 ISSN: 2278-4632
Vol-15, Issue-04, No.02, April: 2025

INTEGRATED SAFETY SYSTEM FOR HEAVY VEHICLE

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Abstract:
Road safety is a major concern for heavy vehicles due to their size, weight, and long driving hours. The Heavy Vehicle Safety System (HVSS) is designed to enhance safety by integrating multiple advanced features into a real-time monitoring and control system. Using an Arduino Uno microcontroller, the system incorporates sensors for alcohol detection, speed monitoring, obstacle detection, and temperature sensing. This proactive approach helps prevent accidents before they occur. The alcohol detection mechanism prevents intoxicated driving by stopping the vehicle if alcohol is detected. Speed monitoring categorizes driving conditions into safe, moderate, and over speeding, triggering alerts when necessary. Ultrasonic sensors detect obstacles and prevent collisions by stopping the vehicle or alerting the driver. A temperature sensor monitors engine heat, preventing overheating-related failures. The system is controlled through an LCD display and Bluetooth communication, enabling remote monitoring via a mobile application. Unlike conventional safety measures that rely on manual intervention, HVSS continuously monitors vehicle parameters and triggers automated actions. The use of cost-effective sensors and microcontrollers makes it affordable and scalable for logistics, transportation, and industrial fleet management. By integrating multiple safety features into a single platform, HVSS enhances driver safety, vehicle efficiency, and road security. Additionally, wireless connectivity allows real-time data transmission to fleet managers, enabling remote supervision and quick decision-making in emergencies. The system is adaptable to various heavy vehicles, making it suitable for industries such as logistics, construction, and public transportation. By reducing human errors and enhancing automation, HVSS contributes to a more efficient and accident-free transportation network, improving road safety and operational efficiency. This system represents a step towards smarter and more reliable transport, reducing accident rates and ensuring compliance with safety standards in the heavy vehicle industry.

Keywords:
Bluetooth communication, Wireless connectivity, Vehicle efficiency, Heavy vehicles, Remote monitoring, Fleet Management

I. INTRODUCTION

In recent years, advancements in vehicular safety and monitoring systems have played crucial role in reducing road accidents and ensuring efficient transportation management [1]. Heavy vehicles, being integral to logistics and industrial operations, face increased risks due to driver fatigue, road conditions, and operational inefficiencies. The Heavy Vehicle Safety System (HVSS) integrates to enhance road safety and optimize fleet performance [2]. A novel approach to real-time driver health and safety monitoring involves integrating personalized health navigation systems [5]. These technologies monitor driver fatigue, alertness levels enabling proactive accident prevention and improving driver well-being. Drowsiness detection algorithms play a crucial role in reducing fatigue-related accidents [3]. Additionally, road surface monitoring and hazard detection mechanisms have significantly improved heavy vehicle safety [6]. Advanced road condition measurement, ultrasonic sensors for surface detection allow for real-time hazard assessment and automated response mechanisms, minimizing risks associated with poor road conditions [7]. These technologies contribute to improving vehicular navigation, optimizing route planning, and preventing collisions [11]. This paper explores the design, implementation, and evaluation of an Arduino-monitored Heavy Vehicle Safety System (HVSS), integrating sensor-based driver monitoring, real-time road hazard detection, and automated safety interventions [4]. By leveraging real-time analytics, this research aims to enhance fleet safety, reduce accident risks, and ensure sustainable transportation solutions.

II. OVERVIEW OF INTEGRATED SAFETY SYSTEM FOR HEAVY VEHICLE

In the Heavy Vehicle Safety System (HVSS), a system is established where an Arduino Uno serves as the central component for data acquisition and control. This module is connected to various sensors on one side and to a motor drive and buzzer on the other side. The prototype system is designed for real-time driver safety monitoring and operates primarily on the Arduino Uno. It is integrated with an LCD display to visualize system status, a 5V buzzer for alert notifications, and multiple sensors including an IR sensor, alcohol sensor, ultrasonic sensor, and temperature sensor. Additionally, a Bluetooth module is incorporated for wireless data transmission, enabling real-time monitoring and alerts.
. The functionality of this HVSS can be monitored remotely using Bluetooth-based applications. Through the interface, users can access real-time data related to driver behaviour, environmental conditions, and vehicle status, facilitating proactive safety measures and accident prevention [5].

