International Journal of Engineering & Extended Technologies Research (IJEETR)

|ISSN: 2322-0163| www.ijeetr.com | A Bimonthly, Peer Reviewed, Scholarly Indexed Journal |

| Volume 8, Issue 2, March - April 2026 |

DOI:10.15662/IJEETR.2026.0802095

Automated Fire Incident Handling and Emergency Protection System for Bus

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Publication History: Received: 25.02.2026; Revised: 20.03.2026; Accepted: 25.03. 2026; Published: 28.03.2026.

ABSTRACT: Fire accidents in public transportation buses present health injuries in public transportation buses present a severe risk to passenger safety and public assests. In many situations, delayed detection and manual emergency response lead to severe damage and loss of life. This paper proposes an automated fire incident handling and emergency protection system for buses that operates with minimal human intervention. This system continuously monitors the bus environment using fire and smoke sensors. Real time status updates are displayed on an LCD screen ti inform the driver and passengers. When a fire related threat is detected, the system immediately activates an alarm to alert occupants. An exhaust fan is triggered to reduce smoke concentration, improving visibility and breathing conditions inside the bus. To ensure safe evacuation, the bus doors are automatically opened. A GPS module tracks the bus vicinity and sends emergency indicators to fire stations and hospitals for rapid response. All system operations are managed by a microcontroller to ensure fast, accurate and reliable execution. The proposed system follows an automated and structured workflow, where all safety actions re triggered based on real time sensor inputs. The integration of sensing, alerting and communication mechanisms ensures a coordinated emergency response. The system is designed to be energy efficient, reliable, and easily adaptable to existing bus infrastructure. This solution enhances passenger safety, minimizes response time, reduces panic during emergencies, and provides a cost effective fire safety system for public transport.

KEYWORDS: Bus safety, Smoke detection, GPS tracking , IoT based monitoring, Emergency alert system, microcontroller, Public transportation safety.

I. INTRODUCTION

Public transportation buses are extensively used due to their cost effectiveness, accessibility and ability to serve large populations. Despite these advantages, fire accidents in buses continue to pose significant risks to passenger safety, driver security and public property. Such incidents are commonly caused by electrical faults, fuel leakage, engine overheating and short circuits, which can escalate rapidly if not detected at an early stage. In many situations, the absence of continuous monitoring and delayed emergency response increases the severity of damage and leads to life threatening consequences. Conventional fire safety systems in buses largely depend on manual detection and human intervention , which may not be reliable during panic or emergency situations. Human error, delayed reaction, and lack of coordination often limit the effectiveness of traditional safety measures. Therefore, there is a critical need for an automated fire safety system capable of detecting fire hazards in real time and initiating immediate protective actions. This paper presents an automated fire incident handling and emergency protection system that integrates intelligent sensing, alert mechanisms, automatic evacuation support, and emergency communication. The proposed system

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enhances passenger safety by minimizing response time, reducing fire spread, and ensuring efficient evacuation during emergency situations.

II. ROLE OF IOT

In this project, IOT playes a key role in enabling real-time monitoring and automated emergency response in buses. Fire and smoke sensors continuously collect environmental data and communicate it to the microcontroller through IoT connectivity. This allows the system to detect fire incidents at an early stage without depending on human intervention. When a fire hazard is identified, IOT enables instant coordination between safety components such as alarms, exhaust fans, and automatic door control. At the same time, the GPS module shares the exact bus location through the communication network, and emergency alerts are transmitted to nearby fire stations and hospitals.

This ensures quick external assistance during critical situations. By integrating IoT, the system achieves reliable data transmission, fast decision making and remote emergency communication. The

IoT-based approach improves response time, enhances passenger safety and makes the fire protection system more effective and suitable for real-time deployment in public transportation buses. Additionally IoT enables system scalability and future enhancements such as remote monitoring, data logging, and predictive safety analysis. These features support continuous improvement of the safety system and strengthen emergency preparedness in smart transportation environments.

I. Future Scope
The proposed IoT-based fireplace incident handling system can be further enhanced by integrating cloud platforms for centralized data storage and remote monitoring. Sensor data collected from multiple buses can be analyzed in real time to perceive styles, predict potential fire risks, and improve preventive maintenance. This enables transport authorities to monitor vehicle safety continuously from a remote control center. In the future, advanced IoT technologies such as machine learning and artificial intelligence can be incorporated to improve fire detection accuracy and reduce false alarms. Mobile applications can be developed to provide real-time alerts and status updates to authorities and passengers.

