J. Mountain Res. P-ISSN: 0974-3030, E-ISSN: 2582-5011 DOI: https://doi.org/10.51220/jmr.v20-i1.36
Vol. 20(1), (2025), 343-353

Improving Road Safety in Mountain Regions: Lessons from Uttarakhand's Accident Data

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Received: 14.04.2025; Revised: 05.06.2025; Accepted: 06.06.2025

Abstract: India faces a significant public health issue with road traffic accidents. While the country has made strides in improving various aspects of health, managing and reducing road accidents remains a considerable challenge. Most states are not on track to achieve the UN Decade of Action for Road Safety 2021-2030 objective of cutting fatalities in half by 2030. The problem is particularly acute in hilly states, such as Uttarakhand, where road transportation is heavily relied upon. Uttarakhand's unique geographical and environmental conditions exacerbate the issue, leading to higher accident and death rates. Mountainous areas present additional hazards like steep inclines, constricted roadways, abrupt turns, and unpredictable weather, which increase pedestrian risks. The study aims to examine road accident data in Uttarakhand over recent years, identify accident causes, and suggest risk reduction strategies. Additionally, it explores the impact of enhancing infrastructure, improving driver skills, promoting education, and implementing technical and regulatory reforms on road safety in Uttarakhand.

Keywords: Road Safety • Mountain Region • Uttarakhand • Uttarakhand Accident Data.

Introduction:

Road accidents claim thousands of lives every year, with India ranking highest globally in this grim category. As per Union Minister of Road Transport and Highways Nitin Gadkari, the country recorded 4.80 lakh road accidents in 2023, leading to 1.72 lakh fatalities—a 4.2% increase in accidents and a 2.6% rise in deaths compared to 2022 (PIB 2024). While a World Health Organization (WHO) report noted a global decline of 5% in road traffic deaths between 2010 and 2021—bringing the number to 1.19 million annually—India experienced an increase from 1,57,593 deaths in 2018 to 1,68,491 in 2022, with a temporary dip during the COVID-19 pandemic years (Global Report on Road Safety 2023).

Roads and transport systems have become essential parts of everyday life. Everyone interacts with the road network in some capacity. As urbanization spreads and road infrastructure expands, the risk associated with road use has increased. Vehicle registrations are growing faster than both population and road construction. India has the world's second-largest road network, extending approximately 66.71 lakh kilometers (PIB 2024). While this network supports socio-economic development, it also poses significant risks. Every year, lakhs lose their lives, and crores sustain serious injuries due to road mishaps.

Globally, road traffic accidents are a major cause of death and disability, imposing heavy socio-economic costs. In India, poor road

design, engineering flaws, and weak enforcement of traffic regulations are key factors contributing to road fatalities. Despite its importance as an economic artery, the road network is also the leading source of accidental deaths. Traffic congestion is increasing by 7–10% annually, while the number of vehicles rises at 12% per year—worsening road safety concerns. Globally, around 1 million people die, and 50 million suffer injuries from road accidents each year. In India alone, approximately 70,000 people lose their lives annually due to such incidents.

Improving road safety is crucial for India to meet the United Nations' target of halving road traffic deaths by 2030 under the Decade of Action for Road Safety 2023. The scale of the issue is comparable to the number of lives lost during the COVID-19 pandemic in 2020 and 2021, yet road safety continues to receive limited attention compared to pandemic response measures.

