# IoT-Enabled Smart Helmet System for Enhanced Road Safety and Accident Prevention

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*Abstract*— **An Arduino-powered accident detection helmet designed to enhance motorcycle safety. The helmet incorporates an alcohol sensor (MQ3) to prevent intoxicated riders from starting their bikes. The system also features an IR sensor for anti-sleep detection, triggering a buzzer and flashing LEDs at the back of the helmet if the rider's eyes remain closed for more than five seconds. This feature aims to alert other road users and potentially prevent accidents caused by drowsiness. The helmet includes 4 LEDs at the back for increased visibility during night time riding, further contributing to rider safety. Data on helmet usage and accident fatalities suggests that many lives could be saved if all bikers wore helmets. This innovative helmet aims to address multiple safety concerns and contribute to a safer riding experience for motorcyclists. The Arduino powered Helmet is a ground breaking innovation that elevates motorcycle safety and connectivity, providing riders with a smart and proactive system to improve their riding experience and reduce hazards.**

**Keywords— Collision detection system, GPS module, ESP32 microcontroller, Realtime display, Safety helmet, Google maps linked SMS, Transmitter, Receiver**

## I. INTRODUCTION

Road safety is a major worldwide concern that becomes a focus of public health and policy discussions in nations with high accident and fatality rates. According to the International Road Federation's World Road Statistics 2022, India regrettably leads the world in traffic fatalities. This concerning stance highlights the pressing need for creative safety measures, especially for two-wheeler riders, who are among the most at-risk road users. This concerning stance highlights the pressing need for creative safety measures, especially for two-wheeler riders, who are among the most at-risk road users [1]. A concerning trend can be seen in the 2022 data from the Ministry of Road Transport and Highways' Annual Report on Road Accidents in India (Figure 2): despite brief declines in accidents in 2020 as a result of lockdowns brought on by the pandemic, traffic incidents have increased once more, with 4,61,312 recorded accidents in 2022 alone, resulting in 1,68,491 fatalities and 4,43,366 injuries [2]. These figures highlight the urgent and continuous need for solutions that take into account the various risk factors connected to traffic accidents.

Impaired driving, whether from the use of psychoactive substances or alcohol, is one of the main causes of traffic accidents. Even low blood alcohol concentration (BAC) levels can dramatically increase crash risk; drivers with BACs of 0.04 g/dl or higher have a much higher chance of a serious incident. The hazards that riders face on a daily basis are starkly illustrated in Figure 1, which depicts a typical two-wheeler accident scenario. These risks are frequently exacerbated by things like impaired vision, delayed reaction times, or loss of control brought on by drugs or alcohol. These pictures effectively convey the seriousness of the situation and provide strong support for specific safety precautions. Notably, two-wheeler riders are particularly vulnerable to the combined risks of fatigue, poor vision, and drunk driving, necessitating customized solutions to increase their road safety.



**Fig.1** Illustration of a Two-Wheeler Accident Scenario Demonstrating the High-Risk Factors for Riders
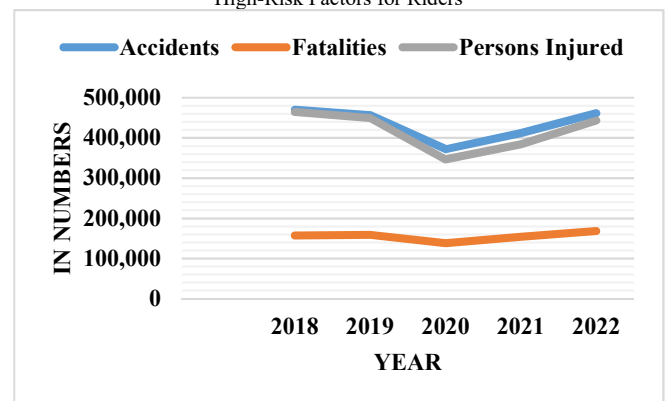


