iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.80666

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

An Intelligent Safety Driver Device using Arduino Uno

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Abstract: Road traffic accidents continue to pose a serious threat to public safety, with major contributing factors including driver fatigue, alcohol impairment, and unexpected vehicle fire incidents. To address these challenges, this work proposes an integrated smart safety system capable of monitoring both driver behavior and vehicle conditions in real time.The developed system employs an eye-blink sensing module to identify signs of driver drowsiness, an alcohol detection sensor to monitor intoxication levels, and a flame sensor to detect potential fire hazards within the vehicle. These sensing units are interfaced with a microcontroller-based platform, which continuously analyzes input data and initiates appropriate safety responses. Depending on the detected condition, the system can generate audible alerts, restrict engine operation, or activate a water-based suppression mechanism to mitigate fire risks.Unlike conventional safety solutions that operate independently, the proposed design combines multiple safety features into a unified and cost-effective embedded framework. The system emphasizes reliability, real-time responsiveness, and ease of deployment in existing vehicle architectures. Experimental validation indicates that the system can effectively detect hazardous conditions and respond promptly, thereby improving driver awareness and reducing accident probability. This solution is applicable to a wide range of domains including public transportation, fleet management, and personal vehicles. Future enhancements may incorporate IoT-based connectivity, location tracking using GPS modules, and intelligent driver monitoring through machine learning techniques. Overall, the proposed system offers a practical and scalable approach toward enhancing vehicular safety and minimizing accident risks.

Keywords: Driver Fatigue Monitoring, Alcohol Sensing System, Vehicle Fire Hazard Detection, Embedded Safety System, Microcontroller-Based Design, Multi-Sensor Integration, Real-Time Hazard Monitoring, Intelligent Accident Prevention.

I. INTRODUCTION

Road transportation is a fundamental component of modern society, supporting economic activities and everyday mobility. However, the rapid increase in road traffic incidents has emerged as a major safety concern worldwide. Reports from international health organizations indicate that road accidents remain a leading cause of mortality, with factors such as driver fatigue, alcohol impairment, and unexpected vehicle fire incidents playing a significant role. Reduced alertness due to fatigue delays reaction time, alcohol consumption affects cognitive and motor abilities, and undetected fire hazards can escalate rapidly, resulting in severe consequences. These challenges emphasize the importance of developing intelligent systems capable of continuously monitoring driver behavior and vehicle conditions to prevent accidents proactively.

To overcome these limitations, this work introduces a Smart Safety Driver Device that integrates multiple sensing modules with an embedded control unit. The system incorporates an eye-blink sensing mechanism to analyze eye closure patterns and identify fatigue conditions in real time. When prolonged eye closure or abnormal blinking behavior is detected, the system generates an immediate alert to regain driver attention. In addition, an alcohol sensing module positioned near the driver's seat monitors breath alcohol levels; if the measured value exceeds a predefined threshold, the system restricts engine operation to prevent unsafe driving. A flame detection module is also included to identify fire-related hazards inside the vehicle. Upon detecting abnormal heat or flame conditions, the controller initiates an alarm and activates an automated suppression mechanism to minimize potential damage.

The entire system is coordinated by a microcontroller-based platform that continuously processes sensor inputs and executes appropriate control actions. The design prioritizes cost efficiency, operational reliability, and ease of integration with existing vehicle systems. By combining multiple safety functionalities into a single embedded framework, the proposed solution provides continuous monitoring without requiring significant structural modifications to the vehicle.

The proposed system can be effectively utilized across various domains, including public transportation, commercial logistics, and private vehicles. In sectors such as bus services and school transportation, where drivers are exposed to long working hours, the system enhances passenger safety by detecting fatigue conditions early. In logistics operations, it reduces risks associated with driver impairment and prolonged driving schedules. For personal vehicles, it offers an additional safety layer by preventing alcohol-influenced driving and identifying fire hazards at an early stage. The implementation of such integrated monitoring systems contributes to improving overall road safety and reducing accident rates.

