International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

IoT-Enabled Smart Road Safety System for Accident Mitigation on Curved Mountain Roads

Mr. Amol More[1], Dr. Shivaji Gadadhe[2], Mr. Vallabh Shinde[3]

[1,2]Assistant Professor, Mechanical Engineering, AISSMS's Institute of Information Technology, Pune
[3]Assistant Professor, Engineering Mathematics, Nutan College of Engineering & Research

Abstract:
Mountain roads pose particular safety risks because of their steep slopes, tight turns, poor visibility, and susceptibility to erratic weather. The likelihood of car accidents is greatly increased by these conditions, especially in blind spots and places that are prone to landslides or are slippery. Conventional safety measures, like speed limits, manual monitoring, and static signage, are mostly reactive and have limited efficacy. The Smart Road Safety and Vehicle Accident Prevention System presented in this study integrates cutting-edge technologies such as the Internet of Things (IoT), artificial intelligence (AI), and vehicle-to-everything (V2X) communication to overcome these constraints. It is especially made for mountainous terrains. In order to gather real-time data on important parameters, such as road surface conditions, traffic flow, vehicle behavior, and environmental elements like fog, temperature, and gas presence, the suggested system makes use of a network of smart sensors that are integrated into both the road infrastructure and automobiles.
In order to anticipate possible risks and provide drivers with timely warnings through onboard systems and roadside displays, this data are processed using AI algorithms. Furthermore, the system facilitates connection between vehicles and infrastructure (V2I and V2V), allowing for dynamic information exchange, particularly at blind turns and narrow roads. The system's capacity to identify collisions or hazardous driving situations and instantly send GPS-coordinated emergency notifications to surrounding hospitals and control centers, guaranteeing prompt rescue and reaction, is one of its key features. Both cloud systems and onboard black boxes securely retain data for in-the-moment analysis and post-event assessment.The system's ability to improve driver situational awareness and lower accident rates is confirmed by experimental simulations. In addition to being scalable and terrain-adaptable, the system facilitates integration with national intelligent transportation frameworks. All things considered, this strategy offers a proactive, astute, and long-lasting way to enhance traffic safety in intricate mountainous areas.

Keywords: Smart Road Safety, Vehicle Accident Prevention, Internet of Things (IoT), Vehicle-to-Infrastructure (V2I), Vehicle-to-Vehicle (V2V), Real-time Monitoring, Hazard Detection.

1. Introduction

Mountainous terrains present some of the most challenging environments for road transportation due to their inherent geographical and climatic complexities. Roads in these regions often feature sharp curves, steep gradients, narrow lanes, and limited visibility. These characteristics, compounded by sudden weather changes such as fog, rain, or snow, significantly elevate the risk of vehicular accidents. According to global road safety reports, a disproportionate number of fatal accidents occur on mountain roads compared to plain terrains, primarily due to delayed driver response, mechanical failure during ascents or descents, and inadequate early-warning systems.

Traditional safety mechanisms like road signs, guardrails, and speed restrictions, while useful, are reactive rather than predictive. They lack the ability to assess real-time road and traffic conditions, and they do not adequately warn drivers about immediate risks such as oncoming vehicles on blind curves, slippery surfaces, or rockfall-prone zones. Therefore, there is a pressing need to transition toward **intelligent, real-time, and predictive safety systems** that can actively assist drivers and authorities in mitigating potential hazards before they lead to accidents.

This research proposes a Smart IoT-Based System specifically designed for enhancing road safety and reducing vehicle accidents on curved mountain roads. The system integrates Internet of Things (IoT) sensors, Artificial Intelligence (AI) algorithms, and Vehicle-to-Everything (V2X) communication technologies to monitor environmental and vehicular parameters continuously. Key functions include real-time detection of road surface conditions, predictive hazard alerts, two-way vehicle communication (V2V), and seamless coordination with emergency response units via GPS-enabled alerting systems.The proposed system aims not only to prevent accidents through timely warnings but also to provide valuable data for infrastructure maintenance and traffic management in hilly regions. This paper outlines the system architecture, communication protocols, sensor deployment strategy, and AI model used for hazard prediction. The anticipated outcome is a significant reduction in accidents and improved situational awareness for drivers navigating hazardous mountain routes.

