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Accident Detection on Curved Roads Using Infrared Sensors in Hilly Regions A Case of Chadoora Tehsil, Badgam (J&K)

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Abstract: This study investigates the application of Infrared (IR) sensors for accident detection and prevention on curved roads in hilly region of Kashmir. The area's narrow, winding roads with poor visibility, especially at sharp curves, pose significant safety challenges. The proposed model leverages IR sensors to detect oncoming vehicles at blind curves, triggering visual alerts through light indicators to warn drivers in real- time. This proactive approach aims to minimize collisions, particularly in low- visibility conditions. The system is designed with sustainability in mind, operating on locally generated power to ensure functionality in remote areas. The research follows a qualitative methodology, analysing secondary data, including accident records from the Chadoora Police Station for. This study demonstrates how IR sensors, combined with visual warning systems, can enhance road safety by extending visibility and providing timely alerts to drivers. Implementation of this model requires adequate funding, technological resources, and administrative support.

Key words: AI-Powered Accident Detection, Smart Sensor Technology, Intelligent Accident Response, Real-Time Detection Systems

I. Introduction

Road safety is a multifaceted issue, encompassing infrastructure development, vehicle safety, legal frameworks, and healthcare provisions. In hilly regions like Chadoora, located in Badgam

District of Jammu & Kashmir, road safety is especially challenging due to narrow, curved roads and limited infrastructure. In India, hilly regions experience a higher incidence of road accidents, often exacerbated by delayed emergency services and limited accessibility. Road characteristics, such as curve radius, sight distance, and gradient, significantly impact accident likelihood.

This study focuses on identifying accident factors specific to Chadoora, understanding the link between its terrain and accident occurrences, and evaluating the potential of IR sensors in improving road safety. Road safety in hilly regions, such as Chadoora Tehsil in Badgam, Jammu & Kashmir, faces significant challenges due to narrow, winding roads with limited visibility, particularly on sharp curves. The average rate accident in India is increasing on daily basis, but the services and emergency preparations are lagging far behind [1]. These structural and geographical constraints increase collision risks and exacerbate the severity of accidents, particularly during fog, rain, or snow, which is common in these areas.

There has been analysed that there is a direct relationship between the geometric designs and accidents on curved roads, such as sight of distance, radius of curvature. Additionally, remote locations result in delayed emergency responses, making post-accident care less effective. The unique issues in these regions highlight the need for an innovative, proactive safety solution that extends beyond traditional measures. In 2020, **India recorded 3, 66,138 road accidents**, according to the Ministry of Road Transport and Highways (MoRTH), 1, 31,714 fatalities and 3,48,279 injuries [1]. Out of the total 366,138 road accidents in India in 2020, two-wheelers accounted for a significant proportion [1]. Two wheelers involved 35% to 40% of that total road accidents in India in year 2020[1]. Road safety is the multi-faceted issue as it inhibits the development and management of road infrastructure, provisional support for safe vehicles, legalized framework, provisional support for health and preventive care. Creating a road safety without jeopardizing the future needs is the prime motive of government and its success depends upon the safety policies and widely based support of all stakeholders. In developing countries like India, the hilly areas witness the large scale accidents due to poorly developed roads, poor infrastructure and unattended hazard zones.

The proposed model uses Infrared (IR) sensors to detect vehicles approaching blind curves. These sensors, strategically placed on curves, detect oncoming vehicles and trigger light indicators positioned before the curve, providing an early visual warning to drivers. Adequate financial support is necessary to cover the cost of equipment, installation, maintenance, and periodic upgrades.

Objectives of the study:

Using infrared (IR) sensors on curved hilly roads can serve various objectives, particularly for enhancing safety, efficiency, and navigation.

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Obstacle Detection and Collision Avoidance: Detecting objects, animals, or vehicles on blind curves or slopes, especially in low-visibility conditions (e.g., fog, night-time). IR sensors provide real-time alerts to drivers or automated systems to prevent collisions. Obstacle detection and collision avoidance on curved roads present additional challenges due to the changing geometry, visibility constraints, and dynamic path planning requirements

Improved Night Vision: Enhancing visibility by detecting heat signatures from vehicles, humans, or animals, aiding safe navigation in dark conditions. Improved night vision for obstacle detection and collision avoidance on curved roads is crucial for enhancing safety, as night-time driving reduces visibility and increases reaction time

Driver Assistance: Supporting advanced driver-assistance systems (ADAS) in guiding vehicles safely through curved roads. Supplementing other sensors like cameras and radar to provide a comprehensive environment analysis. Driver assistance systems for curved roads are essential for enhancing safety, comfort, and convenience while navigating challenging terrains. These systems use a combination of sensors, cameras, and software algorithms to help vehicles adapt to curves effectively.