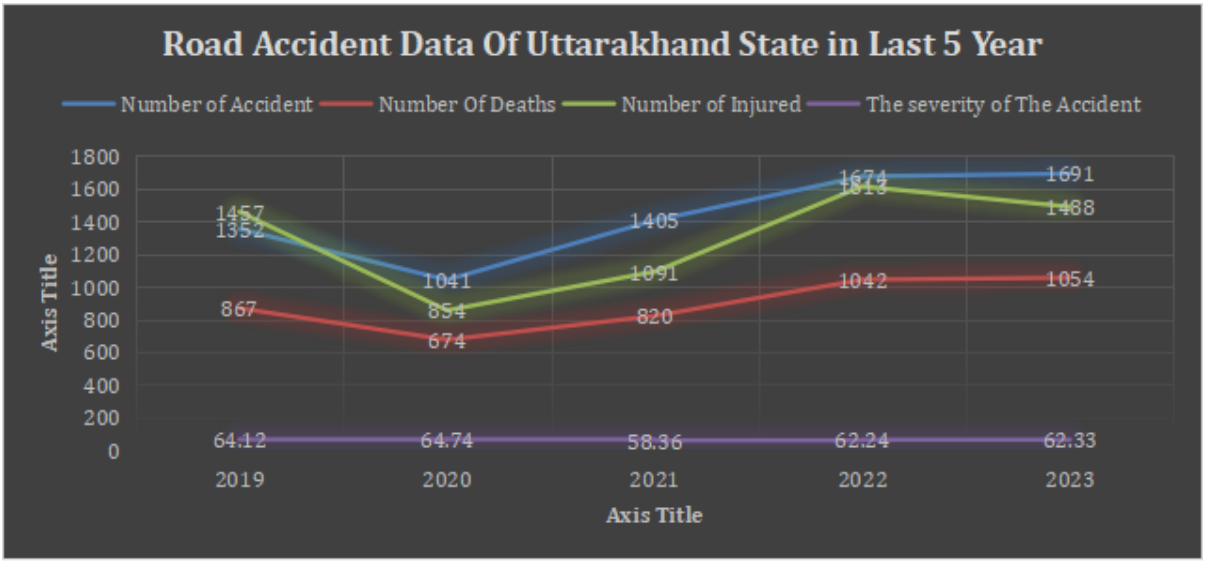
The Himalayan states are particularly vulnerable to road accidents due to their challenging terrain. Providing prompt medical care is difficult, and mountainous roads—with sharp turns, inadequate lighting, and limited barriers—pose unique hazards. Unpredictable weather and poor infrastructure make driving in these regions even more dangerous.

Fig 1: Dimension of Road Safety in Mountain Regions

Importance of Road Safety in Mountainous Areas

Mountainous regions face unique road safety challenges due to their topography and climate. Navigating steep gradients and sharp curves demands skilled driving and precise vehicle control. Additional hazards such as fog, landslides, and unpredictable weather further increase accident risks. According to the World Health Organization (WHO), road traffic accidents are a leading cause of death globally, with developing nations disproportionately affected. In Uttarakhand, these issues are compounded by poor infrastructure, overloaded vehicles, and inadequate driver awareness. Studies show that mortality rates are significantly higher in hilly areas compared to plains, owing to the complex risks involved in high-altitude driving. Uttarakhand, with its 45,000 km road network, connects remote villages, towns, and tourist hubs like Rishikesh, Mussoorie, and Nainital. However, this extensive connectivity carries a high safety cost. Data from the

Uttarakhand Transport Department indicates a steady rise in road accidents, with annual fatalities surpassing 1,000 (Transport Department, 2022), caused by multiple interrelated factors.



Source: Transport Department Uttarakhand, 2023

Uttarakhand ranked eighth among Indian states in accident severity in 2022, with an alarming average of 62.2 deaths per 100 accidents—far above the national average of 36.5. Roads are the primary means of connectivity in this mountainous state, linking remote communities with urban centres. For the transport of essential goods, tourists, and pilgrims, roads are the most accessible and economical option. This is especially evident during the annual Char Dham Yatra, when the state witnesses a massive influx of pilgrims and tourists. The resulting surge in vehicular traffic places immense pressure on transport operators, drivers, and guides. Time and budget constraints often lead to compromises in vehicle maintenance, rest periods for drivers, and the avoidance of night driving in hilly terrain.