III. SYSTEM ARCHITECTURE AND METHODOLOGY

A. Overall System Architecture
The overall system architecture of the proposed automated fire incident handling and emergency protection system is shown in Fig. 1. The system is designed around a microcontroller, which serves as the main control center and coordinates all operations. decision-making component. Various sensing, alerting, actuation, and communication modules are interfaced with the controller to ensure real-time fire detection and automated emergency response.

Fire and smoke sensors are connected to the microcontroller to continuously monitor environmental conditions inside bus. These sensors detect abnormal temperature rise and smoke concentration, and the collected data is processed in real time. A buzzer module is interfaced to provide an audible warning when a fire hazard is detected. An LCD screen is utilized to present information to the user.system status and alert messages for the driver and passengers.

To support smoke control and evacuation, an exhaust fan and automatic door control mechanism are connected through a relay module. When an emergency condition is identified, the controller activates the exhaust fan to remove smoke and operates the door mechanism to allow safe passenger evacuationA GPS module is incorporated to acquire location data. the real-time location of the bus, and emergency alert information is transmitted through the communication interface to nearby fire stations and hospitals. The system is powered using a regulated power supply unit that provides stable voltage to all components. All modules operate in coordination under the control of the microcontroller, forming an integrated and automated safety system suitable for real-time deployment in public transportation buses. For emergency communication, a GPS module is integrated to obtain the exact location of the bus. A communication module transmits this location information along with emergency alerts to predefined contacts, nearby fire stations, and hospitals. All components operate in a coordinated manner under the control of the microcontroller.

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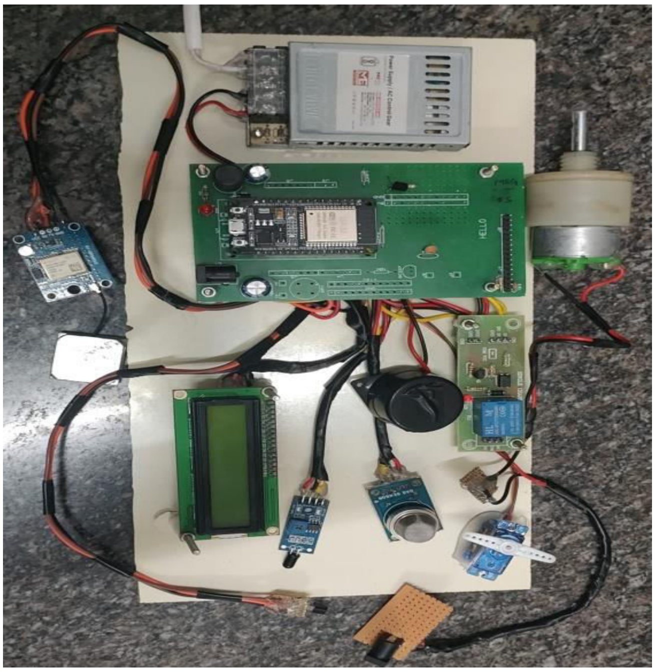

Fig.1.Illustrates the prototype of Automated fire incident handling system.

B. Block diagram

The block diagram of the proposed automated fire incident handling and emergency protection system illustrates between sensing units, control unit, output devices and communication modules. The system is centered around a microcontroller, which receives input signals from fire and smoke sensors and processes them in real time. The fire sensor and smoke sensor continuously monitor the internal environment of the bus and send data to the microcontroller. Based on the received sensor values, the controller determines whether normal or emergency conditions exist. An LCD display is connected to the microcontroller to provide real-time status information to the driver and passengers.

When a fire hazard is detected, the microcontroller activates a buzzer to alert occupants. Simultaneously, a relay module is employed to control the connected components. is triggered to control high-power devices such as the exhaust fan and automatic door mechanism. The exhaust fan helps in removing smoke from the bus, while the door control unit enables quick evacuation of passengers. A GPS module is interfaced with the microcontroller to obtain the real-time location of the bus. This location data, along with an emergency alert, is transmitted through the communication module to nearby fire stations and hospitals. A stabilized power source delivers the necessary supply to the system. voltage to all system components, ensuring stable and reliable operation.The synchronized operation of all these components ensures smooth and efficient performance. ensures an automated and effective response during fire emergencies. The block diagram of the proposed automated fire incident handling and emergency protection system illustrates the overall functional flow of the system. The ESP32 microcontroller acts as the central control and processing unit of the system. It continuously analyzes sensor data and compares it with predefined threshold values. From this evaluation, the controller determines the appropriate action to take. whether the system operates in normal mode or emergency mode. The regulated power supply provides stable voltage to the ESP32 and all connected modules, ensuring reliable system operation

