# An Arduino-Based Smart Car Safety System: Integrating Obstacle Detection, Battery Health Monitoring, and Smoke Detection for Enhanced Vehicle Safety

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**Abstract.** The Arduino-based smart car safety system integrates obstacle detection, battery health monitoring, and smoke detection to enhance vehicle safety. The obstacle detection module utilizes an ultrasonic sensor (HC-SR04) that emits high-frequency sound waves to detect obstacles and triggers an alert if a potential collision is detected. The battery health monitoring system employs voltage, current, and temperature sensors to continuously track battery performance, alerting the driver in cases of overheating or abnormal power fluctuations. Additionally, the smoke detection module incorporates an MQ2 sensor, which detects the presence of smoke and hazardous gases, issuing a warning when threshold levels are exceeded. An Arduino Uno microcontroller processes real-time sensor data and activates safety alerts via buzzers and LED indicators. The proposed system offers an affordable, scalable, and reliable solution for enhancing vehicle safety, making it suitable for integration into both conventional and smart vehicles.

**Keywords:** Arduino-based system · vehicle safety· obstacle detection· battery health monitoring · smoke detection · microcontroller technology.

## 1 Introduction

Recent advancements in automotive technology have shifted the focus of vehicle safety from reactive to proactive systems. Traditional features like airbags, seat belts, and anti-lock braking systems (ABS) primarily serve as passive safety measures, protecting occupants after an incident occurs [1]. However, the growing complexity and automation of vehicles require systems that detect and mitigate risks in real time. Sensor-based technologies integrated with microcontrollers enable vehicles to monitor conditions and respond to potential hazards before they escalate [2].

This paper presents an Arduino-based smart car safety system that combines three essential safety features into a single low-cost platform: obstacle detection, battery health monitoring, and smoke detection. Each module addresses specific vehicle safety risks and contributes to an integrated preventive solution.

Obstacle detection, particularly useful in urban settings and for autonomous driving, is achieved using the HC-SR04 ultrasonic sensor. It continuously calculates the distance between the vehicle and nearby objects, triggering alerts or automated stopping when necessary [3]. Battery-related issues, including overheating or electrical failure, are monitored using voltage, current, and temperature sensors. Early detection of these issues prevents breakdowns and extends battery life [4]. Smoke and gas leaks are addressed using the MQ2 sensor, which detects combustible gases such as carbon monoxide and methane, triggering alerts before fires or toxic exposure can occur [5].

The objective is to develop a unified, real-time safety system based on the Arduino Uno, chosen for its simplicity, low power consumption, and sensor compatibility. Unlike AI-based or high-cost solutions, this system offers a lightweight and scalable alternative suitable for conventional and autonomous vehicles. It is designed to deliver real-time alerts through an LCD interface and is supported by visual and audible indicators.

The proposed system aligns with the growing demand for accessible, embedded safety solutions and provides a foundation for future expansion into features like IoT integration, lane departure detection, and AI-assisted diagnostics.

## 2 Literature Review

Integrating sensor-driven safety systems in modern vehicles has become a core approach to improving road safety and reducing hazard-related incidents. Prior research has explored individual safety components such as obstacle detection, battery health monitoring, and smoke detection, each contributing to accident prevention and system reliability. However, most studies treat these components in isolation, rather than combining them into a unified system. This section reviews relevant literature in these areas, identifies technological advancements, and highlights the research gap that this study addresses.

### 2.1 Obstacle Detection in Smart Vehicles

Obstacle detection is a foundational component in both manual and autonomous vehicles, aiming to reduce collisions by identifying nearby objects. A study on cooperative navigation for industrial autonomous vehicles demonstrated how vehicles could avoid collisions through shared communication and real-time obstacle sensing [6].

Ultrasonic sensors are widely used in obstacle detection systems, particularly in mobile robotics. Azeta et al. [7] validated their effectiveness in real-time proximity sensing across varying distances. Their cost-efficiency and ease of integration make them suitable for Arduino-based automotive applications.

Further advancements include data fusion systems that combine ultrasonic sensing with stereo vision. Gholami et al. [8] showed that fusing visual and ultrasonic data significantly reduces false positives and improves environmental awareness in real-time applications. However, stereo vision systems require higher computational resources, making them less practical for low-cost platforms like Arduino.

### 2.2 Battery Health Monitoring Systems

Batteries play a vital role in powering both electric and hybrid vehicles. Failure to monitor battery health can lead to breakdowns or even fires. Senthilkumar et al. [9] developed an Arduino-based Battery Management System (BMS) that monitors voltage, temperature, and current in real time, with data accessible through mobile interfaces.

