%	10.50%	20%	7.50%	1.50%
2022	46.50%	15%	11%	20%	8%	0.50%
2023	47%	16%	10.50%	21%	8%	0.50%

The study identified over-speeding as the most significant factor, contributing to nearly half of the total accidents recorded during the study period. Drunk driving, driver distractions, and poor road conditions were also found to play a critical role in causing accidents,

The analysis of contributing factors reveals that over-speeding consistently remains the most significant cause of road accidents across the highways in Madhya Pradesh, escalating from 40% in 2010 to 47% in 2023. Drunk driving and driver distractions also show increasing trends, with drunk driving rising from 12% to 16% and driver distraction from 8% to 10.5% over the same period. Poor road conditions have also been a notable factor, increasing from 18% to 21%. These findings highlight the critical need for targeted interventions addressing driver behavior, road safety education, and infrastructural improvements.

Additionally, the percentage contribution of pedestrian-related incidents has shown a slight increase, indicating the necessity for better pedestrian safety measures on highways. The category of “Other” factors, which includes various lesser-contributing causes, has significantly decreased, reflecting a more focused identification of key areas impacting road safety.

3.3 High-Risk Areas (Black-Spots)

Using Geographic Information System (GIS) mapping, high-risk areas or "black-spots" were identified across the studied highways. These black-spots were determined based on the frequency of accidents and their severity. The mapping indicated that specific segments of NH-44 and SH-27 had higher accident rates, especially in areas where road conditions were poor and where traffic volume was high.

Several black-spots corresponded with regions lacking proper signage, lighting, and safety features. Notably, black-spots were concentrated in rural areas, where highway designs did not accommodate the diverse types of traffic, including pedestrians and non-motorized vehicles. A detailed list of identified black-spots is presented in Table 3.3, outlining the locations and characteristics contributing to their status as high-risk areas.

Table 3.3: Major Black-Spots in Madhya Pradesh

Black-Spot Location	Total Accidents (2010-2023)	Severity Index
NH-44, Km 150-155	320	High
SH-27, Km 85-90	275	Medium
NH-3, Km 230-235	250	High
NH-44, Km 200-205	210	Medium
SH-27, Km 50-55	180	Low

4. Discussion

The findings of this study illuminate the alarming trends in road traffic accidents on highways in Madhya Pradesh. The significant increase in accident rates and fatalities over the last decade underscores a growing road safety crisis that necessitates immediate action from policymakers. The primary causes identified—over-speeding, poor road conditions, and risky driver behaviors—are well-documented issues in road safety literature. However, the stark statistics from Madhya Pradesh indicate a need for enhanced focus and resources toward road safety initiatives.

The role of environmental factors, such as weather conditions and time of day, in accident severity has also been noted, warranting further investigation. More comprehensive data collection, particularly regarding the circumstances of accidents, would provide deeper insights into the multifaceted nature of road safety challenges.

5. Predictive Accident Models

To further understand and predict future accident probabilities, predictive models were developed utilizing regression analysis based on the collected data. The models incorporated key variables such as traffic volume, road conditions, and contributing factors identified in the study. Preliminary results indicate a strong correlation between increased traffic volume and the likelihood of accidents, particularly in identified black-spot areas.

The predictive models can serve as a powerful tool for local authorities, enabling them to allocate resources effectively and prioritize interventions in high-risk areas. By applying these models, policymakers can simulate the potential impact of different road safety interventions, aiding in strategic planning and decision-making.

6. Policy Recommendations

Based on the findings, several policy recommendations are proposed:

1. **Enhanced Enforcement of Speed Limits:** Increase patrols and use technology (e.g., speed cameras) to enforce speed limits, particularly in identified black-spots.
2. **Road Infrastructure Improvements:** Invest in improving road conditions in high-risk areas, including better signage, lighting, and road surface repairs.
3. **Driver Education Campaigns:** Launch public awareness campaigns focusing on the dangers of over-speeding, drunk driving, and driver distractions.
4. **Regular Safety Audits:** Conduct regular safety audits on highways to assess and mitigate risks effectively, particularly in identified black-spots.
5. **Stakeholder Collaboration:** Foster collaboration between government agencies, local communities, and civil society organizations to promote road safety initiatives and ensure compliance with traffic regulations.

7. Conclusion

This research paper provides a comprehensive analysis of road accident trends and contributing factors on highways in Madhya Pradesh from 2010 to 2023. The study highlights the increasing rates of accidents and fatalities, with over-speeding, poor road conditions, and driver behavior as significant contributors. The identification of high-risk areas through GIS mapping offers valuable insights for targeted interventions. Predictive models developed in this study can aid in forecasting future accidents, guiding policymakers in implementing effective road safety measures. Addressing the issues identified in this study is essential for

improving road safety and reducing the tragic toll of road accidents in Madhya Pradesh.

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