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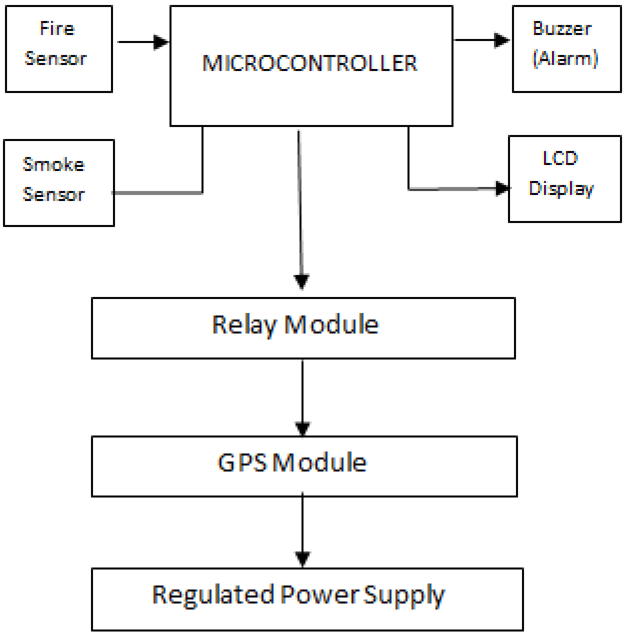

Fig.2. Block Diagram of Automated File Incident Handling and Emergency Protection System

C. Working Methodology

The proposed Automated Fire Incident Handling and Emergency Protection System is designed to function continuously throughout the operation of the bus. The system follows a real-time monitoring approaching which fire and smoke sensors constantly observe the internal environment of the vehicle. The sensed data is periodically transmitted to the microcontroller, where it is analyzed and compared with predefined threshold values stored in system memory.

During normal operating conditions, when the sensor readings remain within safe limits, the system operates in monitoring mode. The LCD display continuously shows the system status, indicating safe operation to the driver and passengers. This ensures transparency and confirms that the safety system is active at all times.

When abnormal conditions such as fire or excessive smoke are detected, the corresponding sensor values exceed the threshold limits. The microcontroller immediately switches the system into emergency mode. An interrupt-based control routine ensures that emergency actions are executed without delay. The buzzer is activated to generate an audible alarm, alerting all occupants inside the bus. Simultaneously, warning messages are displayed on the LCD to provide visual confirmation of the emergency situation.

To support safe evacuation, the exhaust fan is activated through a relay module to reduce smoke concentration inside the bus. This improves visibility and air quality, minimizing the risk of suffocation. At the same time, the automatic door control mechanism is triggered, allowing immediate opening of bus doors without requiring manual operation. These actions occur simultaneously to reduce response time and prevent panic during emergencies.

In parallel, the GPS module retrieves the real-time location of the bus. The location data, along with emergency alert information, is transmitted to predefined emergency contacts such as nearby fire stations and hospitals. This enables rapid external response and ensures timely rescue operations. The system remains in emergency mode until the sensor readings return to safe levels, after which the system can be reset manually.

The proposed system emphasizes minimal response latency by employing continuously sensor polling and interrupt-driven control logic. Sensor data is processed in real time by the microcontroller, ensuring that emergency conditions are identified without delay. This approach significantly reduces the dependency on manual observation and improves the reliability of fire detection, especially in high-risk operating conditions such as long-distance travel and high-temperature environments.

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To enhance system stability, predefined threshold values are selected based on safety standards and experimental observations. These threshold values can be modified through firmware updates, allowing the system to adapt to different bus models and operating environments. The flexibility of threshold configuration improves detection accuracy and reduces false alarms caused by temporary environmental variations such as dust or humidity. The coordinated execution of alerting, evacuation support, and communication function ensures efficient emergency handling.

D. Emergency Decision Logic

The emergency decision logic is implemented using threshold-based comparison and logical validation. Fire and smoke sensor outputs are independently analyzed to improve detection reliability. An emergency condition is confirmed only when sensor readings persist beyond threshold values for a specific duration. This approach minimizes false triggering caused by temporary environmental disturbances.

Once the emergency state is validated, the controller initiates all safety operations in a coordinated manner. Priority is given to passenger alerting and evacuation support, followed by emergency communication. This structured decision logic ensures stable and conflict-free system operation during critical situations.