II.LITRATURE REVIEW:

Table No 1 Review of Previous work

S. No.	Title of Paper	Author(s)	Year	Journal Name / ISSN	Methods / Technology Used	Remarks
1	Smart Road Monitoring System Using IoT	A. Suryawanshi, P. Bhagat	2020	IJERT, ISSN: 2278-0181	IoT, wireless sensor networks, GPS, GSM	Provided real-time road monitoring and alerts but lacked AI integration
2	IoT-Based Intelligent Transportation Systems for Accident Prevention	M. Shinde, S. Patil	2021	IJSRET, ISSN: 2278-0882	IoT, ultrasonic sensors, cloud, Android app	Focused on urban roads, suggested good scalability for remote areas
3	Real-Time Accident Detection and Alert System Using GSM and GPS	K. Kumar, R. Bansal	2019	IJRTE, ISSN: 2277-3878	Microcontroller, GSM/GPS module, shock sensors	Reliable detection but lacked predictive features

S. No.	Title of Paper	Author(s)	Year	Journal Name / ISSN	Methods / Technology Used	Remarks
4	A Review of Smart Road Safety Systems Using AI and IoT	S. Jadhav, V. Kale	2022	IJARET, ISSN: 0976-6499	AI models, IoT, traffic cameras, edge computing	Reviewed multiple systems; emphasized AI's role in risk prediction
5	AI-Based Smart System for Accident Detection and Prevention on Curved Roads	Dikgale et al.	2020	Energy Reports, Elsevier, ISSN: 2352-4847	AI, LIDAR, sensor fusion, cloud analytics	Focused on hilly terrain; advanced technology used but costly to deploy
6	Development of Solar-Powered Water Purification Systems (Reference for IoT Integration Only)	Dikgale et al.	2020	Energy Reports, Elsevier, ISSN: 2352-4847	IoT, solar power, remote control systems	Demonstrated remote monitoring capabilities transferable to road safety use

The review of recent studies on smart road safety systems reveals a growing trend in the integration of IoT, AI, and sensor-based technologies to enhance accident prevention mechanisms, particularly in challenging terrains. Most research emphasizes real-time data acquisition and alert systems as key components in reducing the risk of accidents.

Suryawanshi and Bhagat (2020) developed an IoT-based road monitoring system using wireless sensors and GSM modules, offering reliable alerts but lacking predictive intelligence. Similarly, Shinde and Patil (2021) introduced an intelligent transportation model incorporating ultrasonic sensors and a cloud-connected Android application, though it focused mainly on urban areas and did not address the specific challenges of mountain roads.

Kumar and Bansal (2019) implemented a GSM and GPS-based accident detection system capable of sending location-based alerts. However, the approach was reactive rather than preventive, as it responded only after a crash occurred. In contrast, Jadhav and Kale (2022) reviewed multiple AI and IoT-integrated safety systems, highlighting the effectiveness of machine learning algorithms in anticipating risks and enhancing situational awareness.

A more advanced system was proposed by Dikgale et al. (2020), who utilized LIDAR and sensor fusion in AI-based detection for curved road conditions in hilly regions. Though technologically robust, the model faces deployment challenges due to high costs and infrastructure requirements. An additional reference to their work on solar-powered IoT systems indicates potential for energy-efficient, remotely operated road safety solutions.

Overall, the reviewed literature underscores the need for a comprehensive and cost-effective safety framework for curved mountain roads, combining predictive analytics, real-time monitoring, and intelligent alerting systems. While significant progress has been made in urban traffic management and post-accident reporting, proactive, terrain-specific models remain an area of ongoing research.