The rest of this paper is organized as follows. Section II presents the design and integration of the proposed system, including sensor modules and the embedded controller. Section III describes the system architecture and operational methodology, covering data acquisition, processing, and response mechanisms. Section IV discusses the experimental results and evaluates system performance under different operating conditions. Finally, Section V summarizes the findings and outlines potential future enhancements for developing more advanced intelligent vehicle safety solutions.

II. PROPOSED MODEL

The Smart Safety Driver Device is implemented as a compact embedded system that integrates driver monitoring and vehicle hazard detection into a unified platform. A microcontroller-based unit serves as the central processing element, continuously acquiring and analyzing data from multiple sensors placed within the vehicle. An eye-blink sensing module is positioned to track the driver's eye activity and evaluate fatigue based on closure duration and blinking patterns. When prolonged eye closure is detected, the system generates an immediate alert to regain driver attention and reduce the risk of accidents caused by drowsiness.

To prevent unsafe driving due to alcohol consumption, an MQ-series alcohol sensor is installed near the driver's position to monitor breath alcohol levels. If the measured concentration exceeds a predefined safety threshold, the control unit interrupts the ignition system through a relay interface, thereby restricting vehicle operation. In addition, a flame detection module is incorporated within the vehicle cabin or engine compartment to identify fire-related hazards. Upon detecting flame or abnormal heat conditions, the system activates an alarm and triggers a water pumping mechanism connected to a sprinkler unit to suppress fire at an early stage.

Unlike conventional approaches that address individual safety parameters separately, the proposed system integrates multiple sensing mechanisms into a single embedded framework, enabling real-time monitoring and automatic response. The design emphasizes cost efficiency, reliability, and ease of installation in existing vehicles without major structural modifications. By combining fatigue detection, alcohol monitoring, and fire suppression into one platform, the system provides a practical and scalable solution for enhancing vehicle safety and minimizing accident risks. Figure 1 illustrates the prototype implementation of the Smart Safety Driver Device.

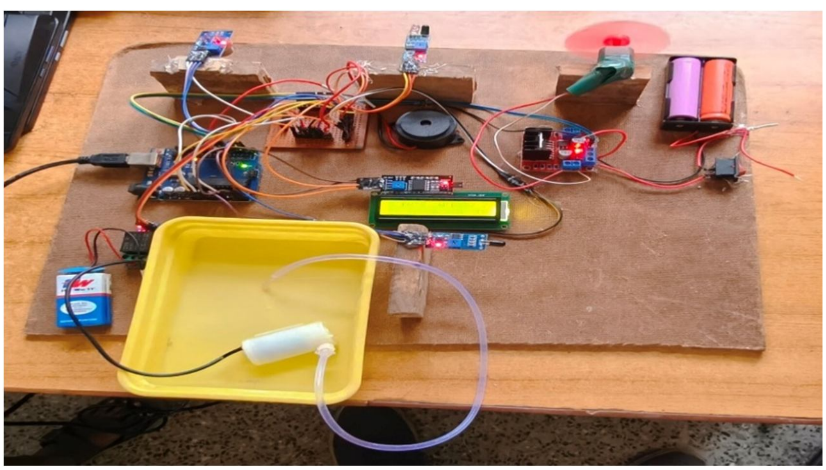

Figure 1: Proto Type of Smart Safety Driver Device

III. SYSTEM ARCHITECTURE METHODOLOGY

The Smart Safety Driver Device operates based on a continuous monitoring framework that combines sensing, real-time data processing, decision-making, and automatic response execution. The system is built around a microcontroller unit that acts as the central controller, receiving input from multiple sensors deployed within the vehicle. A stable power supply ensures proper functioning of all modules. The sensing layer includes an eye-blink sensor to evaluate driver alertness by analyzing eye closure

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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patterns, along with flame and gas/smoke sensors to identify fire hazards and unsafe environmental conditions. The controller continuously interprets these sensor inputs and compares them with predefined thresholds to detect abnormal situations.

