# Helm X – Next-Gen Smart Helmet

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## ABSTRACT

This project presents Road accidents involving two-wheelers are a major cause of serious injuries and fatalities, mainly due to non-compliance with safety rules and delayed medical assistance. The Smart Helmet for Accident Prevention and Detection is an IoT-based safety system designed to enhance rider protection and ensure timely emergency response. The system ensures that the rider wears the helmet and is not under the influence of alcohol before allowing vehicle ignition. It continuously monitors sudden impacts or abnormal tilts to detect accidents. In case of an accident, the helmet automatically fetches the GPS location and sends an SMS alert with live location details to predefined emergency contacts. This system integrates sensors, a microcontroller, GPS, and GSM modules to provide both preventive and post-accident safety, thereby reducing fatalities and improving two-wheeler road safety.

## INTRODUCTION

The Technology dominates education, product manufacturing, transportation, communication, and health. Transportation has always supported the economy and governance. Youth and the world love motorcycles. Motorcycle safety involves equipment, vehicle design, and operator ability. Motorcyclists are unique. They are the most dangerous road users without protection. Even the smallest mistake can kill. Speeding, drunk driving, and traffic offenses kill people. Helmetless caused brain damage and death. Helmets save 80% of head injuries and lives. IoT prevents traffic accidents, modelling motorcycles with sensors, communicating with riders and the environment, and requiring helmets. Road accidents kill 4 people each hour, 70% without helmets, according to a poll. Global statistics show safety rules and new technology are being created to prevent such incidents and ensure rider safety. We encourage 'Safety on Two Wheels' for safe travel. This method aims to build a helmet that protects bikers and prevents drunk driving. If the rider crashes, it alerts the guardian via SMS. Drunk driving causes most accidents in today's fast-paced world. Uncivilized drivers are breaking helmet laws in most nations. Thus, this project aims to get people to wear helmets and ride bikes. The cyclist must not be intoxicated. Drunken riders cannot ride bikes. Another goal is to reduce accident fatalities by notifying passengers' relatives. Advanced features including alcohol detection, accident recognition, location tracking, and hands-free, solar powered use accomplish this. Helmets are required for ignition. The IoT is a network of interconnected computers, mechanical and electronic devices, furniture, living things, and people, all of which have individual IDs and are able to exchange data without the need for human interaction. The IoT makes it possible to integrate the physical world more directly into computer-based systems, improving efficiency, accuracy, and economic value while minimizing human involvement. Additionally, it enables the use of existing network infrastructure for remote sensing and control of objects.

## PROBLEM STATEMENT:

Develop a smart environmental monitoring system using gas, humidity, and temperature sensors to ensure indoor air quality. The system will continuously collect data on gas levels, humidity, and temperature, providing real-time feedback to users. Through this, users can track and analyse air quality, receiving alerts in case of hazardous conditions. The project aims to enhance health and safety in indoor environments by empowering users to make informed decisions and take necessary actions to improve air quality.

Additionally, the system will feature a user-friendly interface for data visualization and analysis, allowing users to easily interpret the sensor data. The project will involve designing a robust sensor network, integrating data collection and processing modules, and developing a responsive alert system. Through this project, we aim to create a reliable and efficient solution for monitoring indoor air quality, ensuring a healthier and safer living environment.

## LITERATURE SURVEY

The A. jesudoos suggested using mems with IR, vibration, and gas sensors. The helmets' gas sensor checks a person's breathe for alcohol consumption. MEMS controls car bars. PIC microcontrollers connect sensors. The gas sensor displays alcohol consumption on the LED display. Vibration sensors detect accidents and relay GPS data to hospitals. The MEME sensor deducts the rider's bank account balance for reckless driving. IR sensors detect helmet wear. This system automatically books ambulances from ten locations and is precise.

K. M. Mehata proposed a method to protect workers or detect workplace falls. The proposed system is two-part. Sensor-equipped wearable devices are one. Cell phones are another component. GSM module connects them. These gadgets continuously monitor worker health and safety. The register person receives medical attention via this fall detection system.