Pradhan and Chakraborty [10] proposed a low-cost monitoring solution using voltage divider circuits and temperature sensors, ensuring early detection of degradation signs. This method enables timely preventive maintenance, enhancing both vehicle safety and battery lifespan.

For more advanced monitoring, Widodo et al. [11] introduced a machine learning-based BMS using sample entropy to detect irregular voltage patterns. While effective, such solutions require high processing power, making them unsuitable for integration into resource-limited microcontroller systems. Thus, simpler Arduino-based systems offer a practical alternative for real-time, low-power battery monitoring.

### 2.3 Smoke Detection in Automobiles

Early smoke detection is crucial in preventing vehicle fires caused by electrical faults or fuel leaks. Smith et al. [12] investigated semiconductor-based gas sensors, showing their efficiency in identifying carbon monoxide and smoke buildup inside vehicle cabins.

The MQ2 smoke sensor, widely used for fire detection, was tested by Kumar and Patel [13] for its responsiveness in vehicle interiors. The sensor successfully detected smoke at low concentrations and triggered timely alerts. Its compatibility with Arduino boards and sensitivity to multiple gases (e.g., CO, methane, LPG) make it a strong candidate for automotive applications.

While AI-enhanced smoke detection has also been explored, such as in the work of Zhang et al. [14], these systems require complex processing capabilities to distinguish between harmless vapors and hazardous smoke. Though promising, they are impractical for real-time deployment in low-power embedded systems. Hence, this project leverages the simplicity and reliability of sensor-based detection using the MQ2 module.

### 2.4 Summary and Research Gap

Although extensive work has been done on individual vehicle safety features, relatively few studies propose a combined safety system using a single microcontroller platform. Most existing solutions are either costly, complex, or focus on only one hazard domain. This paper addresses that gap by presenting an Arduino-based system that integrates obstacle detection, battery health monitoring, and smoke detection in a unified framework.

Compared to AI-based solutions, the proposed model is more accessible, affordable, and easier to implement, especially in resource-constrained environments. It lays the foundation for future developments in modular smart car safety platforms, suitable for integration in both traditional and autonomous vehicles.

## 3 System Design and Architecture

The proposed Arduino-based smart car safety system integrates three core safety modules: obstacle detection, battery health monitoring, and smoke detection. These modules work together through a centralized microcontroller to ensure continuous vehicle safety monitoring and timely hazard alerts. The system follows a modular architecture composed of three functional layers: sensor input, data processing, and response actuation.

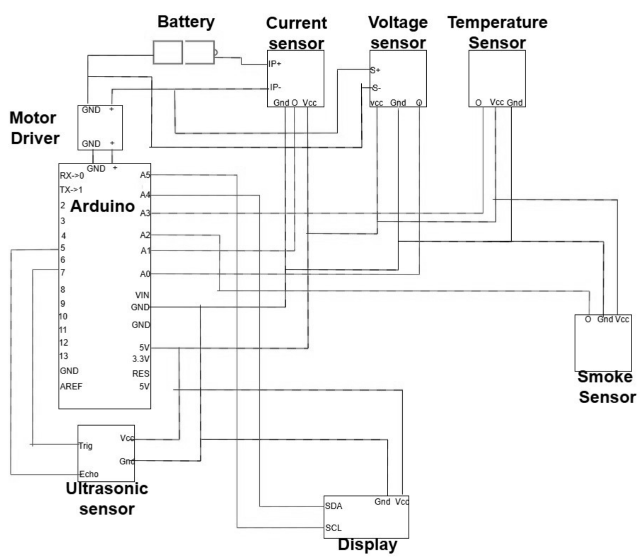



Fig. 1: Circuit Diagram of the System

At the heart of the system is the Arduino Uno, selected for its simplicity, real-time processing capabilities, affordability, and widespread compatibility with sensor modules. Compared to alternatives like the Raspberry Pi or ESP32, the Arduino Uno provides a low-power, hardware-oriented solution ideal for embedded automotive safety systems. The detailed technical specifications of the Arduino Uno are provided in Table 1.The system employs various sensors to detect different safety parameters. The technical specifications of these modules are summarized in Table 2.A visual representation of the full circuit layout, showing how the sensors, microcontroller, motor driver, and output modules are interconnected, is provided in figure 1.