Uttarakhand's growing popularity as a religious and nature-based tourist destination has amplified road usage. Data from the Uttarakhand Transport Department shows a rising trend in accidents: 1468 accidents and 1047 deaths in 2018; 1352 accidents and 867 deaths in 2019; 1041 accidents and 674 deaths in 2020; 1405 accidents and 820 deaths in 2021; and 1674 accidents with 1042 deaths in 2022. In 2023, 1691 accidents led to 1054 deaths—a 27% rise in accidents and a 19.10% increase in injuries. This growing trend presents a serious public safety concern.

Review of Literature:

The complex and fragile topography of hill roads leads to road accidents in mountainous regions having markedly different characteristics compared to those in plains (Rautela and Pant 2007b). A road safety audit conducted on NH-5 in Himachal Pradesh identified several critical shortcomings such as encroachments, poor-quality infrastructure, and inadequate geometric design. These deficiencies are known contributors to traffic accidents. While vehicle occupants generally enjoy greater safety compared to vulnerable road users like pedestrians and motorcyclists, the rugged terrain of the hills—with abrupt curves and narrow passes near steep gorges—significantly heightens the risk of accidents (Singh and Sharma, 2023; Yadav and Hossain 2022).

The Himalayan region faces chronic issues such as landslides, erosion, and harsh weather, which obstruct sustainable road access.

Although road construction guidelines exist, poor implementation and the failure to adopt best practices often compromise road safety (Hearn and Shakya 2017). Frequent landslides and avalanches in this region underscore the need for advanced technologies like Geographic Information Systems (GIS) and remote sensing for effective risk assessment and mitigation (Oberoi and Thakur 2004). Furthermore, substandard design features such as poorly lit tunnels and inadequate drainage after seismic activity increase accident vulnerability, with concealed hazards arising from unstable rocks and a lack of essential safety installations like Kanawha rails (Zhang and Wang 2015).

Modern technologies such as motion detection systems that automatically alert emergency services can improve accident response times and reduce fatalities (Prasanth et al 2024). Identifying high-risk road segments based on parameters such as road gradient, curvature (sinuosity), and width is critical for mountainous terrains. GIS-based analyses, combined with structural improvements and regulatory measures, can significantly reduce accident incidence (Rautela and Pant, 2007a). Additionally, emerging tools like image processing and real-time sensor data are being suggested for deployment in accident-prone hill zones (Patwardhan et al 2023).

The region's natural instability is further exacerbated by developmental activities and road-widening efforts, which frequently cause slope failure (Siddique et al 2020). Research indicates that the 18–37 age group is most affected by road traffic accidents (Ganveer and Tiwari 2005; Raina et al 2019), necessitating urgent safety interventions—particularly during the monsoon and pilgrimage seasons when accident rates spike. Infrastructure such as crash barriers along valley edges and convex mirrors at blind turns can prevent fatal mishaps (Kumar and Kumar 2020). Additionally, controlled blasting during construction should be accompanied by effective warning systems to mitigate rockfall hazards (Joshi et al 2014).

In Uttarakhand, road safety is further compromised by limited maintenance budgets, overburdened road agencies, corruption, and excessive contractor interference (Sarma Sadhu et al 2017). Enhancing planning frameworks, adopting modern technology, and enforcing stricter regulations offer a promising route toward safer roads in mountainous regions.

Objectives

1. To analyse road accident data in Uttarakhand and identify factors contributing to accidents in hilly areas.
2. To propose practical, multi-pronged solutions for reducing road accidents, including infrastructure upgrades, technological interventions, driver education, and policy reforms.

Methodology

The present study adopts a quantitative research approach, utilizing exploratory and analytical methods to examine road safety in the hilly terrain of Uttarakhand. It analyzes longitudinal accident data from 2019 to 2023 to identify patterns, trends, and key causes of road accidents. The analysis includes accident frequency, severity, location, vehicle types, human-related factors such as negligence, over-speeding, and drunken driving, as well as environmental factors like adverse weather, poor road conditions, and landslides.