E. Integration of Control and Communication Modules

The sensing, control, and communication modules are tightly integrated to ensure synchronized system operation. The microcontroller serves as the central control unit, coordinating all hardware components. The relay module provides electrical isolation between Low-power control circuits are used to regulate and manage high-power components and equipment. exhaust fans and door motors, ensuring system safety and reliability.

The GPS module operates continuously to maintain updated location information. This allows immediate transmission of accurate location data once an emergency is detected. The integration of real-time sensing, automated control, and emergency communication forms a compact and efficient system architecture suitable for deployment in public transportation buses

F. System Operation Flow

The overall system operation follows a structured workflow:

1. Continuous monitoring of fire and Smoke conditions.
2. Real-time data acquisition and processing
3. Threshold comparison for emergency detection
4. Activation of alarm and display alerts
5. Automatic control pf exhaust fan and door mechanism
6. GPS- based emergency alert transmission.

IV. SYSTEM IMPLEMENTATION AND WORKING

A. Hardware Implementation

The proposed automated fire incident handling and emergency protection system was implemented as a compact, microcontroller-based hardware prototype suitable for deployment in public transportation buses. The implementation emphasizes real-time operation, reliability, and minimal human intervention. All components were selected based on fast response characteristics, low power consumption, and compatibility with vehicular environments.

Fire and Smoke Sensors were interfaced with the microcontroller through appropriate analog and digital input channels. These sensors continuously monitors the internal environment of the bus and provide real-time data for analysis. The fire sensor detects flame or abnormal heat generation, while the smoke sensor identifies harmful gas and smoke concentration. The combined use of both sensors improves It improves detection precision and minimizes the likelihood of incorrect or false results. alarms.

The microcontroller operates as the main control unit of the system. and processing unit of the system. It continuously acquires sensor data, compares it with predefined threshold values, and executes control logic accordingly. The firmware was designed to support real-time multitasking, allowing simultaneous sensor monitoring, display updating, and output device control. Interrupt-based processing ensures that emergency routines are executed immediately when abnormal conditions are detected.

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An LCD display is integrated to provide continuous system status and emergency alert messages. During normal operation, the display indicates system readiness and safe conditions. When an emergency occurs, warning messages are displayed to inform the driver and passengers. A buzzer is used as an audible alert device to ensure immediate attention even in noisy traffic conditions. The combination of audio and visual alerts enhances communication effectiveness during emergencies.

High-power devices such as the exhaust fan and automatic door control mechanism are interfaced using a relay module. The relay provides electrical isolation between low-voltage control circuitry and high-current loads, protecting the microcontroller from electrical surges. The exhaust fan is positioned to efficiently remove smoke from the passenger compartment, while the door control mechanism ensures immediate opening of exits for safe evacuation.

A GPS module is interfaced with the microcontroller using serial communication to provide real-time location tracking. The module continuously updates latitude and longitude data, which is used during emergency alert transmission. A regulated power supply unit provides stable voltage to all system components, protecting them from power fluctuations commonly observed in automotive electrical systems. The modular hardware design allows easy integration with existing bus infrastructure and supports future system expansion.

B. System Working and Control Logic

The working of the proposed system is based on continuous environmental monitoring and automated decision making. Under normal operating conditions, the fire and smoke sensors continuously sensor the internal environment of the bus. The sensor outputs are sampled at regular intervals and processes by the microcontroller. The processes data is compared with predefined threshold values stored in system memory to determine the operating state.

When the sensor readings remain safe within safe limits, the system operates in monitoring mode. In this mode, the LCD display shows normal operational messages, and no emergency actions are triggered. Power consumption during this state is minimal, ensuring efficient system operation while maintaining constant readiness.

When the system identifies the presence of fire or unusually high levels of smoke., the sensor values exceed the threshold limits and the system immediately transitions into emergency mode. This transition is handled using interrupt-based control logic to ensure zero delay in response. The alarm sounds to notify passengers of the situation. and the driver, while emergency warning messages are displayed on the LCD screen.

Simultaneously, the relay module is triggered to activate the exhaust fan and automatic door control mechanism. The exhaust fan reduces smoke concentration inside the bus, improving visibility and air quality. The automatic door system opens the bus doors instantly, allowing passengers to evacuate safely without manual intervention. These actions are executed in parallel to minimize emergency response time.

At the same time, the GPS module retrieves the most recent location information of the bus. Emergency alert messages containing location details are transmitted to predefined emergency contacts such as fire stations and hospitals. This enables rapid external assistance and accurate emergency response coordination.