A. **LCD Display:** A Liquid Crystal Display (LCD) used to present real-time data, system status, and alerts. It provides a clear and user-friendly interface for monitoring safety parameters.
B. **IR Sensor:** An Infrared (IR) Sensor detects obstacles or objects in close proximity. In HVSS, it can be used for driver presence detection or collision avoidance mechanisms.

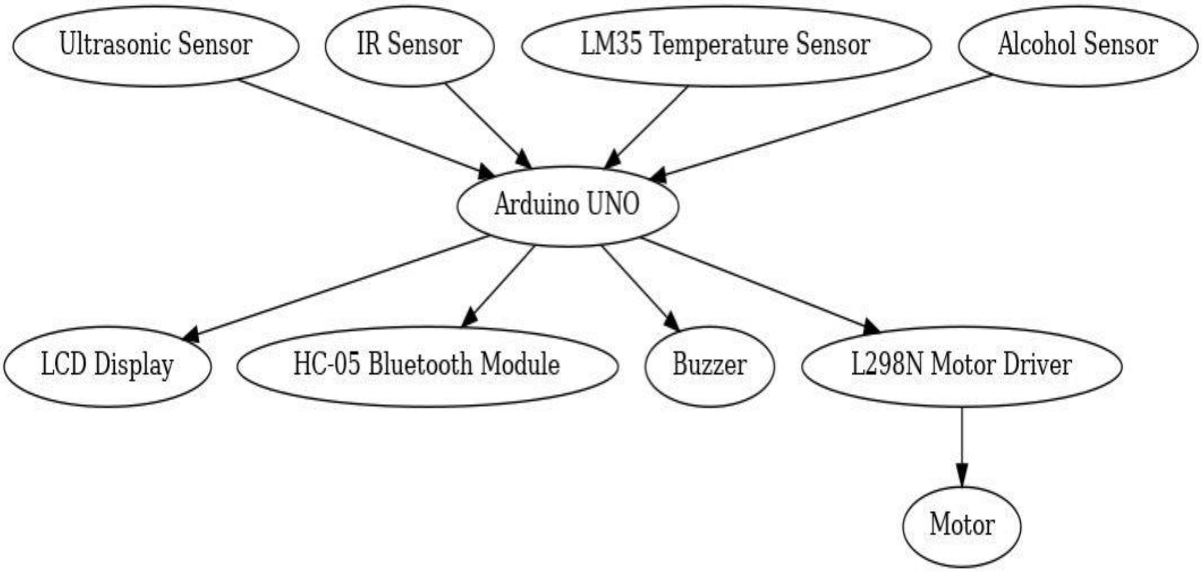

Fig.1. Block Diagram of Integrated Safety System for Heavy Vehicle

C. **Alcohol Sensor:** This sensor is used to detect the presence of alcohol in the driver's breath. It helps in preventing drunk driving incidents by triggering alerts if alcohol is detected beyond a threshold level.
D. **Ultrasonic Sensor:** Measures distance by sending and receiving ultrasonic waves. It is utilized for obstacle detection and proximity sensing, ensuring safe maneuvering of heavy vehicles.
E. **Temperature Sensor:** Detects and measures the temperature in the vehicle cabin or surroundings. It helps in monitoring driver comfort and detecting extreme temperature conditions that could affect safety.
F. **Bluetooth Module:** A wireless communication module that enables **data transmission** between the HVSS and an external monitoring system or mobile application, allowing remote safety monitoring.
G. **Motor Drive:** Controls the movement of motors used in automated components of the HVSS, such as seat adjustments or safety mechanisms.

ISSN: 2278-4632
Vol-15, Issue-04, No.02, April: 2025

H. Buzzer: A sound alert device that generates beeps or alarms in case of driver drowsiness, alcohol detection, or proximity warnings, enhancing safety measures in real-time.