N.Divya sudha presented a system using an IOT modem to prevent accidents and monitor alcohol intake. IOT modems notify police and specified numbers of accidents. This helmet is cheaper than others are.

Manish Uniyal proposed a helmet-two-wheeler system. The TW microcontroller continuously checks helmet position. The TW vehicle also has accelerometers, Hall-effect sensors, and GPS modules. If there is an internet connection, sensors provide data to the microcontroller, which then sends it to the server. This technology lets anyone check the vehicle speed anytime. This system shows vehicle speed. Parents may see if their kids wear helmets.

Shoeb Ahmed Shabbeer designed smart helmets to detect and report incidents. This approach uses microcontroller with accelerometer and GSM module. Cloud infrastructures report accidents. This system identified accidents 94.82% of the time and sent correct coordinates 96.72%.

P. Rojaet presented a system with six units: remover sensor, IR sensor, air quality sensor, Arduino UNO microcontroller, GPRS, GSM. If removed, this helmet alerts miners to harmful gases and sends information to the server. IOT transmits this info.

C. J. Bheret presented a smart mining helmet that detects dangerous gases, helmet removal, and collisions. They use IR, gas, and accelerometer sensors.

## METHODOLOGY

The development of the *Smart Helmet System* followed a structured, multi-phase methodology to ensure systematic design, integration, and validation of all hardware and software components. The methodology consists of five major stages: requirements analysis, hardware design and sensor selection, firmware development, software application development, and system testing and evaluation.

### Requirements Analysis and Related Work Review

The initial phase involved an in-depth investigation of the key challenges faced by delivery riders, such as helmet non-compliance, vulnerability to fall-related injuries, and inefficiencies in communication and reporting mechanisms. A review of existing IoT-enabled smart helmet systems (Elabd et al., 2025; Impana et al., 2019) provided insights into prevailing approaches and technologies.

Prior work shows that most systems incorporate inertial sensors including accelerometers and gyroscopes for detecting crashes or falls (Alcantara et al., 2023; Jadhawar et al., 2016; Ahmed & Uddin, 2020; Kavianand & Padmapriya, 2015; Rasli & Madzhi, 2013). Additional mechanisms include pressure sensors or FSRs for monitoring helmet usage (Rajitha et al., 2021; Shahare et al., 2021), and GPS modules for real-time localization (Manjesh & Raj, 2014;Sireesha et al., 2020). Communication technologies frequently utilized in these systems include BLE, Wi-Fi, and GSM, while cloud platforms such as Firebase serve as the backend for data handling and analytics (Divyasudha et al., 2019; Alim et al., 2020).

Insights from the literature, combined with stakeholder consultations, enabled the identification of the core functional requirements for smart helmet

- reliable helmet-wear detection,
- accurate fall detection,
- real-time GPS tracking,
- seamless rider–system communication, and

- efficient and secure data management.

**Hardware Design and Sensor Selection**

The electronics integrated into the helmet were designed with emphasis on safety, energy efficiency, ergonomics, and seamless rider experience. The major hardware components include:

- **MPU-6050 Accelerometer and Gyroscope:** Captures motion and orientation data critical for fall or crash detection.
- **FSR-406 Force-Sensitive Resistor:** Detects helmet usage by monitoring pressure variations.
- **Bluetooth Headset and Microphone:** Enables hands-free communication through smartphone pairing.
- **ESP32-WROOM-32 Microcontroller:** Serves as the central processing unit, featuring BLE support and low-power operational modes.

The system is powered by a **6800 mAh Li-ion battery** with a **TP4056 charging module** and indicator LEDs, securely housed within a custom black acrylic enclosure integrated into the helmet structure.