Table 1: Arduino Uno – Technical Specifications

| Parameter | Specification |
|---|---|
| Microcontroller | ATmega328P |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7–12V |
| Digital I/O Pins | 14 (6 PWM-enabled) |
| Analog Input Pins | 6 |
| Clock Speed | 16 MHz |
| Flash Memory | 32 KB (0.5 KB used by bootloader) |
| SRAM | 2 KB |
| EEPROM | 1 KB |
| Communication Interfaces | UART, SPI, I2C |

Table 2: Sensors Used in the Smart Car System

| Sensor Type (model) | Parameter and Range |
|---|---|
| Ultrasonic Sensor (HC-SR04) | Distance: 2–400 cm, ±3 mm |
| Voltage Sensor (Generic) | Voltage: 0–25 V, ±0.1 V |
| Current Sensor (ACS712 (5A)) | Current: ±5 A, ±1.5% |
| Temperature Sensor (DHT11) | Temp: 0–50 °C, ±2 °C |
| Smoke Sensor (MQ2) | Smoke/Gas: 300–10,000 ppm, 2–5s |

The obstacle detection module uses an HC-SR04 ultrasonic sensor positioned at the front of the vehicle. This sensor emits 40 kHz sound waves and calculates the time taken for the echo to return after bouncing off an object. Using the formula 1 the system accurately detects objects within a 2 cm to 4 m range. If an obstacle is detected within the predefined safety threshold, the system stops the motor and activates visual and audible alerts, thus preventing collisions. The process and output of this system during real-time testing are illustrated in Figure 2.

$$Distance = \frac{Speed of Sound \times TimeDelay}{2} \tag{1}$$

The battery health monitoring module integrates three sensors:

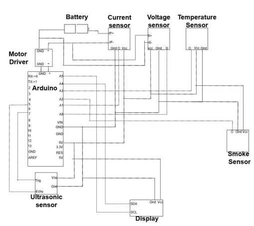
- A **voltage sensor**, to track the overall battery voltage;
- A **current sensor (ACS712)**, to measure the current draw and identify overcurrent conditions; and
- A **temperature sensor (DHT11)**, to detect battery overheating.

These sensors provide continuous input to the Arduino Uno, which processes the data and checks for deviations from predefined safe operating ranges. If conditions such as low voltage, excessive current, or high temperature are detected, the system triggers an alert. Additionally, the real-time battery metrics are displayed on an LCD screen, giving the driver continuous visual feedback. This enables proactive decision-making and easy diagnostics during regular operation or servicing. The display updates dynamically and reflects any changes in battery health conditions. A live example of the monitoring interface is shown in Figure 3 (Battery Health Monitoring System Output).

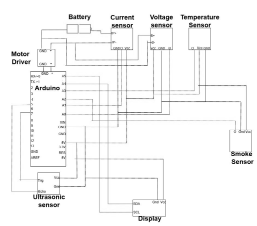
The smoke detection module utilizes the MQ2 gas sensor, which is capable of detecting various hazardous gases including smoke, methane, carbon monoxide, and LPG. The sensor monitors the vehicle's internal air quality continuously and communicates readings to the Arduino. If the concentration of gases exceeds the defined safety threshold (typically starting around 300 ppm), the system issues a hazard alert. In addition to activating buzzers and LED indicators, the air quality alert is also shown on the same LCD display used for battery monitoring. This unified alert interface allows the driver to receive both visual warnings and gas concentration data in real time, which enhances awareness and response speed. The smoke detection response is illustrated in Figure 4 (Smoke Detection Alert System).

The entire system is powered by a DC source, and all sensors are connected to the Arduino Uno through analog/digital input pins. The motor driver (L293D) acts as the interface between the Arduino and the DC motors, enabling controlled movement based on sensor feedback. Alerts are delivered through buzzer modules and LED indicators, providing both visual and auditory cues in hazardous conditions.

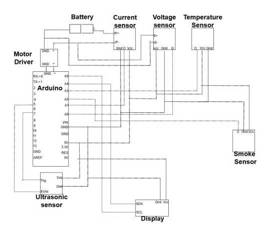
This modular and scalable architecture enables efficient real-time monitoring and immediate hazard response. It ensures affordability and compatibility for both traditional vehicles and autonomous platforms, making it a viable prototype for modern smart car safety applications.




(a) Caption 1




(b) Caption 2




(c) Caption 3

## 4 Results and Discussion

The performance of the Arduino-based smart car safety system was evaluated through a series of test cases designed to simulate real-world conditions. The system was assessed on three primary features—obstacle detection, battery health monitoring, and smoke detection—with emphasis on response time, accuracy, and reliability. All modules were tested on a working prototype vehicle in a controlled lab environment, with performance validated through repeated trials.