Based on the evaluated data, the system activates appropriate output mechanisms to ensure safety. An audible buzzer is used to alert the driver, while an I2C-based LCD module displays real-time warnings and system status. In the case of fire detection, a relay module is triggered to operate a water pump, enabling immediate suppression of flames. Additionally, a motor driver is used to control a DC motor that represents vehicle motion, allowing speed reduction or complete stoppage under critical conditions. Through this integrated approach, the system ensures continuous supervision and automatic intervention, thereby improving driver awareness and enhancing overall vehicle safety. Figure 2 presents the block diagram of the proposed system.

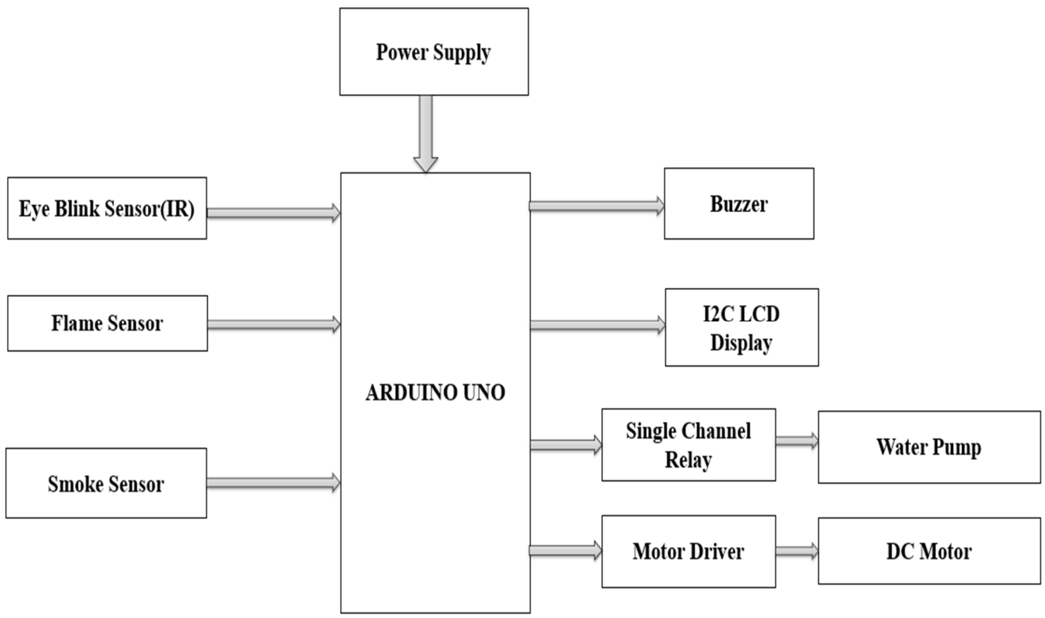

Figure 2: Block Diagram of the Proposed Intelligent Safety Driver Device

A. Methodology

1) System Initialization

At the moment the vehicle ignition is activated, the microcontroller initializes all interfaced components, including the eye-blink sensor, alcohol sensing module, flame detector, buzzer, relay unit, and water pump. During this stage, predefined threshold values related to fatigue detection, alcohol levels, and fire conditions are loaded into the system. Once initialization is complete, the device transitions into continuous monitoring mode.

2) Data Acquisition

The sensing modules continuously gather real-time information from the driver and the surrounding environment. The alcohol sensor measures the presence of alcohol vapors in the driver's breath, while the eye-blink sensor tracks eye movement patterns and evaluates the duration of eye closure. Simultaneously, the flame sensor monitors for any signs of fire or abnormal temperature rise within the vehicle. The collected data is transmitted to the microcontroller in the form of analog and digital signals for further processing.

3) Data Processing and Analysis

The microcontroller analyzes the incoming sensor data by comparing it with predefined threshold limits. When the detected alcohol level exceeds the permissible range, the system identifies an intoxication condition. Similarly, extended eye closure beyond the normal duration is interpreted as driver fatigue. Detection of abnormal flame intensity or heat levels indicates a fire hazard. This evaluation process is performed continuously to ensure rapid identification of unsafe situations.