Fig.2. LCD Display

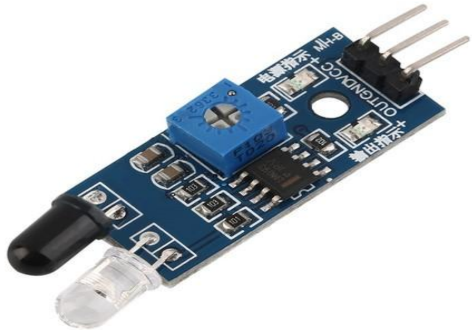

Fig.3. IR Sensor

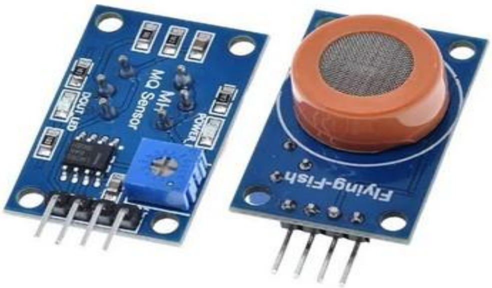

Fig.4. Alcohol Sensor

Fig.5. Ultrasonic Sensor

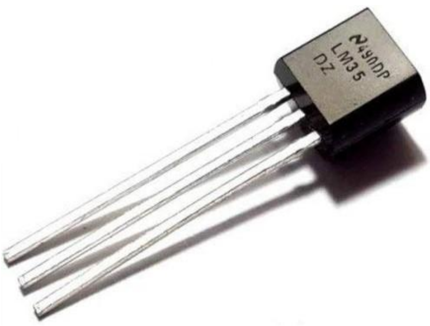

Fig.6. Temperature Sensor

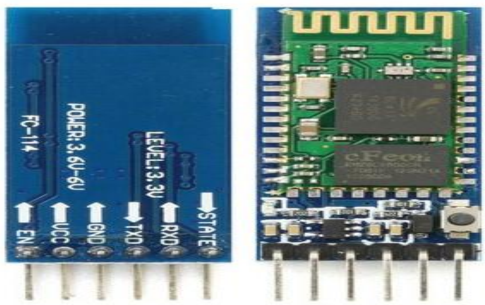

Fig.7. Bluetooth Module

Fig.8. Motor Driver

Fig.9. Buzzer

Fig.10. Aurdino UNO

I. **Arduino UNO**: A microcontroller board based used as the central processing unit for the HVSS. It controls the sensors and modules, processes data, and triggers necessary actions like alerts and motor operations. The Arduino Board is a user-friendly software used to write, compile, and upload code to Arduino microcontroller boards. It provides a simple interface for programming projects, supports multiple programming languages, and offers a library of pre-written code examples. With its easy-to-use features, it's ideal for beginners and professionals alike in creating a variety of electronic projects.

J. **C++:** C++ is a versatile, high-level programming language that supports both procedural and object-oriented programming. It is widely used for embedded systems due to its efficiency and hardware interaction capabilities. In the HVSS project, C++ is utilized for programming the Arduino Uno, enabling real-time data processing, sensor integration, motor control, and Bluetooth communication. Its structured approach ensures reliable system performance and smooth execution of automation tasks.

III. ANALYSIS AND DISCUSSION

The primary objective of this research is to design, implement, and evaluate an Arduino-based Heavy Vehicle Safety System (HVSS) that integrates multiple sensors and real-time monitoring capabilities. By combining advanced sensing technology with real-time alert mechanisms, the goal is to develop a safety-oriented system that enhances driver awareness and ensures vehicle security.