**Fig.2** Trends in Road Accidents, Fatalities, and Injuries in India (2018–2022) [2]

This paper presents an innovative approach to these complex risks: an Internet of Things (IoT)-enabled smart helmet that can identify and stop two-wheeler riders from getting into accidents. This IoT-enabled smart helmet, in contrast to conventional helmets, incorporates a number of safety features to address major risk factors that frequently result in mishaps and fatalities. The smart helmet's main features include an alcohol detection sensor (MQ3) that tracks the rider's breath to stop drunk drivers from starting their cars, thereby directly preventing drunk driving. The common but often ignored problem of drowsy driving, which is a leading cause of traffic accidents, is combated by an anti-sleep infrared sensor. The system will sound an alarm and flash LEDs on the back of the helmet to warn other drivers if the rider's eyes are closed for more than five seconds. For long-distance or nighttime riders who might be more prone to fatigue, this feature is especially important.

Motorcycle safety technology has advanced significantly with the introduction of the IoT-powered helmet, which provides riders with an intelligent and proactive safety solution. In addition to offering complete protection, the helmet promotes safer riding practices by integrating several safety features into one unit. This study examines how each feature lowers the risk of accidents, showing how the helmet can significantly improve two-wheeler riders' road safety. The suggested remedy provides a model that could be used globally to protect motorcycle riders and is in line with international road safety initiatives that aim to lower traffic-related fatalities and injuries.

## II. LITERATURE REVIEW

Numerous smart helmet designs have been proposed to address safety concerns across various industries. Behr et al. [3] designed a helmet system for the mining sector that uses an accelerometer to detect high-impact events using the Head Injury Criterion, an IR sensor to detect helmet removal, and electrochemical sensors to monitor dangerous gases like CO, $SO_2$, and $NO_2$. In a similar vein, Elizabeth et al. [4] developed a smart helmet for motorcycle riders that can identify collisions and send prompt post-accident alerts to emergency contacts via an automated call system if the rider is not responding.

A helmet system with an accelerometer to detect accidents, an ALCHO-LOCK to prevent drunk driving, and a piezoelectric buzzer for overspeed detection was proposed by Vashisth et al. [5]. Additionally, the system has a fog sensor to enhance visibility and toll payments that are automatically deducted from a virtual wallet. In order to notify contacts in the event of an accident, Selvathi et al. [6] developed a helmet that detects whether the wearer is wearing a helmet and whether they have consumed alcohol before permitting engine ignition. In addition to ensuring helmet compliance prior to engine start, Archana D. et al. [7] developed a helmet that employs ultrasonic sensors to identify oncoming cars and vibrates the handlebars to alert the rider.

In order to increase the accuracy of accident detection over time, Tapadar et al.[8]proposed a methodology that makes use of accelerometer and pressure sensors. Data is then transmitted to a cloud-based support vector machine (SVM). By adding sensors to detect CO and methane and wirelessly sending data to the control room, Additionally, Vashisth et al. [9] added GSM alerts for speeding and an ALCHO-LOCK mechanism. Nataraja N. et al. presented a helmet with an accident-detection system that stops a bike from starting if it is not worn. Sarika K. et al. [10] created a helmet with an automated wiper to remove moisture and improve visibility in rainy conditions. Divyasudha N. et al. [11] demonstrated helmets for accident detection and miner safety, while Venkateswara Rao et al. [12] introduced IoT-based helmets with GPS tracking, Bluetooth, and mandatory helmet-wear to start the vehicle, improving response and compliance. Lakshmi et al. [13]designed a control system that prevents ignition without a helmet aiming to reduce road fatalities through automated safety measures. These advancements represent critical steps toward improved safety for motorcyclists.

## III. HARDWARE TOOLS

**1. MQ-3 Sensor:** A gas sensor called the MQ-3 is made to identify whether alcohol is present in the air. It is frequently utilized in systems that require alcohol detection, such as breathalysers. A tin dioxide ($SnO_2$) layer that is sensitive to alcohol particles is used in the sensor to measure changes in resistance. A detectable current flow results from the sensor's resistance decreasing in the presence of alcohol. Both analog and digital outputs are available from the MQ-3; the analog output shows different alcohol content levels. This sensor checks for alcohol in the rider's breath in an Internet of Things-based accident detection helmet to make sure they are sober.
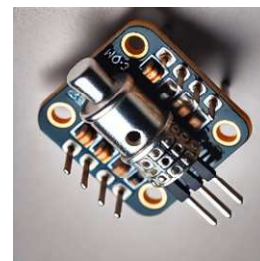