4) Decision-Making Mechanism

Based on the analyzed data, the controller executes conditional logic to determine appropriate safety actions. In the presence of alcohol, the ignition system is disabled using the relay interface, accompanied by an alert signal. If drowsiness is detected, an audible warning is generated to alert the driver. In the case of fire detection, both an alarm and an automatic suppression mechanism are activated. These decisions are executed almost instantaneously to minimize risk.

5) Safety Action Execution

Once a hazardous condition is confirmed, the system initiates the required response mechanisms. The buzzer produces an alert sound to notify the driver, the relay module controls the ignition system to prevent unsafe vehicle operation, and the water pump activates to suppress fire when necessary. These actions are designed to mitigate risks at an early stage and prevent escalation.

6) Continuous Monitoring and Reset

After executing the necessary safety responses, the system continues to monitor all sensor inputs without interruption. When the detected parameters return to normal levels, the system automatically resets and resumes standard operation, ensuring uninterrupted protection and readiness for subsequent events.

IV. RESULTS AND DISCUSSION

The Smart Safety Driver Device was implemented and evaluated through experimental testing under controlled conditions to verify its capability in detecting driver fatigue, alcohol presence, and fire-related hazards. The observations indicate that the system is capable of monitoring multiple parameters simultaneously and generating rapid responses when abnormal conditions are detected. The integrated operation of sensing modules and control mechanisms ensures timely alerts and preventive actions, thereby improving overall safety performance

The developed system incorporates various modules, including an MQ-series smoke sensor, eye-blink sensor, flame detection unit, motor driver, buzzer, relay interface, and LCD display, all coordinated by a microcontroller-based platform. During operation, the system initializes all components and begins continuous monitoring of sensor inputs. The eye-blink sensor tracks driver alertness, while the smoke and flame sensors detect hazardous environmental conditions inside the vehicle.

Figure 3: Initialize the Smart Safety System

Based on the sensor data, the controller activates warning signals and controls the motor and alarm mechanisms accordingly. This coordinated functionality enables the system to reduce risks associated with drowsiness, fire, and smoke exposure. Figure 3 illustrates the initialization stage of the proposed system.

A. Alcohol Detection Results

The alcohol and smoke detection functionalities were evaluated under controlled testing conditions to analyze system performance and response behavior. During system startup, an initial safety check is performed using the MQ-2 sensor to identify the presence of smoke within the vehicle environment. If smoke is detected, the system immediately restricts engine operation, activates an audible alert through the buzzer, and displays a warning message on the LCD, thereby preventing vehicle ignition under unsafe conditions.
In parallel, the alcohol sensing module continuously monitors the driver's breath to detect alcohol concentration levels.

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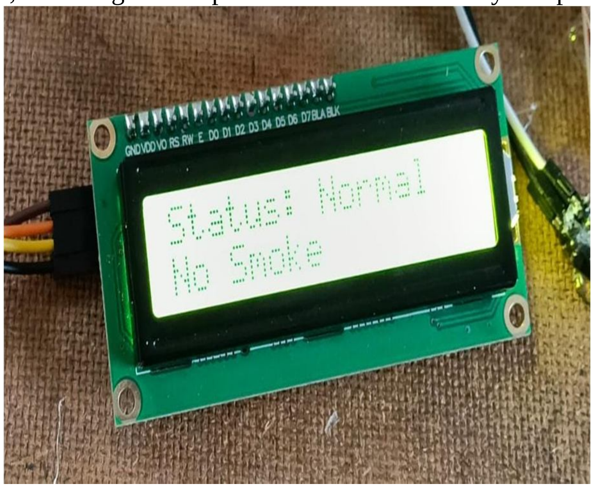
When the measured value exceeds the predefined threshold, the microcontroller initiates a safety response by disabling the ignition system through a relay interface and activating an alert mechanism. This dual monitoring approach, combining smoke and alcohol detection, enables effective identification of hazardous conditions and ensures automatic preventive action. As a result, the system enhances vehicle safety by restricting operation in the presence of unsafe environmental or driver-related factors. Figures 4 and 5 illustrate the detection process and corresponding system response.