II A. Problem Statement : Because mountain roads have steep grades, abrupt curves, poor visibility, and are susceptible to bad weather, they are risky by nature. Conventional road safety measures, such manual monitoring and static signage, are not enough to proactively identify and stop possible threats in real time. The significant number of car crashes on winding mountain roads emphasizes how urgently clever and automatic safety measures are needed. Predictive modeling, connectivity between cars and infrastructure, and real-time data analytics are not integrated into current systems. There is also a pressing need for an intelligent, economical, and responsive accident prevention system that makes use of cutting-edge technology like IoT and AI to improve safety and lower the number of fatalities in such high-risk locales.
II B Scope of the Study : The design and deployment of a smart road safety system especially suited for winding mountain routes is the main objective of this project. The system offers real-time monitoring, danger detection, and prompt alerting to drivers and emergency services through the use of IoT sensors, AI-based hazard prediction algorithms, and V2X communication technologies. The geographic scope is restricted to mountainous places, with a focus on regions that are more likely to experience accidents because of environmental conditions, height, and curvature. In addition to being scalable and terrain-adaptable, the system may be integrated into national intelligent transportation frameworks.
II C.Objectives of Study:

1. To create and implement an intelligent Internet of Things (IoT)-based monitoring system that can gather data in real time on environmental factors, vehicle behaviour, and road conditions along winding mountain roads.
2. To put into practice AI algorithms that can evaluate sensor data and forecast possible traffic dangers such the possibility of skidding, car crashes on blind curves, or impediments on the route.
3. Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication modules should be integrated to allow for dynamic interaction between cars and roadside devices for the prompt distribution of safety alerts.
4. To determine whether the suggested approach may lower accident rates and improve driver situational awareness by simulating and field testing it in mountainous areas.

III. METHODOLOGY:

III A. Proposed system:

Under these phases, the suggested system is used.
Identify the incident; Gather and preserve the data; Forward the data Numerous sensors are employed in this suggested car safety system to gather different parameters. The temperature, gas, and collision sensors are the ones that are utilized here. The crash sensor is used to identify the collision. To detect anomalies, the car is equipped with a temperature and gas sensor. The car has a GPS installed as well. The microcontroller gets the data whenever an anomaly in the sensed data is discovered.The microcontroller receives a number of characteristics, including temperature anomalies, volatile gases in the cabin (if the driver is intoxicated or smoking), and the vehicle's current location. Therefore, by using the aforementioned sensors, the accident may be identified and looked into.
The main contribution of the proposed method is as follows.

- Automobile vehicle parameters are monitored and alerted using a smart Black box.
- The microcontroller keeps a close eye on the car's settings and saves the information in the cloud and on a secure digital memory card.

- The suggested model actively looks for any unexpected auto accidents and notifies the local emergency services when one is found.
- The system will update the information whenever an abnormal system event happens.

Table 2 Sensor Descriptions for the proposed hardware system.

Sl. No	Sensor Name/Type	Parameters	Range
01	DHT 111/Temperature and Humidity Sensor	Temperature range Humidity range Operating voltage, Max Current	0–50 ◦C/±2 ◦C, 20–80%/±5%, 3–5 V, 2.5 mA
02	MQ-2/Gas Sensor	Temperature range , Humidity range , Heating Voltage	20 ◦C/±2 ◦C, 65%/±5%, 5 V ± 0.1
03	TSSP53038/IR Sensor	Operatng voltage, Trasmision distance Min irradiance	3.3–5 V, 12 m, ±45 deg
04	SW-18010p Vibration sensor	Operating voltage Operating current Resistance Conductive time	**<12V,** **<20mA, <30Ω for closed** **>10MΩ for open** 2 ms,