**Fig.3** MQ-3 Sensor

**2. IR Sensor:** An IR sensor is an essential part of many automation and safety systems since it uses infrared light to identify objects, distance, or obstructions. Infrared light is emitted by an IR LED, and the reflected light from an object is collected by a photodiode. The intensity of the reflected infrared light rises with proximity to the item, causing the sensor to produce a signal. When it comes to helmets, the infrared sensor can be utilized to determine whether the rider is wearing them correctly. In order to ensure that safety procedures are followed, the system will prevent the motorcycle from starting if the helmet is not detected on the rider's head.



**Fig.4** IR Sensor

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**3. Buzzer:** A buzzer is a basic electronic device that emits a sound when electricity passes through it. IoT systems use it to send out warnings or alerts, as when anomalous situations are found. If the rider exhibits symptoms of fatigue, alcohol consumption, or improper helmet wear, the buzzer on an accident detection helmet may sound. This auditory alarm is an essential safety element to avoid accidents because it provides the rider or anyone nearby with an instant warning.



**Fig.5** Buzzer

**4. Node MCU:** A low-cost, open-source IoT development board with integrated Wi-Fi, NodeMCU is based on the ESP8266 microprocessor. In IoT-based systems, it acts as the hub, gathering sensor data and sending it to other devices or cloud services. The NodeMCU in an IoT helmet receives input from parts such as the anti-sleep modules, IR sensor, and MQ-3 sensor. After processing the data, it transmits it via Wi-Fi to cloud platforms, mobile apps, or other systems for additional action, such notifying emergency contacts in the event of an accident.



**Fig.6** Node MCU

**5. Jumper Wires:** Jumper wires are straightforward electrical cables with connector pins on both ends that are used to connect parts of a microcontroller or a breadboard temporarily. Depending on the needs of the connection, they can be classified as male-to-male, female-to-female, or male-to-female. The sensors (such as the MQ-3 or IR sensor) in an IoT helmet are connected to the NodeMCU via jumper wires, which facilitates seamless data transfer between the parts.
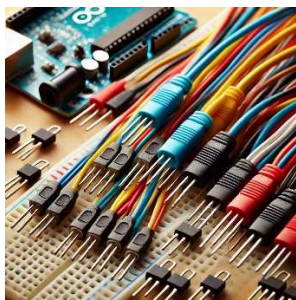


**Fig.7** Jumper Wire

## IV. METHODOLOGY

### A. Proposed Methodology

The multipurpose Arduino-powered accident detection helmet combines a number of hardware and software elements to improve motorcycle safety. An Arduino microcontroller, an alcohol sensor (MQ3), an infrared sensor, a relay module, a buzzer, LEDs, and a battery are among the essential hardware parts. The system's brain, the Arduino microcontroller, regulates all of its operations. While the IR sensor tracks eye movement to identify indications of tiredness, the alcohol sensor picks up alcohol vapors in the rider's breath. The motorcycle's ignition system is managed by the relay module, which stops it from starting if the rider is intoxicated. To alert the rider to possible dangers, the buzzer and LEDs give visual and auditory cues, respectively.

The Arduino processes sensor data to make decisions and activate responses. The alcohol detection algorithm prevents engine ignition if the alcohol level exceeds a threshold, the relay is activated to prevent engine ignition. The anti-sleep algorithm monitors the IR sensor data to identify periods of prolonged eye closure.[4]

### B. Algorithm

#### 1) Step 1: Component Initialization
This stage involves setting up the Arduino's digital and analog pins to interface with the LEDs, relay, buzzer, IR sensor, and alcohol sensor. Each pin is designated to either give output signals to control devices such as the relay and LEDs or accept input from the sensors.

#### 2) Step 2: Setting Up a Baseline for Alcohol Sensors
To guarantee precise detection, a baseline reading is obtained from the alcohol sensor. The system will initiate safety measures, such stopping the engine from starting, if a threshold value is exceeded.