B. Drowsiness Detection Results

The eye-blink sensing module was tested by simulating both normal blinking behavior and prolonged eye closure to evaluate its effectiveness in detecting driver fatigue. Under normal conditions, the system remained in monitoring mode without generating any alerts. However, when extended eye closure was introduced, the system identified it as a drowsiness condition and initiated a two-stage safety response. Initially, the motor speed was reduced to provide an early warning to the driver, and if the condition persisted, the system brought the vehicle to a complete stop while activating an audible alarm through the buzzer. The response time was observed to be within milliseconds, ensuring quick detection and timely intervention. These results confirm that the fatigue detection mechanism operates reliably and efficiently under the tested conditions. Figures 6 and 7 illustrate the drowsiness detection process, including motor speed reduction followed by complete vehicle stoppage.



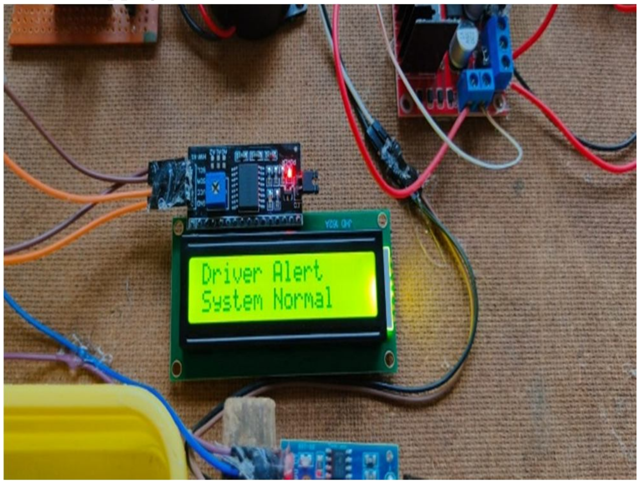
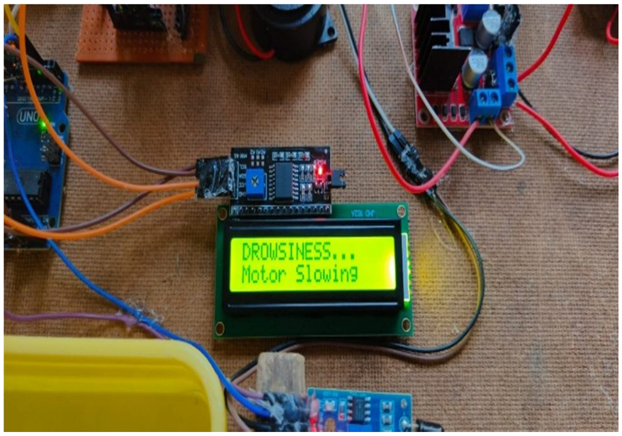


Figure 4: Detection of the Alcoholic or Smoke   Figure 5: Cheeking the Driver Alertness



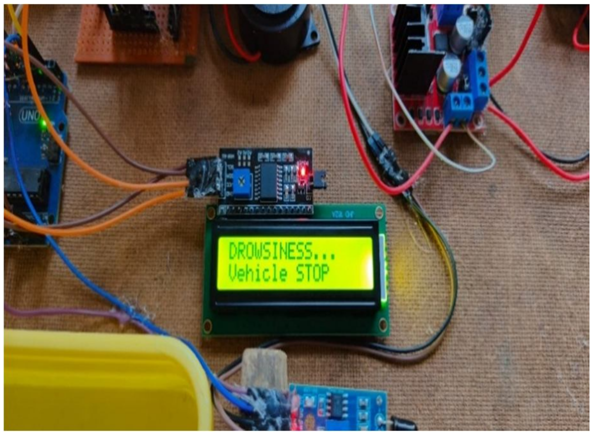


Figure 6 & 7: Cheeking the Drowsiness Detection; If detected the Motor Slowdown and After Sometime Vehicle Stop

C. Fire Detection and Suppression Results

The fire detection module was evaluated using a controlled flame source to verify its response and suppression capability. When the flame sensor detected the presence of fire, the system immediately activated an audible alert through the buzzer and triggered the water pumping unit connected to the sprinkler mechanism.