Speed and Distance Monitoring: Measuring the distance to nearby vehicles or obstacles, helping in adaptive cruise control or safe braking. Detecting speed variations on inclines or declines to adjust vehicle control systems. Monitoring speed and distance on curved, hilly roads poses unique challenges due to changing gradients, curvature, visibility, and the possibility of sudden changes in driver behaviour.

Weather Adaptability: Functioning effectively in adverse weather conditions like fog, rain, or snow, where conventional cameras and radar may struggle. It crucial for enhancing safety and maintaining efficient traffic flow in challenging conditions such as rain, snow, fog, and ice.

Automated Driving Applications: Enabling autonomous vehicles to navigate safely on winding and hilly roads by creating a heat map of the surroundings. Assisting in precise lane-keeping and obstacle management on complex terrains. Automated driving applications on curved and hilly roads pose unique challenges due to the complexity of the terrain and the dynamic driving conditions.

Traffic Management: Monitoring traffic flow and identifying stalled vehicles or accidents, aiding in quick response and better road management. Managing traffic on curved, hilly roads is critical to ensure safety, efficiency, and the preservation of road infrastructure.

Wildlife Detection: Identifying the presence of wildlife near or crossing roads to prevent accidents, especially in remote or forested hilly areas. Wildlife detection on hilly and curved roads is an important safety measure to protect both animals and humans. The combination of limited visibility, uneven terrain, and potential wildlife crossing increases the need for effective detection systems.

Energy Efficiency: Enabling predictive driving behaviour (e.g., slowing down or speeding up based on detected obstacles) to optimize fuel or energy usage. Energy efficiency on hilly, curved roads can be impacted by several factors, including the gradient of the road, the vehicle's speed, and the driving behaviour.

Incorporating IR sensors in vehicles or roadside infrastructure on hilly curved roads enhances safety, operational efficiency, and environmental adaptability, addressing unique challenges posed by these terrains.

II. Research Methodology

This research methodology section outlines the framework and techniques adopted for exploring the causes and consequences of accidents in the Chadoora region of Jammu and Kashmir. The study takes a **qualitative approach**, emphasizing in-depth understanding and interpretation rather than numerical generalizations. The study employs **qualitative and analytical methods** to gather insights into the dynamics of road accidents in Chadoora [6]. The analysis prioritizes thematic coherence and the logical organization of findings.

The research relies on **secondary data**, including, academic research journals and articles, news reports relevant to the study area. Official records and data obtained from the **Chadoora Police Station**. Data on **36 accidents**, extracted from the **First Information Reports (FIRs)** for the years **2021-2022** maintained by the Chadoora Police Station, serve as the core dataset [2]. These FIRs include information regarding nature and frequency of accidents, causes of accidents and impact on human lives and socio-economic conditions [2]. The research adopts an **analytical approach** to thoroughly evaluate the data.

The accidents are categorized into **themes** based on their causes, such as road conditions, driver behaviour, or weather influences. The impact of these accidents is assessed across **human, economic, and social dimensions**, creating a comprehensive accidental profile. The findings are structured into **thematic sections**, ensuring that the data is presented in a coherent and synchronized manner. This thematic categorization enhances the understanding of the interplay between accident causes and their consequences. This methodology provides a structured lens to explore the accident profile of Chadoora, offering valuable insights into the socio-economic implications of these incidents.

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Geographic Focus: Chadoora Tehsil in Badgam, Jammu & Kashmir

The topography of Chadoora, located in the Badgam district of Jammu and Kashmir, reflects the typical characteristics of the region, influenced by its position within the Kashmir Valley. Below are the main aspects of the area's topography: Chadoora is situated in a relatively flat area of the Kashmir Valley, with gentle undulations and stretches of agricultural land. The region is flanked by the foothills of the Pir Panjal Range to the south and southwest, which provides a scenic backdrop. The elevation of Chadoora is approximately 1,500–1,600 meters (4,920–5,250 feet) above sea level [3]. The area is nourished by several streams and water bodies. The Doodhganga River, a tributary of the Jhelum River, flows near Chadoora and is a crucial water source for agriculture and local use.