The study relies on secondary data sourced from the Uttarakhand Police Department, Uttarakhand Transport Department, National Crime Records Bureau, Ministry of Road Transport & Highways (MoRTH), and relevant newspaper and government reports. To ensure accuracy and comparability, preprocessing steps such as duplicate removal, category normalization, interpolation for missing data, and cross-verification from multiple sources were conducted.

Descriptive and inferential statistical tools were employed. Trend analysis helped visualize accident patterns annually and seasonally, while categorical comparisons evaluated variations in accident types across different road and vehicle categories, as well as weather conditions at accident sites.

Limitations of the study include potential biases in secondary data reporting, incomplete information on accident causes, and the absence of real-time monitoring. Nevertheless, the findings offer valuable insights for policymakers. This research aims to inform interventions for enhancing road safety in Uttarakhand's mountainous regions through infrastructure improvements, stricter enforcement of traffic laws, and better emergency response systems.

Result and Discussion

Due to the complex geometry of the mountain roads and most of the state being mountainous, in case of an accident, the loss of life is higher than the loss of life on the plains. The analysis of road accident data in Uttarakhand reveals that multiple factors, including seasonal travel trends, time of day, vehicle types, road characteristics, and weather conditions, influence road safety challenges in mountainous regions.

Month-Wise analysis: As is evident from the month-wise distribution of the data (Table 1), the highest number of deaths are observed between April and November, indicating two peaks in April and November. Since the annual Char Dham Yatra in Uttarakhand begins in April and continues till the end of October, an increase in road traffic is observed, increasing the accident rate. But with the advent of monsoon in June, heavy rains and occasional cloudbursts lead to landslides and highway damage, disrupting traffic and reaching a minimum in July. Hence, the death rate also varies with the frequency of traffic. However, the death rate remains high in June and October, indicating that seasonal travel trends directly impact accident severity.

Table 1.1: Details of road accidents, deaths, and injuries occurring month-wise in the state

Month	Accident	Death	Injured
January	106	66	102
February	99	65	90
March	148	98	124
April	164	89	151
May	142	91	127
June	162	124	165
July	135	77	212
August	143	69	119
September	120	71	104
October	147	120	149
November	149	87	149
December	159	85	121

Source: Trasport Department Uttarakhand 2022

If we look at the data (Fig 2), it is clear from the time-wise distribution that most accidents occur between 6 pm and 9 pm because in Uttarakhand, there is a lack of proper lighting on the sides of the roads in the evening, so most people die. At the same time, the number of road accidents is also the highest between 6 am and 9 am, the main reason for which is fog because due to heavy rainfall in the monsoon in the mountainous areas, fog is the highest in the morning due to which the vehicles coming from the front are not clearly visible on the curves, which increases the chances of accidents. These findings highlight the need for improved road lighting, reflective markers, and real-time weather alerts to mitigate risk during these high-accident time slots.