During emergency operation, the system continues to monitor sensor readings to track environmental changes. Once situations go back to safe tiers, the system remains in a controlled standby state until manual reset is performed. This prevents accidental deactivation and ensures system safety throughout the incident. The automated working mechanism minimizes human error, reduces panic, and significantly enhances passenger safety during fire emergencies.

The implementation of the proposed system was evaluated under different operational conditions to ensure stability and reliability. Special attention was given to synchronization between sensing, alerting, and actuation modules to avoid delays during emergency response. The device turned into designed to characteristic autonomously as soon as activated, requiring minimal human intervention.

Fault tolerance was considered during system implementation. In case of temporary sensor fluctuation or communication delay, the system maintains its emergency states until verified safe conditions are detected. This prevents premature deactivation and ensures continuous safety monitoring throughout the incident duration.

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The modular layout method allows person additives to be replaced or upgraded without affecting the overall system operation. This flexibility enhances maintainability and enables future integration of additional safety features such as camera-based fire detection or wireless communication modules.

System reliability was further enhanced through repeated testing under simulated emergency scenarios. The system demonstrated consistent performance in detecting fire and smoke conditions and executing automated safety actions. The stable interaction between hardware modules ensures dependable operation, making the system suitable for real-world deployment in public transportation.

V. EXPERIMENTAL SETUP AND RESULTS

A. Experimental Setup

The experimental framework for the proposed Automated Fire Incident Handling and Emergency Protection System was developed to assess its operational efficiency, reliability, and reaction time under conditions resembling real-life fire emergencies. A functional hardware prototype was implemented using a microcontroller-based control unit integrated with fire and smoke sensing units, alert and evacuation mechanisms, and a GPS-enabled emergency communication module.

Trying out became conducted in a controlled surroundings to emulate potential fire-related incidents inside a public transportation bus. Fire scenarios were simulated by positioning a controlled flame source at a safe distance from the fire sensor, whereas smoke conditions were created using smoke-generating materials to evaluate the performance of the smoke sensor. All experimental methodswere carried out with appropriate safety precautions while maintaining realistic operating conditions.

The hardware prototype comprised a microcontroller, fire and smoke sensors, LCD display, buzzer, relay-driven exhaust fan, automatic door control system, GPS module, and a regulated power supply unit. The components were interconnected according to the system architecture presented in the previous section. A stable power supply ensured uninterrupted and reliable operation throughout the experimental process.

During testing, the sensors continuously monitored environmental parameters and relayed data to the microcontroller. System responses such as detection accuracy, alert initiation, actuation of safety devices, and response time were closely observed and recorded for further analysis.

B. Hardware and Software Configuration

The hardware setup consisted of a fire sensor, smoke sensor, microcontroller unit, LCD display, buzzer, relay module, exhaust fan, automatic door mechanism, GPS module, and power supply unit. The fire sensor was used to identify abnormal heat or flame presence, while the smoke sensor monitored variations in smoke and gas concentration within the bus environment.

The microcontroller firmware was programmed using embedded C and structured to support real-time system operation. Tasks such as sensor data acquisition, threshold evaluation, display updates, alarm triggering, and emergency communication were executed concurrently. Interrupt-driven routines were incorporated to ensure rapid system response during critical emergency situations.

Threshold levels for fire and smoke detection were selected based on experimental observations and standard safety considerations. These values were stored in the system memory and could be modified through firmware updates to accommodate varying operational environments. The implemented software logic ensured accurate detection while reducing false activations caused by temporary environmental fluctuations.

C. Test Methodology

The system performance was validated under several simulated emergency conditions. Initially, the system was operated under normal environmental conditions to confirm stable monitoring and accurate status display on the LCD. During this phase, no alarms or control actions were triggered, verifying correct threshold configuration and system stability.

Fire detection tests were conducted by introducing a flame source near the fire sensor. When the sensed temperature exceeded the predefined threshold, the system immediately switched to emergency mode. Similarly, smoke detection

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tests were performed by gradually increasing smoke concentration around the smoke sensor until the threshold value was reached.

For each test scenario, the following performance factors were evaluated:

1. Sensor response time
2. Accuracy of emergency detection
3. Alert generation delay
4. Activation of exhaust fan and automatic door mechanism
5. GPS-based emergency location transmission

Each experiment was repeated multiple times to confirm consistency and reliability of the system operation.