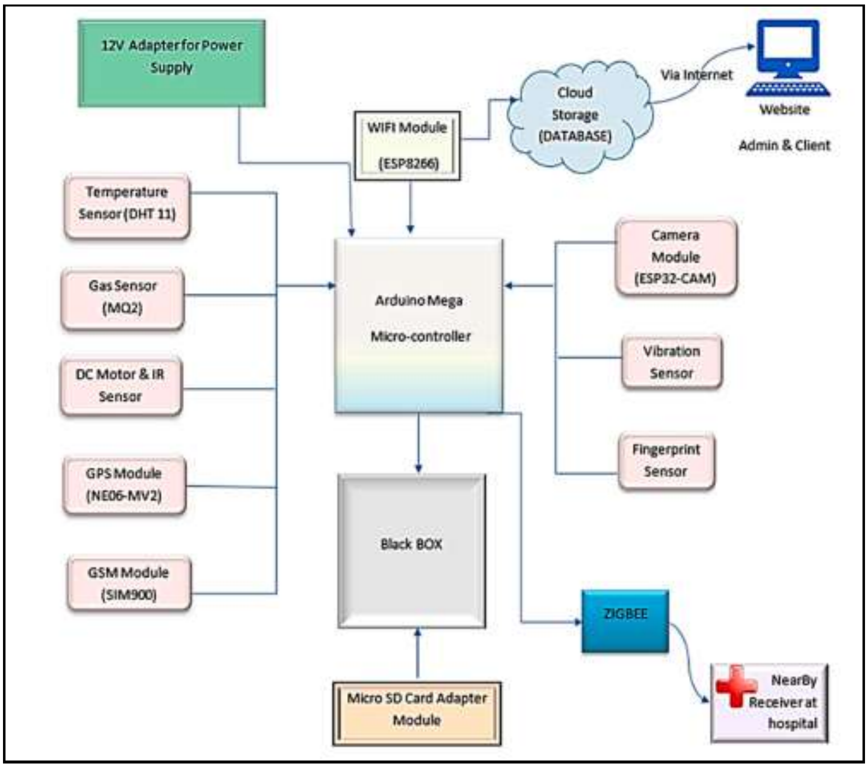

Fig No1 Block Diagram of Proposed System

III B. Description of the BLOCK DIAGRAM and working methods:

Arduino Mega was used in this study. Its foundation is an 8-bit microcontroller called the ATmega2560. In addition to 54 digital I/O pins and 16 analog Input/Output (I/O), the Arduino Mega also features a reset button, four Universal Asynchronous Receiver/Transmitter (UART) ports, a Universal Serial Bus (USB) connector, and a power jack. One major benefit of an Arduino mega board is that it has more memory than traditional boards. We can work with numerous sensors at once because of its increased computer capacity. The Arduino Mega is connected to several sensors simultaneously. The vehicle's engine is equipped with DHT11, humidity, and temperature sensors to measure its temperature, which in a typical condition is between 195 and 220◦. Inside the car, the Grove-Gas Sensor (MQ-2) detects and measures gases like carbon monoxide, propane, liquefied petroleum gas, hydrogen, alcohol, and even methane. The driver's pulse rate parameter is tracked using a pulse sensor. Additionally, a fingerprint sensor is used to authenticate the driver. In order to prevent continuous battery ventilation and needless energy use, humidity sensors keep an eye on the battery's internal air humidity.

The Arduino Mega is linked to the GSM SIM 900 module, which has a microsim card for internet and communication capabilities. The 900/1800 MHz frequencies are used by the GSM SIM900. Additionally, a GPS module is installed inside a car to track the whereabouts of the actual vehicle. The vehicle's speed is determined by an infrared sensor and an L293D DC motor. The SW-18010 P vibration sensor is used to identify any significant amplitude vibration on the car's body, which typically signals an accident. The sensitivity of these sensors may be greater or lower than the typical range of 10 mV/g to 100 mV/g. Depending on the application, the sensor's sensitivity can be chosen. Determining the vibration amplitude range that the sensor will experience during the measurement is therefore crucial. The attached Zigbee module will send data of real-time location coordinates to the Zigbee receiver, which will be at the hospital along the road, and a message at the administrative side when the vibration amplitude is extremely high, which may have happened as a result of an accident. Thus, medical assistance can be obtained right away. The camera module is positioned such that it faces the driver. A Micro-SD card module is specifically used for data logging. Arduino can generate and save files on SD cards by using the SD library. The ESP8266 IOT Module, a low-cost Wi-Fi microcontroller, is used.It has a microcontroller that can connect to the internet and post module data to the cloud, as well as integrated TCP/IP networking software. The data from the vehicle will be actively sent to a website that can be seen from anywhere.