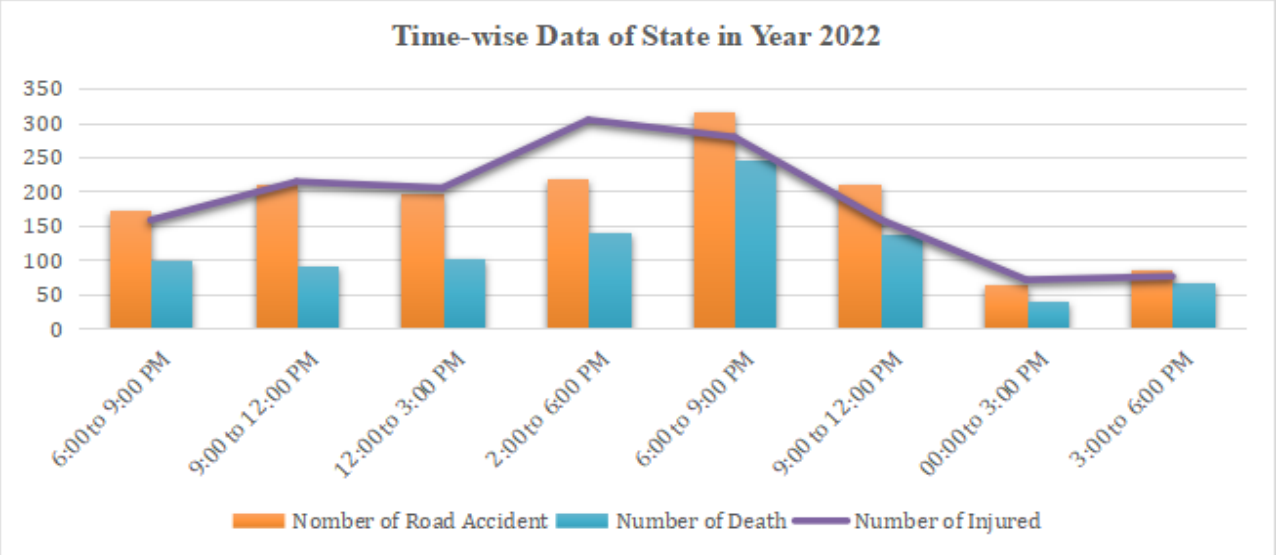


Fig 2: Time wise data of State in the Year 2022 (Source: Transport Department of Uttarakhand 2022)

Age-wise Analysis: The data indicates that the age group most affected by road accidents falls between 18 and 45 years (Table 2). This age group represents the working and economically productive population, making their high fatality rate a primary socio-economic concern. Younger drivers (18–25 years) often engage in riskier driving behaviours, such as overspeeding and reckless overtaking, contributing to a high accident rate. Elderly individuals (60+ years) have a relatively lower accident rate but are more vulnerable to severe injuries due to physical fragility. These findings suggest the need for targeted interventions, such as strict driving regulations for younger individuals and improved pedestrian safety for older adults.

Table 2: Age and Gender-wise details of victims of road accidents that occurred in the state in the year 2022

People	**Death**		**Injured**	
Age Group	**Women**	**Men**	**Women**	**Men**
Below 18 years of Age	52	14	99	40
18 to 25 Age	180	15	269	52
25 to 35 Age	241	35	355	87
35 to 45 Age	224	25	275	68
45 to 60 Age	161	27	274	54
Above 60 years of Age	50	12	59	23
Unknown Age	5	1	34	24
Total	**913**	**129**	**1265**	**348**

Source: Transport Department Uttarakhand 2022

Analysis According to Vehicle Categories: In the year 2022, 1674 road accidents occurred in the state. Of these incidents, 555 (33.5%) involved pedestrians. The highest fatality rate was associated with two-wheelers, accounting for 327 (19.53%) deaths. The primary contributing factor to this statistic is the widespread non-compliance with helmet usage among two-wheeler riders. Consequently, when road accidents involve two-wheelers, many individuals succumb to their injuries at the scene (Fig 3).