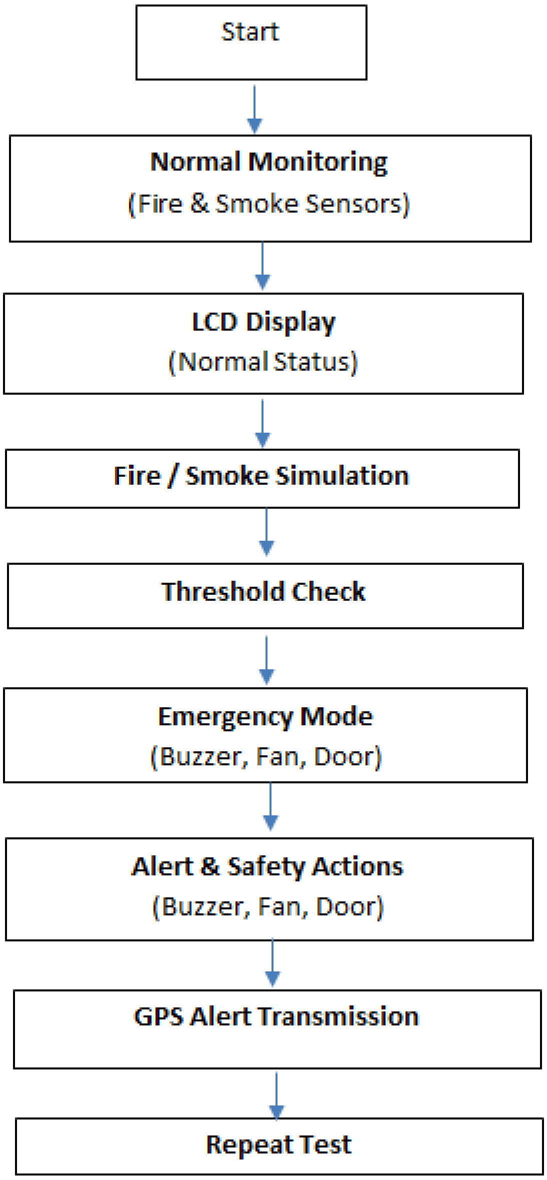

Fig3. Operational flowchart of the proposed Automated Fire Incident Handling and Emergency protection system for bus

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D. Performance Parameters

The effectiveness of the proposed device was assessed using the following key performance metrics:

1. Detection Time: Time required by sensors to identify fire or smoke conditions
2. System Response Time: Delay between detection and activation of safety mechanisms
3. Alert Accuracy: Ability to trigger alarms correctly without false activation
4. Evacuation Support Efficiency: Timely door operation and smoke extraction
5. Communication Reliability: Successful transmission of location data during emergencies

These parameters collectively provide a comprehensive evaluation of the system's suitability for real-time fire safety applications in public transportation systems.

E. Emergency Detection and Validation Mechanism

To improve detection accuracy and minimize false alarms, the proposed system incorporates an emergency detection and validation mechanism. The outputs from the fire sensor and smoke sensor are processed independently and continuously evaluated before initiating any emergency response. An emergency condition is confirmed only when the sensor readings exceed their respective threshold values for a predefined validation duration.

This time-based validation approach effectively filters out false triggers caused by transient environmental factors such as dust, humidity variations, or momentary temperature fluctuations. Upon successful validation of an emergency condition, the system immediately activates alert mechanisms, evacuation support functions, and emergency communication modules in a synchronized manner, ensuring a prompt and reliable response.

F. Power Consumption and Reliability Analysis

An analysis of power consumption was carried out to assess the suitability of the proposed system for continuous operation in real-world applications. Under normal monitoring conditions, the system exhibited low power consumption, as only the sensing units and display module were active. This operational mode ensures energy efficiency during routine usage.

During emergency conditions, additional components such as the buzzer, exhaust fan, automatic door control mechanism, and GPS module were activated, resulting in a temporary increase in power consumption. However, the regulated power supply and optimized control logic enabled the system to operate reliably without voltage fluctuations or performance degradation.

Repeated emergency simulations confirmed stable system performance, with no observed system resets or component failures. These results show that the system is strong and dependable, which means it can work well over time in public transportation settings.

G. Comparative Analysis with Conventional Fire Safety Systems

A comparative evaluation was performed between the proposed automated fire safety system and conventional fire safety approaches commonly used in public transportation buses. Traditional systems predominantly depend on manual detection and human intervention, which often leads to delayed response, particularly in high-stress or panic situations.
In contrast, the proposed system provides automated detection and rapid response, significantly reducing the time between fire occurrence and safety action initiation. The coordinated activation of alerting, evacuation, and emergency communication mechanisms enhances overall safety and operational efficiency.