The system workflow can be categorized into three different levels:

1. **Data Acquisition Level:** This level consists of multiple sensors, including the IR sensor, alcohol sensor, ultrasonic sensor, and temperature sensor. These sensors continuously monitor the driver’s condition, vehicle surroundings, and environmental factors to detect any potential safety threats.
2. **Control Level:** The Arduino Uno microcontroller acts as the core processing unit, collecting real-time data from sensors, processing the inputs, and determining necessary actions such as alerts or motor activation.
3. **Output/Display Level:** This level includes an LCD screen to display real-time sensor data and system status. Additionally, the Bluetooth module enables wireless communication with external monitoring systems, allowing data to be accessed remotely. A buzzer is incorporated to provide audible alerts in case of drowsiness detection, alcohol presence, or potential collisions.

ISSN: 2278-4632
Vol-15, Issue-04, No.02, April: 2025

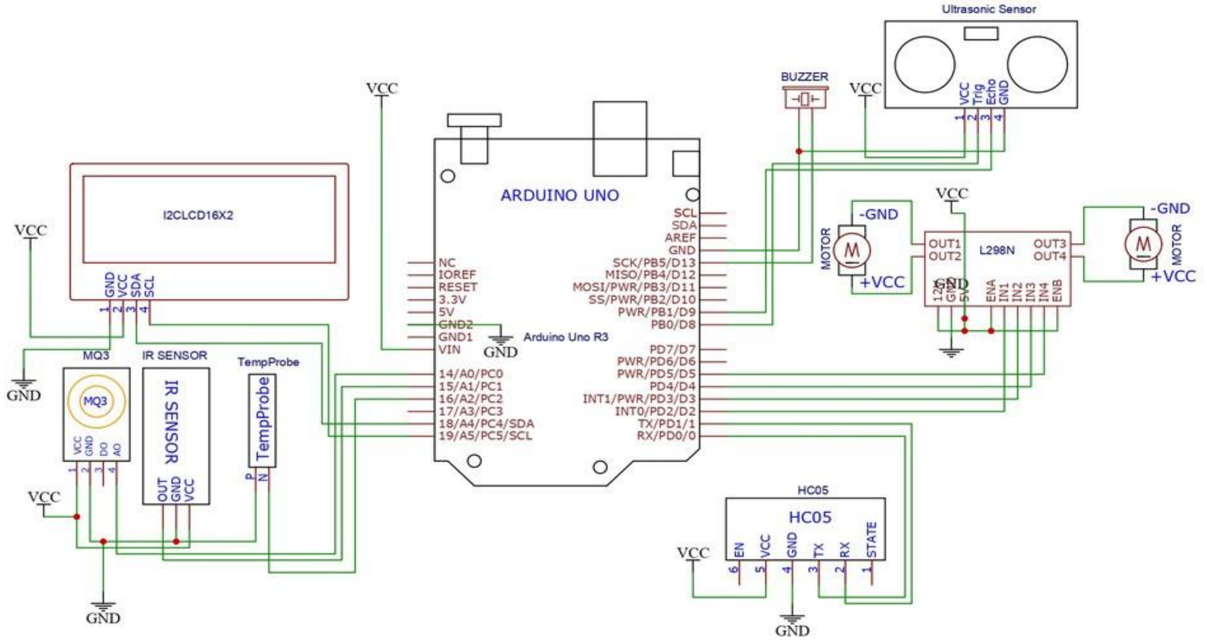

Fig.10. Architecture of the project

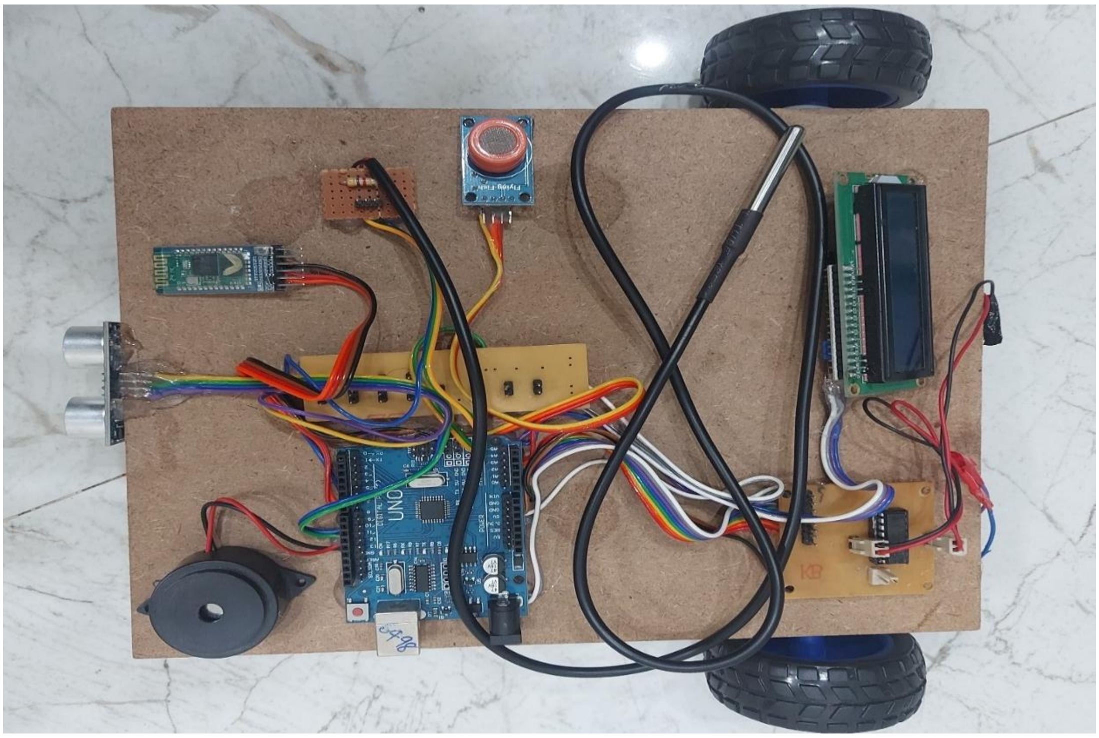
Fig.11. Top View of the Project