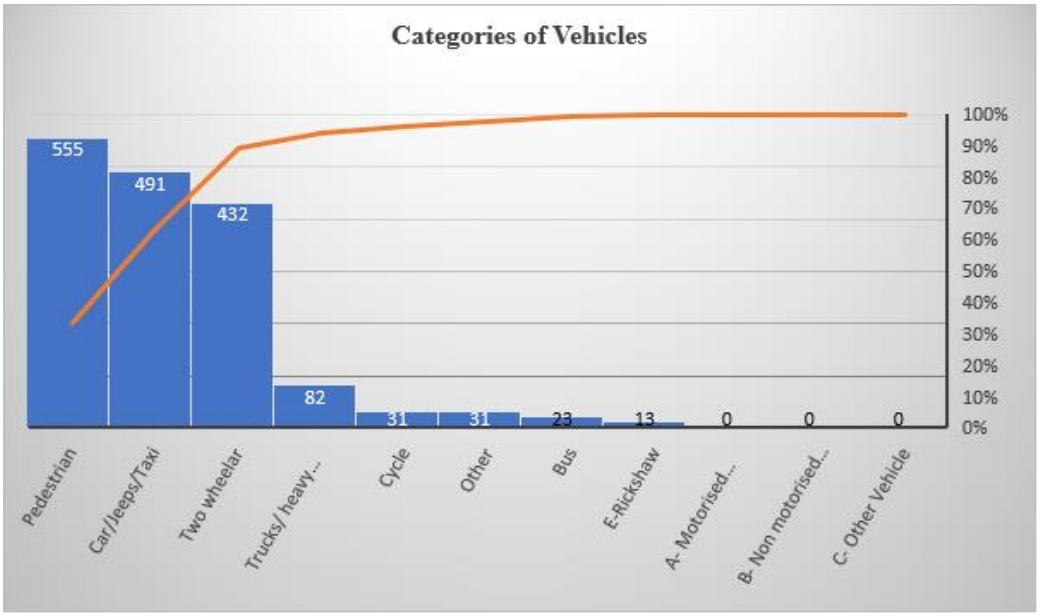


Fig 3: Categories of vehicle

Analysis Of Road Characteristics:

In 2022, based on road specifications (Table 3), the highest number of road accidents (1276) occurred on straight roads in the state, resulting in 807 fatalities and 1086 injuries. The data indicates that road accidents are higher on straight roads than on winding roads. The primary factor contributing to this phenomenon is excessive speed. Motorists tend to exercise caution on roads with potholes, and vehicle traffic is reduced on such roads. Conversely, drivers tend to exceed speed limits on straight roads. Additionally, bridges and culverts contribute to fewer accidents, emphasizing that accident prevention efforts should focus more on enforcing speed limits on straight roads.

Table 3: Details of Dead and Injured in Accidents based on Road Characteristics in the Year 2022

Road Characteristics	**Number of Road Accidents**	**Death**	**Injured**
Straights Road	1276	807	1066
Curved Road	359	205	503
Bridge	24	19	16
Culvert	1	0	1
Steep Road	2	1	2
Other	12	10	25
Total	**1674**	**1042**	**1613**

Source: Transport Department of Uttarakhand 2022

Analysis of Climate Conditions:

In 2022, the highest number of road accidents in the state, 1423, occurred in sunny and precise weather conditions, resulting in fatalities and injuries based on various climatic factors (Fig 4).

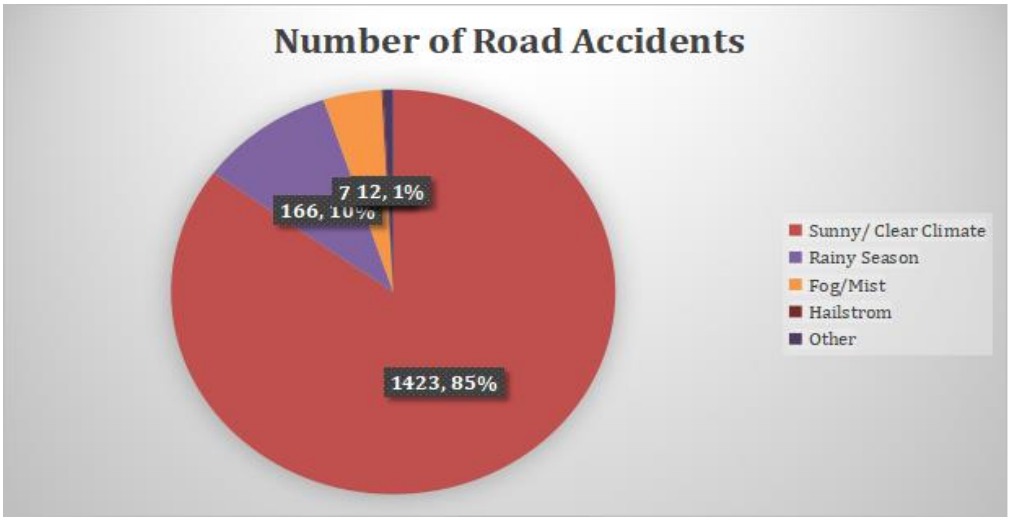


Fig 4: Number of Road accidents (Source: Transport Department of Uttarakhand 2022)