The reduction in reliance on human intervention minimizes response delays and improves consistency in emergency handling. This comparative analysis highlights the effectiveness of intelligent, automated fire safety systems over conventional methods, particularly for actual-time protection programs in public transportation.

H. Experimental Results and Analysis

The experimental assessment of the developed fire and smoke detection system confirms its dependable operation across a range of controlled testing environments. Several experiments were carried out to evaluate the system's accuracy in identifying emergency conditions, the speed of response, and its ability to remain stable during normal environmental situations without producing false alerts.

During testing, the fire sensor was assessed using controlled flames at varying distances and intensities. It detected flame presence in all trials, with an average response time of about 1.2 seconds. Minor response variations occurred due to lighting conditions, flame intensity, and sensor positioning, but overall system performance remained stable and within safe operating limits..
The smoke sensor was examined by generating controlled smoke to replicate realistic fire scenarios. The sensor effectively detected abnormal smoke levels with an average response time of nearly 1.5 seconds. Slight differences in detection time were influenced by ventilation, air movement, and smoke density within the testing area. Nevertheless, the sensor reliably identified hazardous smoke concentrations without delays that could affect emergency response.

Once an emergency condition was validated by the microcontroller, the system initiated alert and control actions without noticeable delay. The buzzer was activated and warning messages were displayed on the LCD within roughly 0.5 seconds. This ensured immediate notification to occupants. The LCD display remained clearly readable even under low-light conditions, improving overall system usability during critical situations.

Simultaneously, the relay module activated the connected safety devices. The exhaust fan reduced smoke concentration and improved air quality, while the automatic door system opened promptly to ensure a clear evacuation path.

The GPS module showed consistent and accurate performance throughout all experiments. Location data was acquired reliably, and emergency alert messages containing real-time coordinates were successfully transmitted to predefined contacts in every test case. Furthermore, no false alarms were recorded during normal operating conditions, confirming the effectiveness of the selected threshold values and control logic.

Overall, the results demonstrate that the proposed system delivers fast, accurate, and reliable fire safety monitoring, making it suitable for real-time applications in residential, industrial, and institutional settings.

VI. DISCUSSION

Overall, the experimental results validate the effectiveness of the proposed Automated Fire Handling and Emergency Protection System for Buses. The system demonstrated reliable real-time sensing of temperature, smoke, and flame conditions, along with stable communication between the sensing units and the central control module under various simulated fire scenarios. The automated fire suppression mechanism responded rapidly, significantly reducing fire spread and response time compared to manual intervention.

The integration of multi-sensor data processing with embedded control logic minimized false triggers and enhanced decision accuracy during abnormal conditions. Further, the mixed use of local alarm systems and GSM-GPS based emergency alerts ensured timely notification to passengers, drivers, and emergency authorities. The hybrid architecture, supporting autonomous onboard operation with optional remote monitoring, improves system reliability even during network interruptions. These effects affirm that the proposed machine is efficient, scalable, and well-suited for real-world deployment in public transportation safety applications.

VII. CONCLUSION

This paper presented an Automated Fire Handling and Emergency Protection System for Buses aimed at improving passengers safety through early fire detection, rapid response, and intelligent emergency coordination. The proposed system integrates multi-sensor monitoring with an embedded control unit to continuously supervise critical zones such as the engine compartment and passenger cabin. Upon detecting abnormal conditions, the system automatically activates fire suppression mechanism and generates timely alerts to both onboard occupants and external emergency services.

Experimental evaluation under simulated fire scenarios demonstrated reliable sensor performance, stable system operation, and fast response times, significantly reducing the dependence on manual intervention. The combination of autonomous onboard functionality with optional remote communication enhances system resilience during network failures and ensures continuous protection even in constrained connectivity environments.

In addition, the modular design of the system allows easy integration into existing bus infrastructures without major modifications. The low-cost hardware components and minimal computational requirements make the solutions

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economically viable for large-scale deployment across public transport fleets. The system is also adaptable to different bus types, including electric buses, where thermal risks are higher.

Overall, the proposed solution is practical, scalable, and cost-effective for deployment in public, school, and long-distance buses. By minimizing response time and improving emergency preparedness, the system contributes to safer public transportation infrastructure and offers a promising direction for intelligent vehicle safety systems.