The riverbanks and wetlands surrounding it are key ecological features. The soil in Chadoora is fertile and suitable for various crops, including paddy, maize, and saffron. Horticulture, especially apple orchards, is also significant in the region (See Figure 1). The area is part of the broader agricultural belt of Badgam. The topography and elevation contribute to a temperate climate, with cold winters, moderate summers, and a monsoon season influenced by the Himalayan climate patterns [4]. The area includes a mix of cultivated fields, meadows, and patches of forested land in the vicinity, especially toward the hilly areas. Wetlands and marshy lands also contribute to the biodiversity of the region [4]. The combination of flat fertile plains, proximity to the Pir Panjal foothills, and abundant water resources defines Chadoora's unique geographical character within Badgam district. Chadoora’s road characteristics — narrow, winding paths prone to low visibility — make it a suitable test location for this IR sensor model.

This initial focus allows for a controlled pilot, where the model’s effectiveness can be assessed before potential expansion to other similar terrains. Accident risk in hilly regions like Chadoora is influenced by various road characteristics. Sharper turns and steeper slopes require slower speeds and careful driving, increasing collision risk if drivers are unaware of oncoming vehicles. Limited visibility on curves leaves drivers with little reaction time [6]. Thermal imaging or infrared (IR) technology system often used in night vision applications for safety and navigation. Advanced Driver-Assistance Systems (ADAS) play a crucial role in enhancing road safety, especially on challenging curved roads. These systems integrate multiple sensors, cameras, algorithms, and control mechanisms to help vehicles navigate curves efficiently and safely. Strategically placed IR sensors would extend this sight distance, giving drivers more time to adjust. Frequent fog, rain, and snow in hilly areas limit visibility, but IR sensors are less affected by such conditions, ensuring consistent performance throughout

Figure 1: Map of Chadoora

Data Analysis:

Total 4.5 accidents have been recorded, during the peak months, from May to September, due to increased flow of tourists and commuter traffic. High-risk hours are recorded **8 AM to 6 PM**, most accidents occurred during peak travel hours. This timing data suggests that road safety risks escalate with increased daytime traffic, particularly during tourist season (See fig 1 below)

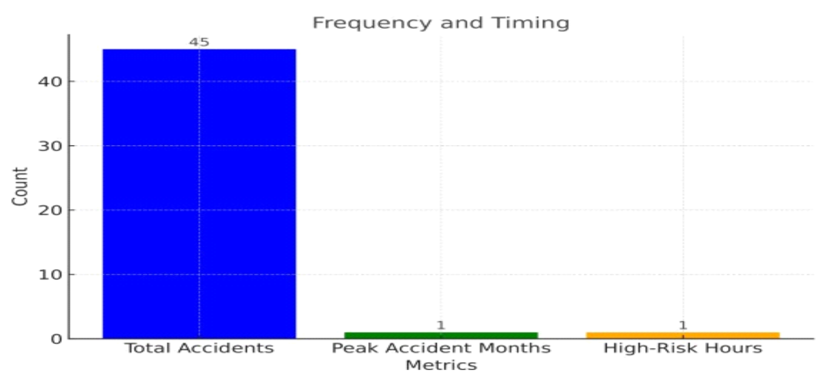

Fig 1. Frequency and Timing

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Road Width Impact:

The width of a road can have several important impacts on traffic flow, safety, and environmental considerations. Wider roads can typically accommodate more lanes of traffic, leading to a greater capacity for vehicles. This can reduce congestion, especially during peak hours.

Accidents on Narrow Roads (<12 feet wide): **30 out of 45 [5]**

Accidents on Standard-Width Roads (>12 feet): **15 out of 45 [5]**

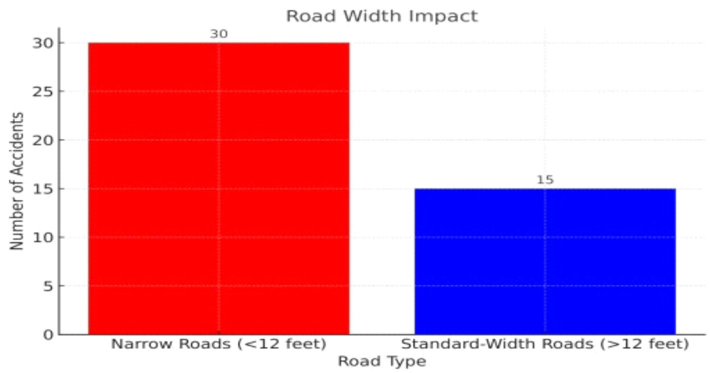

Fig 2: Road width Impact

Data reveals that 66% of accidents occurred on roads with widths less than 12 feet, indicating that narrow roads pose a higher accident risk, especially at curves [5]

Vehicle Type Involvement:

Primary Vehicles Involved: **Passenger Cars** and **Tourist Vehicles**

Common Accident Types: **Vehicle overturning, road runoff**, and **collisions**

With another vehicle

This indicates that vehicles carrying passengers—particularly those unfamiliar with the terrain—are at higher risk for incidents, often due to limited manoeuvring space on narrow, curved roads.