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The response was observed to be rapid, enabling early-stage intervention and effective suppression of the flame before it could escalate. The coordinated operation of detection and suppression components demonstrates the reliability of the system in handling fire-related hazards. Figures 8, 9, and 10 illustrate the fire detection process and the corresponding activation of the suppression mechanism.

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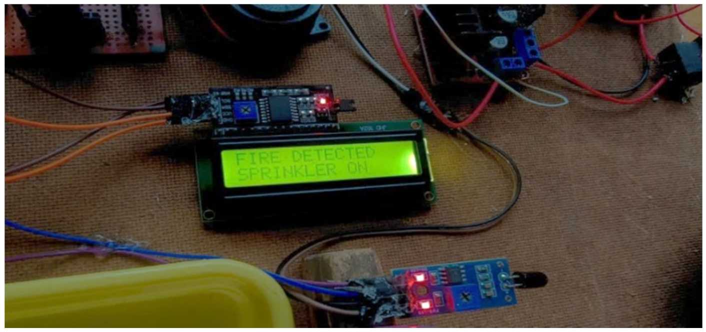

Figure 8: Cheeking the Fire Detection; If detected the Water Sprinkler to the Fire

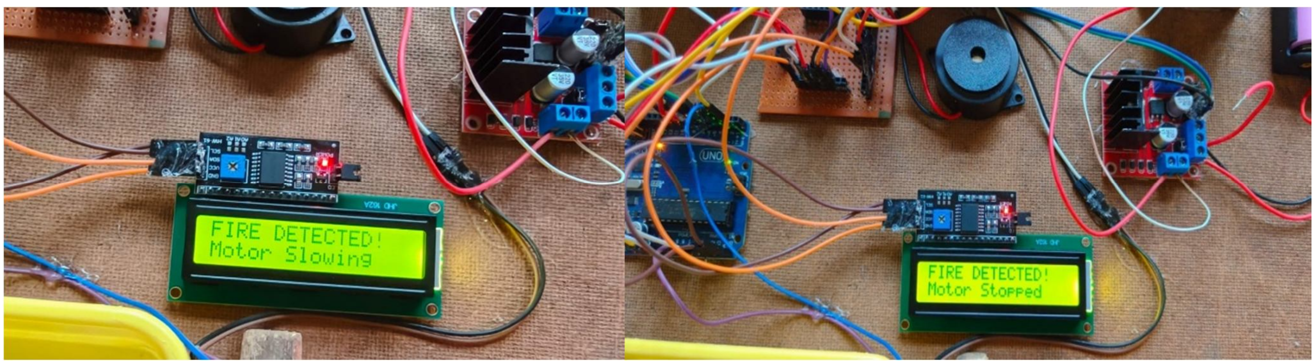

Figure 9 & 10: Cheeking the Fire Detection; If detected the Motor Slowdown and After Sometime Vehicle Stop

D. Integrated System Performance

The complete system was evaluated by operating all modules simultaneously to assess its ability to handle multiple inputs in real time. The microcontroller efficiently processed data from all sensors without any noticeable delay or interference between modules. Based on predefined conditions, appropriate safety actions were executed promptly, demonstrating the system's capability to manage concurrent events. The integrated architecture simplifies implementation compared to standalone safety systems and improves overall system reliability.

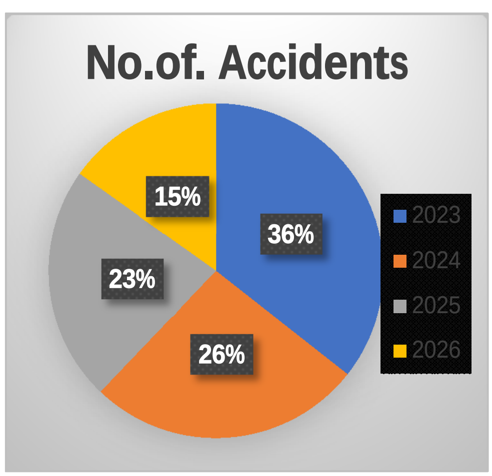

Figure11: Year-wise Reduction in Road Accidents (2023–2026)

Figure 11 presents a graphical representation of the reduction in road accidents from 2023 to 2026 following the implementation of the proposed system. The data indicates a gradual decline in accident rates over the years, with the highest percentage observed in 2023 and a significant reduction by 2026. This trend highlights the effectiveness of continuous driver monitoring and hazard detection in improving road safety. The decrease can be attributed to timely detection of drowsiness, alcohol presence, and fire-related risks, along with immediate preventive actions.