Fig4. Hardware Prototype of the Automated Fire Incident Fire Handling and Emergency Protection System for Bus

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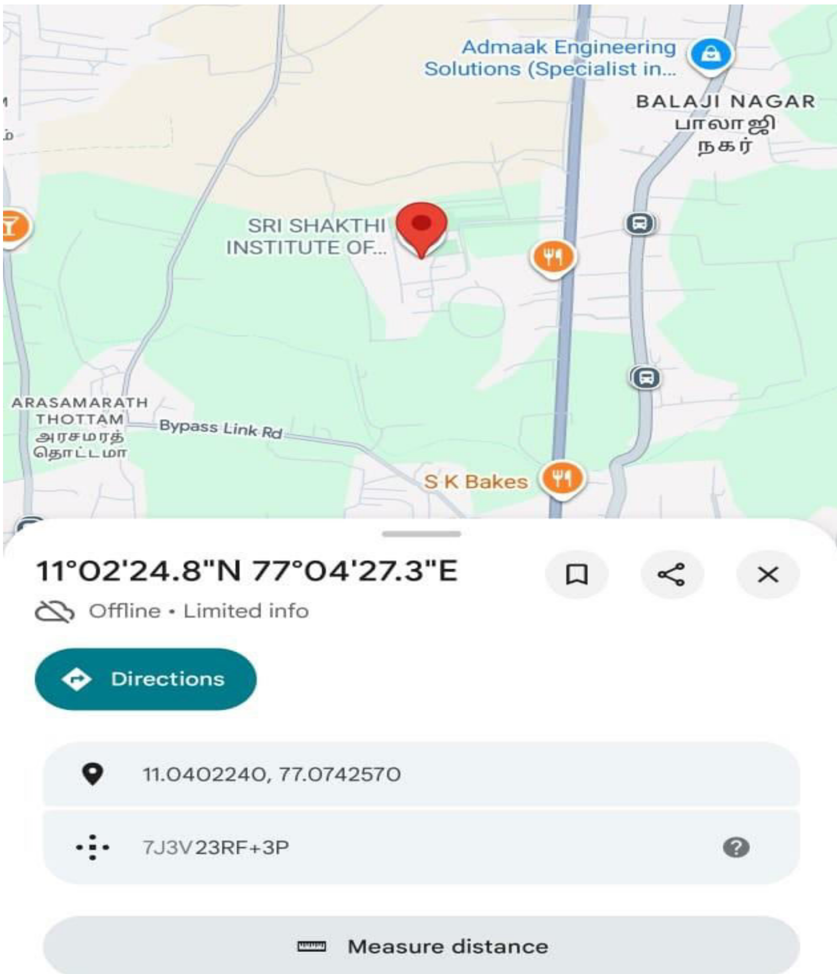

Fig5. GPS based real time location tracking displayed on digital map interface.

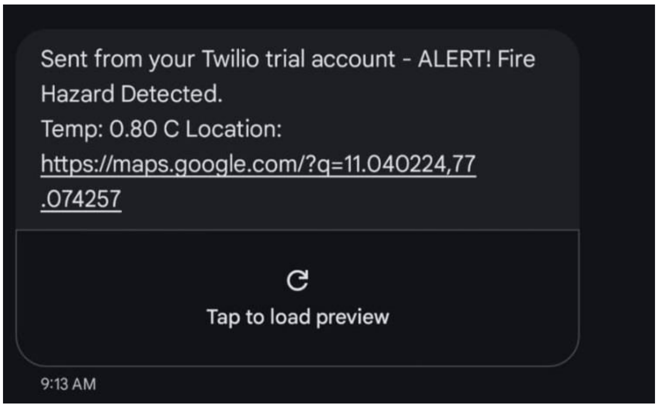

Fig6. SMS alert notification with GPS link sent during fire emergency

VIII. ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the department and institution for providing the necessary facilities and technical support to carry out this work. We extend our application to our project guide and faculty members foe their valuable guidance, continuous encouragement, and constructive feedback throughout the development of this project.

Their cooperation was essential in ensuring the reliability of the experimental setup. We are grateful to our peers and classmates foe their insightful discussion and collaborative spirit, which contributed to refining the system design and implementation. Additionally ,we acknowledge the support of transport professionals and industry resources whose practical insights helped to align the proposed system with real-world safety requirements.

We also thank our laboratory staff and peers for their assistance during system implementation and testing. Their support and cooperation were instrumental in successfully completing this work. Finally, we acknowledge the use of open-source hardware and software resources that contributed significantly to the validation of the proposed Automated Fire Incident Handling and Emergency Protection System for Buses

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