### 4.1 Obstacle Detection Performance

The ultrasonic sensor (HC-SR04) accurately detected objects within a range of 2 cm to 4 meters, with an average response time of ¡50 milliseconds. When an object was placed within a predefined critical distance (e.g., 25 cm), the Arduino stopped the motor instantly and triggered a buzzer and LED alert. This immediate action prevented simulated collisions. However, some limitations were observed: soft or uneven surfaces like foam absorbed sound waves, resulting in occasional false negatives.

Environmental factors were also considered. In low-light and dry indoor conditions, detection was highly reliable. However, in the presence of strong air currents, water droplets, or acoustic interference, accuracy was slightly reduced. These factors may degrade ultrasonic signal quality. In future work, integrating infrared or LiDAR sensors could compensate for limitations in fog, rain, or electromagnetic interference (EMI).

### 4.2 Battery Health Monitoring Results

The voltage sensor was able to track input levels within $\pm 0.1$ V of true values. The current sensor (ACS712) reliably detected deviations when current exceeded 3.5 A in a 5 A-rated setup. The DHT11 sensor showed consistent readings of ambient temperature with $\pm 1$ °C accuracy. Critical values, such as low voltage ($\leq 10.5$ V), overheating ($\geq 45$ °C), or overcurrent conditions, triggered alerts. These conditions were shown on the LCD screen in real time, allowing the user to proactively monitor and respond before component failure occurred.

### 4.3 Smoke Detection Accuracy

The MQ2 sensor responded to simulated smoke and gas leaks within 1–2 seconds, detecting concentrations as low as 300 ppm. When a lit match or alcohol vapor was introduced, the sensor detected gas presence and activated both the buzzer and LED indicators. Additionally, the LCD displayed the air quality warning, showing gas concentration levels alongside battery data. The sensor showed good sensitivity in enclosed environments but had a slight delay during startup due to sensor warm-up time.

### 4.4 System Comparison with Existing Solutions

To evaluate the system's practicality, we compared it against other vehicle safety platforms based on cost, accuracy, and ease of implementation. The results are summarized in Table 3.

We tested the system across multiple scenarios, with approximately 10 iterations per feature. Data logs showed a 95–98% success rate in correct hazard detection and alert activation under normal conditions. Minor false positives or lag were noted only in edge conditions (e.g., high humidity or unstable power supply). These results affirm the system's suitability for entry-level smart vehicles, educational labs, and budget-sensitive use cases.

Table 3: Comparative Analysis of Smart Vehicle Safety Systems

| Feature | Proposed System (Arduino-Based) | AI-Based System | Traditional System |
|---|---|---|---|
| Obstacle Detection | HC-SR04 Ultrasonic Sensor (±3 mm) | LiDAR / Stereo Vision (High accuracy, high cost) | Infrared Sensors (Low range) |
| Battery Monitoring | Voltage, current, temperature sensors | ML-based predictive BMS | Voltage-only checks |
| Smoke Detection | MQ2 Sensor (Multi-gas detection) | AI Smoke Classifier (Needs GPU) | Basic CO sensor |
| Display Feedback | LCD interface (real-time alerts) | App/cloud interface | No display or basic LED |
| Cost (per unit) | Low (<INR 4000 or $50) | High (INR 50,000+) | Medium (INR 10,000) |
| Implementation Effort | Easy (DIY-compatible) | Complex (Data training needed) | Moderate |

## 5 Conclusion and Future Scope

This study presented an Arduino-based smart car safety system integrating obstacle detection, battery health monitoring, and smoke detection into a unified platform. The system successfully detected obstacles within a safe range using ultrasonic sensors, continuously monitored battery voltage, current, and temperature, and responded effectively to hazardous gas concentrations using the MQ2 sensor. Real-time data visualization through an LCD display enhanced driver awareness and system usability. Testing demonstrated reliable performance under normal conditions, with alerts triggered accurately and consistently across multiple iterations. Compared to traditional and AI-based systems, the proposed solution offers a cost-effective, low-complexity alternative suitable for entry-level vehicles and educational prototypes. Future developments could include integrating machine learning algorithms for adaptive safety responses, IoT connectivity for remote monitoring, and expanded features like lane departure warnings, alcohol detection, and cloud-based diagnostics. These enhancements would further advance the system's capabilities and position it as a scalable, intelligent safety solution for next-generation vehicles.

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