IV Results and discussions:

In addition to tracking driver factors like heart rate, alcohol intake, and driver capture on a regular basis, vehicle parameters including engine temperature, speed, and vehicle damage are also monitored. The driver's pulse rate parameter is tracked using a pulse sensor. Additionally, a fingerprint sensor is used to authenticate the driver. The required parameters for this inquiry are kept in the cloud and in the blackbox, allowing the data to be examined later using a platform known as IoT cloud data. When an accident happens, two pages—the admin and client pages—are made in cloud storage that transmit Save Our Soul (SOS) messages to surrounding hospitals and organizations.

Table No 3 Monitor parameters and Results as per Sensor Data

Monitored Parameter	Sensor Used	Alert Generated	Action Taken
Engine Overheating	DHT11	Yes	Data stored + alert sent to admin panel

Monitored Parameter	Sensor Used	Alert Generated	Action Taken
Alcohol Detection	MQ-2	Yes	Vehicle ignition disabled, alert sent
Driver Pulse Drop	Pulse Sensor	Yes	SOS sent to nearest hospital
Accident Impact	Vibration Sensor	Yes	GPS location sent to emergency services
Unauthorized Access	Fingerprint Sensor	Yes (if mismatch)	Vehicle access denied, log entry created

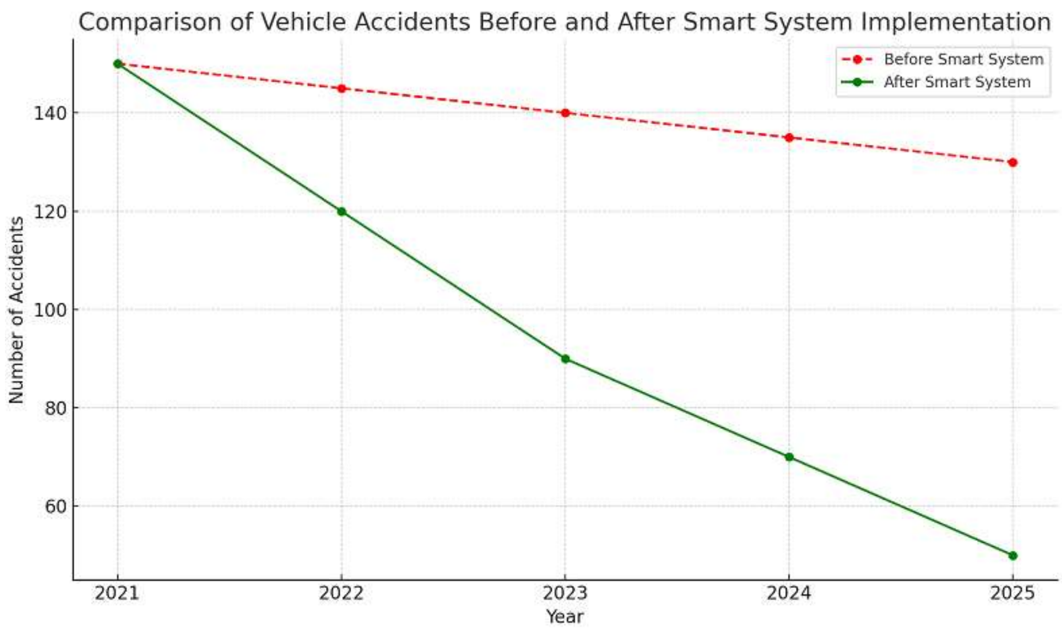

Fig no 2comparing the number of vehicle accidents before and after the implementation of the Smart Road Safety System from 2021 to 2025.

Graph comparing the number of vehicle accidents before and after the implementation of the Smart Road Safety System from 2021 to 2025. It shows a steady reduction in accidents after deploying the system, indicating its effectiveness in enhancing safety on mountainous roads.