**Firmware Development and Sensor Integration (ESP32)**

Firmware for the ESP32 was developed using the **Arduino IDE** in **C++**, focusing on seamless integration of sensors, optimized processing algorithms, and reliable communication protocols. The major firmware functions include:

- **Sensor Data Acquisition:** Continuous real-time collection of data from the MPU-6050 and FSR sensors.
- **Fall Detection Algorithm:** Implementation of threshold-based or machine-learning-enhanced methods to identify fall events accurately while reducing false alarms.
- **Helmet Wear Detection:** Analysis of FSR sensor patterns to verify helmet usage and provide timely compliance feedback (Rajitha et al., 2021; Dharani et al., 2020).
- **BLE Communication Protocol:** Secure and energy-efficient transmission of sensor data and alerts to the mobile application using BLE (Alim et al., 2020; Patil et al., 2021).

The firmware underwent extensive testing in controlled conditions to evaluate sensor precision, detection reliability, latency, and power efficiency.

**Mobile Application Development**

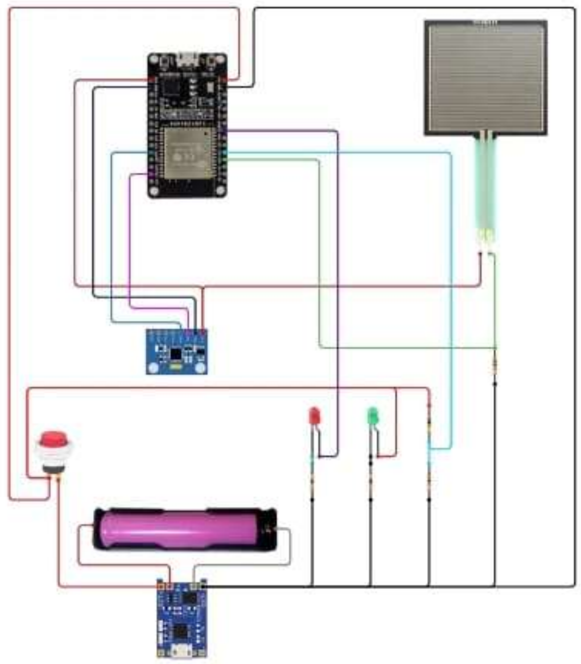
A dedicated Android application was developed to serve as the primary interaction interface for delivery riders. The application performs several essential functions to support safety and operational workflows. It receives real-time sensor data from the smart helmet via Bluetooth Low Energy (BLE), provides navigation assistance by integrating the Google Maps API, and offers live GPS tracking. User authentication is managed through Firebase Authentication, ensuring secure access to the platform. Additionally, the application delivers fall-detection alerts, helmet-compliance notifications, and displays delivery schedules and updates. Emphasis was placed on designing an intuitive UI/UX, ensuring real-time responsiveness, and implementing secure data-handling practices throughout the application lifecycle.

**Cloud Backend and Web Dashboard Development**

The cloud backend is built using Firebase Cloud Services. Firestore acts as the central database, storing rider profiles, delivery orders, safety logs, and alert events. Firebase Authentication ensures secure access control for both riders and administrators.

A web-based administrator dashboard, developed using HTML, CSS, JavaScript, and Firebase integration, provides operational oversight. The dashboard includes live driver tracking via an embedded Google Maps interface. Real-time latitude and longitude coordinates from the rider's smartphone GPS are transmitted through the mobile application to Firebase, allowing accurate visualization of the rider's position on the map. The dashboard also supports order management, monitoring of safety alerts (including accident or violation pop-ups with audio prompts), and management of rider activity records.

**CIRCUIT DIAGRAM**



**ESP32 Microcontroller (Core Processing Unit)**

The ESP32 module serves as the central controller of the entire system. Its functions include:

- **Reading sensor inputs** such as the FSR (helmet-wear sensor) and MPU6050 (accelerometer/gyroscope).
- **Processing fall-detection algorithms** based on motion data.
- **Managing Bluetooth Low Energy (BLE)** communication with the mobile application.
- **Controlling indication LEDs** that display system status.
- **Managing power-efficient operation** using sleep modes.

It acts as the brain of the system, coordinating all hardware modules.