Figure 12 illustrates a comparative analysis between conventional vehicle safety systems and the proposed Smart Safety Driver Device. Traditional systems generally focus on a single safety parameter, such as fatigue detection or alcohol monitoring, operating independently. In contrast, the proposed system combines multiple sensing modules within a unified microcontroller-based framework, enabling simultaneous monitoring and automated response. This multi-sensor integration enhances functional capability, reduces system complexity, and provides a more comprehensive safety solution compared to existing approaches.

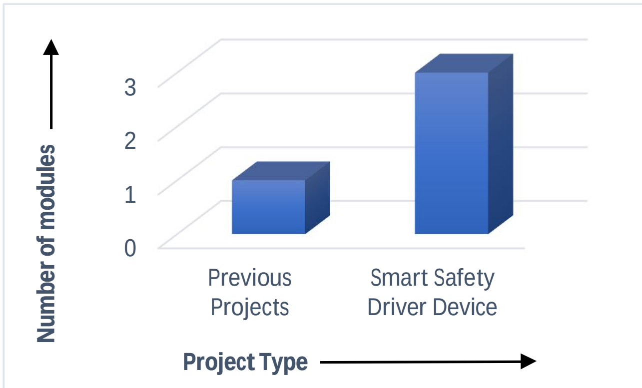

Figure 12: Comparison of Integrated Safety Modules in Existing and Proposed Smart Safety Driver Systems

E. Comparison Table

S. No	Parameter	Previous Systems	Proposed Intelligent Safety Driver Device
1	Safety Features	Focused on single feature (only drowsiness or only alcohol or only fire detection)	Integrates drowsiness, alcohol, and fire detection in one system
2	Monitoring Type	Single-parameter monitoring	Multi-parameter real-time monitoring
3	Controller Usage	Sometimes separate modules without centralized control	Centralized control using Arduino microcontroller
4	Response Mechanism	Mostly alert-based (buzzer or warning only)	Alert + automatic preventive actions
5	Engine Control	Limited or not available	Engine ignition disabled during alcohol detection
6	Fire Handling	Fire detection with alarm only	Fire detection + automatic water sprinkler activation
7	System Integration	Independent and separate systems	Fully integrated compact system
8	Real-Time Processing	Limited or delayed processing	Continuous real-time monitoring and quick response
9	Installation	Complex installation of separate systems	Easy installation in existing vehicles

Table 1: Comparison of Existing Driver Safety Systems and the Proposed Smart Safety Driver Device

V. CONCLUSION

The Smart Safety Driver Device presents a practical and effective approach for minimizing road accidents associated with driver fatigue, alcohol influence, and vehicle fire hazards by combining multiple safety mechanisms within a single embedded system. The microcontroller-based platform continuously acquires and evaluates data from the eye-blink sensor, alcohol sensing module, and flame detector to identify unsafe conditions in real time. Upon detection, the system not only provides immediate alerts through an audible buzzer but also initiates preventive control actions such as restricting ignition during alcohol detection and activating a water-based suppression mechanism in case of fire.

Experimental evaluation demonstrates that the system operates with quick response and consistent reliability, thereby enhancing driver awareness and overall vehicle safety. In comparison with conventional systems that focus on individual safety parameters, the proposed integrated design offers improved functionality, reduced system complexity, and cost-effective implementation suitable for a wide range of applications, including public transportation, logistics operations, and private vehicles. Furthermore, the system can be extended with advanced features such as IoT-based connectivity and GPS-enabled emergency notifications, enabling the development of a more intelligent and scalable vehicle safety solution.