The sensor data is continuously monitored by the Arduino Uno and displayed on the LCD screen. If any parameter exceeds predefined safety thresholds, the system triggers an alarm via the buzzer to alert the driver. Additionally, the Bluetooth module can transmit alerts to a connected mobile device, enabling remote monitoring of vehicle safety conditions. This process operates continuously and fosters the development of intelligent safety algorithms that can automate safety responses based on predefined conditions. The integration of remote monitoring capabilities enhances proactive decision-making, allowing for immediate corrective actions in response to potential hazards. The model has been tested out on field under different conditions to obtain real time work results an to determine its efficiency in the terms of remote sensing.

Case-1 (Obstacle Detection): Ultrasonic sensors measure the distance in front of the vehicle. If an obstacle is detected within 10 cm, the system stops the motors and activates a buzzer. It also waits for 2 seconds after clearance before resuming to ensure safety.

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Fig.11. a. LCD Output-1

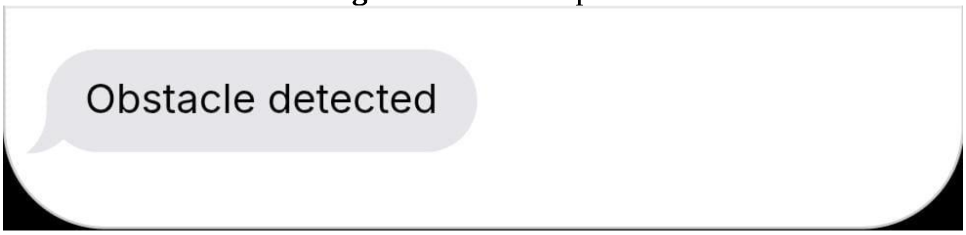

Fig.11. b. SMS Output Case-1

Case-2 (Temperature Detection): The system uses a DS18B20 temperature sensor to monitor ambient conditions. If the temperature exceeds a critical threshold (e.g., overheating), the vehicle stops automatically to prevent damage. An alert message is shown on the LCD and sent via Bluetooth, accompanied by a buzzer warning.