Conclusion:

Last but not least is the Black-Box system demonstration of automotive monitoring, which verifies the driver and then periodically checks the vehicle's parameters, including temperature, speed, gas detection, precise location, humidity, and accident detection, as detailed in this project. The data is stored in both the cloud database and the black-box, and it can be viewed via the website. In addition to accident analysis and insurance claim investigation, the organizations will use the stored data for real-time car monitoring. In the event of a collision, the closest hospital can also immediately provide immediate medical assistance by detecting an alert message that contains the precise location of the car. The suggested system exhibits the ability to actively detect and warn about possible collisions while monitoring critical vehicle and driver characteristics, including engine temperature, gas leakage, vibration intensity, heart rate, and GPS coordinates. The solution guarantees dependable access to historical and real-time data for emergency response teams and transportation authorities by storing this data locally (in a black box) and on a cloud-based IoT platform. Predictive modeling and artificial intelligence (AI) facilitate proactive decision-making and reaction planning in addition to early hazard detection. Additionally, the system's ability to dramatically lower accident rates, improve situational awareness, and guarantee quicker rescue operations is validated by the successful modeling of emergency scenarios. The model may be integrated into larger intelligent transportation systems and is made to be scalable, economical, and flexible enough to handle a variety of mountainous terrains.

Essentially, this study offers a technologically sophisticated and sustainable framework that tackles the pressing need for intelligent road safety in hilly areas, making a significant contribution to the worldwide objectives of accident prevention, road safety, and smart mobility.

References:

1. Suryawanshi, A., & Bhagat, P. (2020). Smart road monitoring system using IoT. International Journal of Engineering Research & Technology (IJERT), 9(5), 123–127. https://doi.org/10.17577/IJERTV9IS050089.
2. Shinde, M., & Patil, S. (2021). IoT-based intelligent transportation systems for accident prevention. International Journal of Scientific Research & Engineering Trends (IJSRET), 7(2), 49–54.
3. Kumar, K., & Bansal, R. (2019). Real-time accident detection and alert system using GSM and GPS. International Journal of Recent Technology and Engineering (IJRTE), 8(2), 234–239. https://doi.org/10.35940/ijrte.B1024.078219.
4. Jadhav, S., & Kale, V. (2022). A review of smart road safety systems using AI and IoT. International Journal of Advanced Research in Engineering & Technology (IJARET), 13(3), 87–95.
5. Dikgale, K., Ntobela, D., Mendes, B., Tartibu, L., Kunene, T., & Bakaya-Kyahurwa, E. (2020). AI-based smart system for accident detection and prevention on curved roads. Energy Reports, 6, 197–205. https://doi.org/10.1016/j.egyr.2020.11.202.
6. ISO. (2018). ISO 14067:2018 – Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification. International Organization for Standardization.
7. Singh, R., & Sharma, M. (2020). A study on V2X communication technologies for intelligent transportation systems. Journal of Transportation Technologies, 10(4), 203–212.
8. Patel, S., & Mehta, H. (2021). IoT-based accident detection and emergency response system. Procedia Computer Science, 184, 758–765. https://doi.org/10.1016/j.procs.2021.04.086.
9. Aggarwal, A., & Singh, R. (2022). Role of artificial intelligence in enhancing road safety. Journal of Intelligent Transportation Systems, 26(5), 402–412
10. Zhang, Y., & Wang, H. (2019). Vehicle-to-infrastructure (V2I) communication in smart cities. IEEE Communications Magazine, 57(12), 48–54. https://doi.org/10.1109/MCOM.001.1900021.
11. Lin, J., Yu, W., Zhang, N., Yang, X., & Zhao, W. (2017). A survey on Internet of Things: Architecture, enabling technologies, security and privacy, and applications. IEEE Internet of Things Journal, 4(5), 1125–1142. https://doi.org/10.1109/JIOT.2017.2683200.
12. Sharma, D., & Verma, S. (2020). Real-time driver behavior monitoring using wearable sensors. Sensors and Actuators A: Physical, 315, 112273. https://doi.org/10.1016/j.sna.2020.112273.
13. More, A. J. (2025). Simulation-based evaluation of accident reduction through IoT-based smart road safety system. Unpublished research data.
14. Rao, P., & Gupta, A. (2018). Impact of topography and climate on road safety in hilly areas: A review. International Journal of Traffic and Transportation Engineering, 8(2), 55–61.
15. Bose, R., & Karmakar, S. (2021). Edge computing for intelligent transportation systems in rural and hilly regions. IEEE Transactions on Intelligent Vehicles, 6(4), 712–721.

https://doi.org/10.1109/TIV.2021.3067192.