**2. MPU-6050 Accelerometer & Gyroscope Module**

This motion sensor detects:

- **Sudden acceleration**,
- **Angular rotation**,
- **Impact or abnormal tilt**,

which are used to identify **falls or crash events**. The sensor communicates with the ESP32 using **I2C lines (SDA, SCL)**.

**3. Force-Sensitive Resistor (FSR) – Helmet Wear Detection**

The large square FSR pad detects whether the helmet is worn by measuring pressure applied when the rider's head contacts the interior padding.

- When **pressed**, the resistance drops → ESP32 detects "helmet worn".
- When **not pressed**, resistance is high → "helmet not worn".

This ensures **helmet compliance monitoring** in real time.

**4. Li-ion Battery (Rechargeable Power Source)**

A single-cell lithium-ion battery is used to power the circuit.
Its features include:

- Provides long-duration power for embedded use.
- Suitable for portable systems like smart helmets.
- Connected to the TP4056 charging module for safe charging.

**5. TP4056 Charging Module**

This module manages:

- **Charging the Li-ion battery** safely from an external USB source.
- **Overcurrent and overcharge protection**.
- **Status LED outputs** (charging / fully charged).

It ensures safe power management for daily charging cycles.

**6. Push Button Switch**

The push button functions as:

- **System power toggle** or
- **Manual emergency alert trigger**

depending on firmware configuration.
It allows the rider to manually activate certain features.

**7. System Status LEDs (Red & Green)**

Two LEDs provide quick visual feedback:

**Red LED**

- Indicates errors, low battery, fall detected, or system fault.

**Green LED**

- Indicates system ready, helmet worn, or Bluetooth connected.

Each LED is connected via current-limiting resistors for protection.

**8. Power Rails and Wiring Architecture**

The circuit uses:

- **Red wires**: Power lines (VCC).
- **Black wires**: Ground lines (GND).
- **Other colour**: Signal connections for sensors, LEDs, and control pathways.

This visual separation helps identify digital communication paths, analog sensor lines, and power distribution.

**ADVANTAGE**

1. Real-time automated safety monitoring reduces the need for rider intervention.

2. Accurate fall detection and helmet-wear validation enhance rider safety and compliance.

3. Live GPS tracking provides continuous situational awareness for supervisors.

4. Low-power components and BLE communication ensure long battery life and efficient operation.

5. Cloud-connected dashboard enables centralized monitoring of rider behavior and safety alerts.

6. Data analytics capabilities help identify safety trends and improve operational decision-making.

7. Modular and scalable design allows easy integration of future IoT upgrades and additional sensors.

8. Improved logistics management through real-time updates and route visibility for administrators.

**DISADVANTAGES**

□ **Fall detection and wear sensing accuracy** may be affected by vibration, posture, or external conditions.

□ **Continuous GPS tracking** can increase smartphone battery consumption.

□ **Electronics require weatherproofing** to withstand rain, heat, and other environmental factors.

□ **System performance relies on BLE and internet connectivity**, which may cause delays during network issues.

□ Potential false positives or missed detections under extreme riding conditions.

□ Regular charging and maintenance of the helmet electronics may be required.

□ Initial cost of hardware integration may be higher than conventional helmets.

□ User dependency on the mobile app means issues in the app can affect system functionality.

**Conclusion**

The project demonstrates the successful development of an integrated smart helmet ecosystem designed to enhance safety and operational efficiency in last-mile delivery environments. By combining a sensor-equipped helmet with a mobile application and an administrator dashboard, the system effectively addresses major challenges such as poor helmet compliance, delayed accident response, and communication gaps. The integration of the MPU-6050, FSR sensor, and ESP32 microcontroller enabled accurate fall detection and wear monitoring, while BLE connectivity and Firebase services ensured reliable real-time communication. Simulated and controlled testing showed alert response times of under five seconds, validating the system's potential for practical deployment. Overall, the solution contributes to safer working conditions and offers valuable operational insights to businesses, aligning with rapidly evolving IoT-based safety innovations (Nagaraju et al., 2024; Lakshmi et al., 2024; Kalita & Boruah, 2023).

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