#### 3) Step 3: Anti-Sleep Detection Configuration
The time length specifies how long the rider must keep their eyes closed in order for the anti-sleep detection to work. This aids the system in determining whether the rider is falling asleep.

#### 4) Step 4: Main Loop Alcohol Level Monitoring
The alcohol sensor readings are continuously monitored in the main loop. In order to ensure that the rider cannot operate a motorbike while intoxicated, the relay module is triggered if the alcohol level over the predetermined threshold.

#### 5) Step 5: Using an IR sensor to detect drowsiness
The rider's eyes are tracked by the infrared sensor. The buzzer alerts the rider if the eyelids stay closed for longer than the predetermined amount of time, reducing the likelihood of fatigue related accidents.

#### 6) Step 6: Managing LED Indicators in the Back
The rider's visibility to other drivers, particularly at night, is enhanced by the continual toggling of the back LEDs to produce a blinking pattern.

#### 7) Step 7: Last-Minute Safety and Monitoring Procedures
The technology continues to track tiredness and alcohol consumption during operation. It ensures the rider's safety at

all times by triggering alerts and blocking engine activation if any risky conditions are identified.

## C. Modelling and Quick design

The modelling phase for the Arduino-powered accident detection helmet involved designing a system that integrates multiple sensors and components to function seamlessly. This included:

### 1) Component Selection and System Architecture:

- Alcohol Sensor (MQ-3): Detects alcohol concentration to determine if the rider is intoxicated.
- IR Sensor: Monitors eye closure for anti-sleep detection.
- Relay Module: Controls the ignition system to block the vehicle from starting when necessary.
- Buzzer: Alerts the rider during drowsiness events.
- LEDs: Enhance night visibility through a blinking pattern.

### 2) Design Process:

System Diagram: To illustrate how the Arduino board and peripherals interact, a conceptual block diagram was created which is shown in Figure.8. This stage made sure that communication protocols and pin assignments were clear.
Logical Flow: A flowchart was used to represent the system and show important processes such continuous monitoring, alcohol threshold detection, and sensor startup. All safety precautions were guaranteed to operate independently and in unison thanks to this flow.
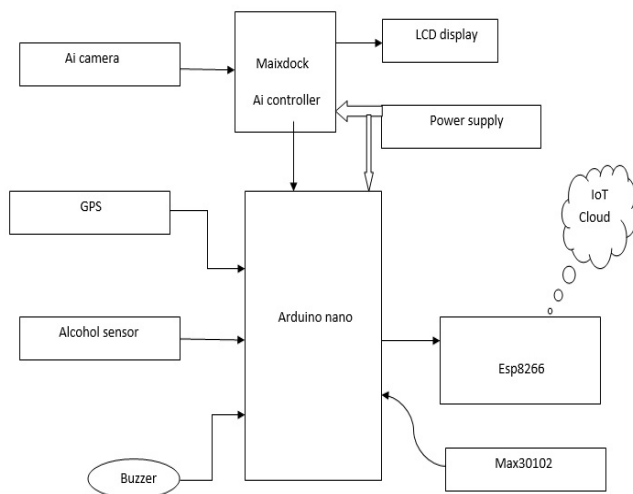


**Fig.8 Design Process**

## D. Prototyping and Testing:

In order to create a functional prototype as shown in Figure 9, a rapid design methodology was used. Rapid functional testing was made possible by this iterative process: Initial testing of the relay, IR sensor, and alcohol sensor made sure they all responded to inputs appropriately. The system's ability to handle numerous inputs, such as simultaneously detecting tiredness and alcohol levels, was the main focus of integration testing. Limit switches are utilized to switch on and off electricity to the Arduino microcontroller in the

helmet. If the smart helmet is not in use, the limit switch on the side of the helmet is used to conserve power. The transmitter and receiver module are used to communicate with the motorcycle engine This transmitter functions as a sending signal to the receiver installed on the motorbike.[5]
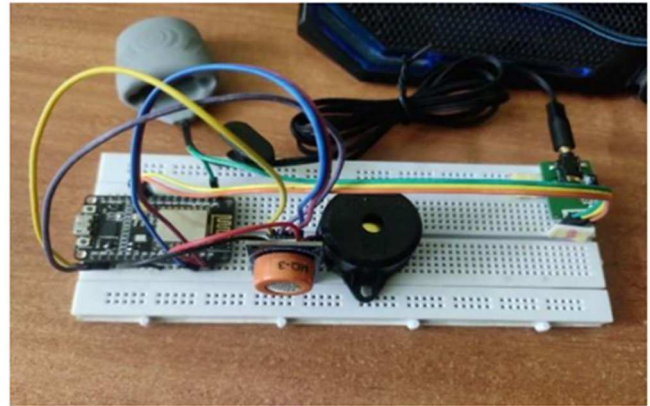