Fig.12. a. LCD Output-1

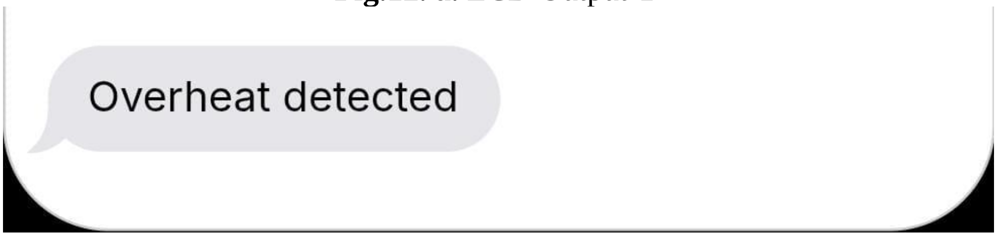

Fig.12. b. SMS Output Case-2

Case-3 (Alcohol Detection): The system uses an MQ3 alcohol sensor to monitor the driver's breath. If alcohol is detected, the vehicle halts immediately to prevent unsafe driving. A warning is displayed on the LCD and sent via Bluetooth, along with a buzzer alert.

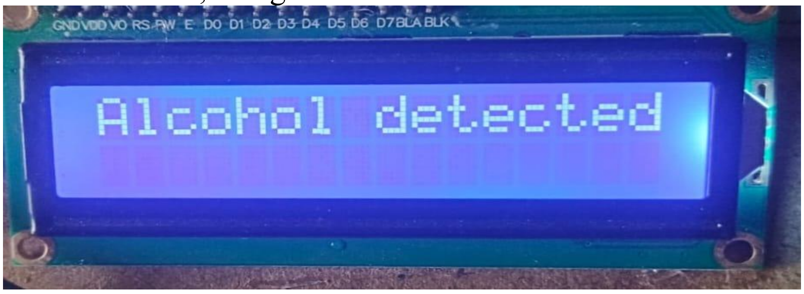

Fig.13. a. LCD Output-1

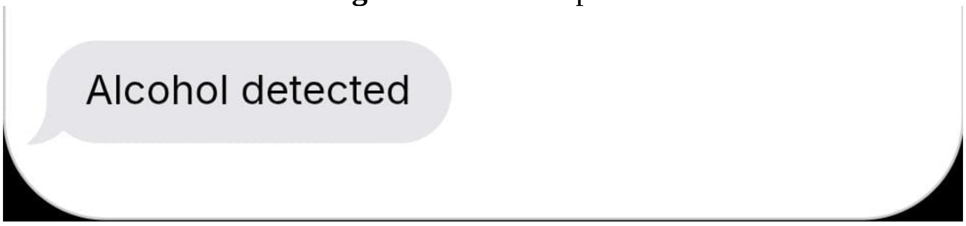

Fig.13. b. SMS Output Case-3

Case-3 (Speed detection): Speed is monitored through motor speed control values. When the speed exceeds a predefined threshold (over 100), the system displays “Overspeed!” on the LCD and triggers the buzzer. This ensures the vehicle operates within safe limits.

Fig.14. SMS Output Case-4

IV. CONCLUSION

The Heavy Vehicle Safety System effectively combines multiple safety technologies to enhance road safety and minimize accident risks. Utilizing Arduino-controlled sensors, it enables real-time detection of obstacles, speed monitoring, and prevention of drunk driving through alerts and automatic vehicle stoppage. Key components like the ultrasonic sensor and MQ3 alcohol sensor ensure prompt hazard detection and driver sobriety, while speed categorization and Bluetooth-based feedback enhance driver awareness. The system proved reliable during testing, accurately responding to varied road conditions and reducing risks linked to human error and environmental factors. Though limitations such as limited obstacle detection range, Bluetooth constraints, and environmental sensitivity of sensors were observed, future upgrades like GPS tracking, AI-based accident prediction, and IoT communication can greatly enhance functionality. Overall, this paper successfully demonstrates a practical and intelligent approach to heavy vehicle safety, offering significant potential to improve transportation safety standards and support smarter road systems.

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