Weather conditions such as sunny, clear, rain, fog or mist, and hail affect the road surface and driver visibility, increasing the likelihood of accidents. In adverse weather conditions, fog, rain, and hail render driving more hazardous due to reduced visibility and slippery road surfaces, leading drivers to reduce their speed and potentially decreasing the probability of accidents. These findings suggest that while weather conditions play a role in accidents, driver behaviour remains the primary determinant. Road safety measures such as speed regulation in clear conditions, fog-prone zones, and better drainage systems could help mitigate these risks.

Mismanagement

The lack of adequate Uttarakhand Pari Vahan (state transport) buses during festivals leads to severe transportation mismanagement, resulting in tragic accidents due to overloading. During peak pilgrimage seasons and significant festivals like Char Dham Yatra, Kanwar Yatra, and Nanda Devi Raj Jat, thousands of devotees and tourists visit the state. However, the public transport system fails to accommodate the passenger surge, forcing people to rely on overcrowded private buses, jeeps, and trucks. Overloading is a significant safety hazard, especially in the mountainous terrain of Uttarakhand, where steep inclines and sharp turns require vehicles to be in optimal condition. Excess weight puts immense pressure on brakes and tyres, increasing the risk of fatal accidents such as bus rollovers and falls into deep gorges. Many accidents occur due to brake failures, loss of control, and poor road conditions, all aggravated by overloading.

This situation highlights the mismanagement of transport planning during festival seasons. Authorities fail to deploy additional buses or regulate private operators, leading to chaos. Better planning, strict enforcement of passenger limits, and increased government bus services are essential to prevent such avoidable tragedies and ensure safe travel for devotees and tourists.

Suggestions

Road safety is a critical issue in the Himalayan states of India that requires immediate attention and improvement. The climate and geographical conditions in these states exacerbate the challenges associated with road safety. To enhance road safety, it is imperative to improve infrastructure and promote public awareness programs. Given that the mountainous region is undergoing development and progress, addressing road hazards should be a priority for sustainable development and community well-being. Improving road safety in these areas necessitates collaborative efforts among

government agencies, local communities, and stakeholders.

Additionally, there is a need to enforce road safety regulations, such as mandatory helmet use and speed limits, with stringent measures. The reports of social workers should also be taken into consideration. For instance, in Uttarakhand, Anoop Nautiyal has been working on the UDAAI report for two years, which stands for Uttarakhand Disaster Accident Analysis Initiative. This report provides detailed information on natural disasters and accidents in Uttarakhand, indicating that one death occurs every eight hours in the state, with an even higher number of injuries. The state government is not addressing the issue of road accidents with sufficient seriousness, nor is it acknowledging these reports. Furthermore, regular training and assessment of vehicles, drivers, and driving skills should be ensured. Thus, improving road safety requires a multifaceted approach that extends beyond legislation, encompassing the participation and cooperation of various departments, community engagement, social awareness, and individual responsibility.

Conclusion

Road safety in mountainous regions necessitates a multifaceted approach to improvement, involving various governmental departments and ensuring public participation and cooperation. In addition to reducing the frequency of accidents, enhancing the efficiency of rescue operations and medical treatment can significantly reduce fatalities. The local and state governments should implement additional preventive and safety measures during monsoon, rainy, and pilgrimage seasons, as these periods are associated with the highest incidence of road accidents due to excessive precipitation, road deterioration, and landslides. Interventions such as the installation of additional crash barriers on valley sides and convex mirrors on curves may contribute to a reduction in mortality rates. Driving during crepuscular periods in the morning and evening, coupled with the absence of proximate healthcare facilities on mountainous roads, have been identified as significant hazardous factors contributing to fatalities. Law enforcement agencies should conduct regular assessments of bus and taxi drivers, particularly those in the younger demographic, to ensure their proficiency in driving skills and adherence to traffic regulations.

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