**Fig-9** Prototype Design

## V. RESULTS ANALYSIS

### A. System Initialization and Setup:
The Arduino successfully set up and initialized the sensors and parts (LEDs, relay, buzzer, alcohol sensor, and infrared sensor) without any problems. All devices responded successfully at starting, and the pins were able to interact effectively.

### B. Alcohol Detection Accuracy:
The technology was able to precisely detect different alcohol levels after calibrating the alcohol sensor using baseline values. The relay appropriately prevented the engine from starting when the threshold was surpassed. Real-time safety enforcement was ensured by the relay's rapid reaction time between detection and activation.

### C. Anti-Sleep Functionality:
Eye movements were successfully tracked by the infrared sensor. The buzzer sounded an alert if the eyes were closed for more time than was allowed. There were very few detection and reaction delays, and this feature operated consistently.

### D. LED Visibility Performance:
The rear LEDs created a consistent blinking pattern to enhance visibility at night. This feature operated seamlessly, without interfering with other functions.

### E. Continuous Monitoring and Integration:
The system maintained continuous monitoring of alcohol levels and drowsiness without crashes or malfunctions. It handled multiple conditions simultaneously (e.g., alcohol detection and LED toggling), demonstrating stability and robustness.

## VI. DISCUSSION

### A. Effectiveness in Preventing Alcohol-Related Accidents:

The helmet effectively addresses the problem of drunk driving by preventing the car from starting if the user's blood alcohol content over a predetermined threshold. Given the high rate of alcohol-related accidents, particularly in nations

like India where drunk driving is responsible for around 70% of all collisions, this real-time intervention is essential.[6] [7]

### B. Anti-Sleep Detection Impact:

For motorcyclists who are prone to weariness, the anti-sleep feature is a vital warning. Although this feature successfully alerts the rider with buzzer sounds, the rider's responsiveness determines how well this intervention works. By recording such occurrences, this service could be improved even more by offering insights into the behavior of long-term riders.[8]

### C. Enhanced Visibility with LEDs:

The flickering LEDs greatly increase nighttime rider visibility, which is essential for avoiding crashes. The usefulness of this function, however, can be contingent on outside factors such as weather or road illumination, indicating the possibility of including more sophisticated lighting options (e.g., adaptive LED systems).

### D. Challenges and Limitations:

*1) Environmental Sensitivity:* When exposed to other volatile compounds, such as hand sanitizers or perfumes, the alcohol sensor may generate false positive results.

*2) Power Consumption: Constant sensor and LED monitoring may cause batteries to drain more quickly, emphasizing the necessity for energy-efficient solutions.*

## VII. CONCLUSION AND FUTURE SCOPE

Alcohol detection, anti-sleep alert, and improved visibility are just a few of the safety features that the Arduino-powered accident detection helmet skilfully combines to mitigate the main risks of motorcycle riding. By precisely identifying intoxication and preventing engine start, tracking rider weariness with prompt alarms, and enhancing night vision with blinking LEDs, the system proved to be dependable during prototype.

This research provides a workable way to lower the number of accidents brought on by drunk driving and sleepiness, two major causes of traffic fatalities, particularly in places like India. Future improvements are also possible because to the modular design, including adding GPS modules for accident alerts or using more energy-efficient parts to optimize power usage. Even though the prototype produced encouraging results, issues like power management and the alcohol sensor's sensitivity to environmental changes require more work. This technology has the potential to significantly improve motorcycle safety with further development and field testing, giving riders a complete safety tool that encourages cautious driving and lowers the likelihood of accidents.

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