Casualties and Impact:

Total number of fatalities recorded were **12,** total number of injuries recorded were **33**. The age group that was most affected were **18-45 years**. With **12** fatalities and **33** injuries over the period, these accidents predominantly affect individuals aged **18-45**, reflecting a significant socio-economic impact on families and the community due to loss of life or long-term injuries. (See graph 3 below)

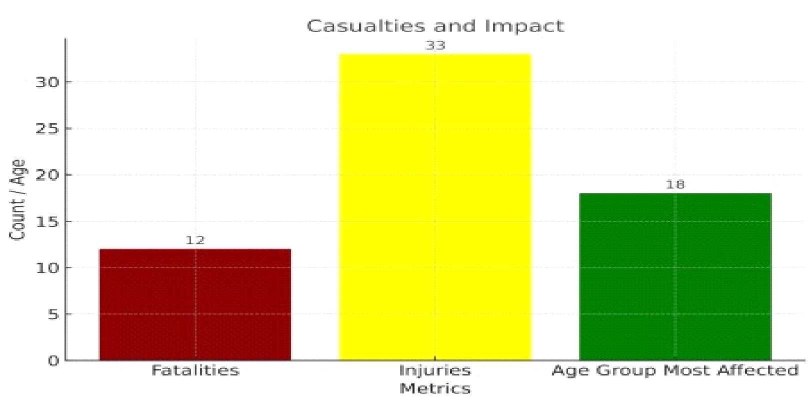

Fig 3: Causalities and Impact

Environmental Conditions:

Environmental conditions like fog, rain and ice ads up in reduced visibility and slippery surfaces due to harsh winters and frequent fog increase accident risks. Winter conditions lead to icy surfaces, creating dangerous driving conditions and reducing braking effectiveness [7]. Environmental factors such as fog and ice are particularly dangerous for drivers unfamiliar with these conditions, amplifying accident likelihood.

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Human Factors:

Drivers may overestimate their control on curves, particularly on downhill slopes. Accidents are often linked to drivers being distracted, especially among tourists unfamiliar with the terrain. Inexperienced tourist drivers increase accident rates, especially during high-traffic seasons. The combination of challenging driving conditions and human errors such as speeding and distractions poses a high safety risk in peak tourist seasons.

IR Sensor Model:

Sensors detect approaching vehicles around blind curves and activate warning signals for drivers on the opposite side. The process of detecting objects, animals, or vehicles on blind curves or slopes, especially in low-visibility conditions (e.g., fog, night-time) can be done efficiently using IR sensors.

IR sensors provide real-time alerts to drivers or automated systems to prevent collisions. Activated sensors trigger light signals to alert oncoming drivers, helping them anticipate oncoming traffic before reaching the curve. The light system provides visual cues to drivers, significantly lowering collision risks on narrow curves.

III. Conclusion:

Chadoora's narrow, curved roads present complex safety challenges for drivers, contributing to a high rate of accidents that have considerable socio-economic impacts. The IR sensor model presents a proactive approach to improving road safety by providing real-time alerts for oncoming traffic, reducing the likelihood of collisions. Real-time alerts enable drivers to approach curves with caution, preventing accidents on blind curves. The effectiveness of this model depends on obtaining sufficient funding, establishing a reliable technological infrastructure, and securing strong administrative support. Chadoora could potentially benefit other hilly regions with similar road safety challenges, making it a scalable and valuable innovation. This passage presents a focused and coherent overview of a potential solution to road safety challenges in Chadoora through the use of an IR sensor model. Consider providing specific examples or data to illustrate the socio-economic impacts of the high accident rate in Chadoora, such as costs related to healthcare, vehicle damage, or lost productivity. Expand on how the IR sensor works and its integration into vehicles or roadside infrastructure. This would help readers understand its functionality and feasibility. Include examples of how the model could be adapted to other hilly regions, emphasizing the similarities in road conditions or traffic patterns that make it applicable. Provide examples of potential funding sources or strategies to garner administrative support. Discussing challenges and solutions in these areas would add depth to the argument.

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