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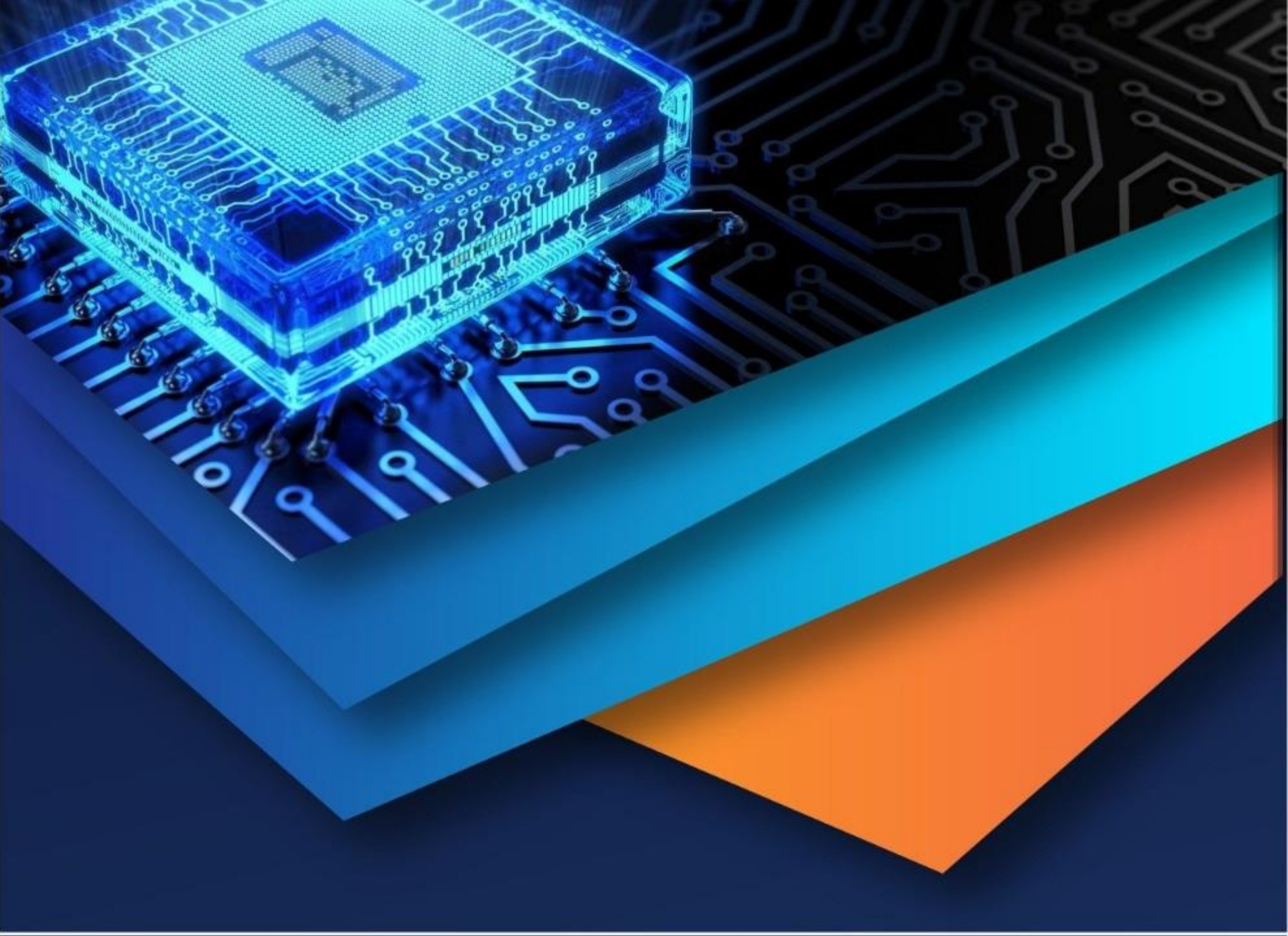

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