Smart Railway Safety System Using IoT and Sensor Integration

Y.Dileep Kumar[1], Yaddalapuri Lohitha[2] , Elumalai Teja[3], Gonasani Venkata Kiran[4], Kuruva Manjunath[5] and Mustur VijayKumar[6]
{y.dileepkumar1983@gmail.com[1], lohithayaddalapuri198@gmail.com[2], rohithtej454@gmail.com[3], kiranvenkat728@gmail.com[4], manjunathmanju25691@gmail.com[5], musturviju95017@gmail.com[6] }

Professor, Electronics and Communication Engineering, Mohan Babu University (Erstwhile Sree Vidyanikethan Engineering College), Tirupati, Andhra Pradesh, India[1]
UG Student, Electronics and Communication Engineering, Mohan Babu University (Erstwhile Sree Vidyanikethan Engineering College), Tirupati, Andhra Pradesh, India[2, 3, 4, 5, 6]

Abstract. Accidents at railway crossings and on train tracks pose a persistent safety challenge, necessitating the adoption of advanced preventive measures. This project introduces an "Accident Prevention and Track Proximity Alert System for Trains Using IoT," designed to enhance railway safety through real-time monitoring and automated alerts. The system integrates multiple sensors, including a flame sensor for fire detection, an ultrasonic sensor for obstacle identification, a metal proximity sensor for track integrity assessment, and a gas sensor to monitor hazardous gases in the railway environment. An Arduino microcontroller processes data from these sensors, interfacing with key components such as an LCD for real-time status display, a motor driver for train movement control, and a buzzer for audible warnings. Additionally, a servo motor automates railway door operations, improving safety at stations. The system leverages IoT connectivity via a NodeMCU module, enabling remote monitoring by transmitting alerts and sensor data to a cloud platform or mobile application. By integrating real-time detection, automated responses, and IoT-based alerts, this system aims to significantly reduce railway accidents, enhance operational reliability, and improve overall safety standards in railway transportation.

Keywords: Railway Safety, IoT-Based Accident Prevention, Track Proximity Alert, Sensor Integration, Arduino, NodeMCU, Real-Time Monitoring, Obstacle Detection, Fire Hazard Detection, Gas Sensing, Automated Railway Doors, Train Movement Control, Smart Transportation Systems etc.

1 Introduction

Railway transportation is one of the most widely used modes of transit due to its efficiency, cost-effectiveness, and ability to transport large volumes of passengers and goods. However, railway accidents remain a major safety concern worldwide, resulting in significant casualties, infrastructural damage, and economic losses [1]. Railway accidents primarily occur due to collisions, derailments, track failures, signal failures, human errors, and unsafe railway crossings [2]. Unmanned railway crossings and track obstructions pose severe threats to railway safety, often leading to fatal crashes involving pedestrians and vehicles [3].
The advent of Internet of Things (IoT)-based solutions has facilitated real-time monitoring, automation, and proactive accident prevention in railways [4]. Several studies have explored the use of sensor-based railway safety systems to monitor track conditions, detect hazardous

ICITSM-Part I 2025, April 28-29, Tiruchengode, India

DOI 10.4108/eai.28-4-2025.2357938

situations, and provide early warnings [5][6]. Additionally, IoT-enabled smart railway stations and automated level crossings have been proposed to enhance railway safety and operational efficiency [7]. Despite these advancements, existing railway safety systems still face significant limitations that hinder their effectiveness in preventing accidents.
Previous research on railway accident prevention has identified critical limitations that need to be addressed for enhanced railway safety. Some key challenges include:

1. Limited Real-Time Hazard Detection: Many traditional railway safety systems lack real-time monitoring capabilities, making it difficult to detect fires, obstacles, and hazardous gas leaks in a timely manner [8].
2. Inefficient Track Integrity Monitoring: Current railway track monitoring methods often rely on manual inspections or outdated sensor systems, leading to delays in detecting track failures that may cause derailments [9].
3. Inadequate Automation at Railway Crossings: Many unmanned level crossings remain unprotected, and existing automated doors have poor response times, increasing the risk of collisions between trains and vehicles [10].
4. Lack of Integrated IoT-Based Safety Solutions: Most railway safety approaches focus on isolated solutions (e.g., fire detection, track monitoring, or obstacle detection), but fail to provide a comprehensive, integrated IoT-based system for railway accident prevention [11].
5. Limited Remote Monitoring and Alerting: Some accident prevention systems lack remote connectivity, preventing railway authorities from receiving instant alerts and real-time data visualization [12].

Considering these challenges, there is an urgent need for an intelligent, IoT-based accident prevention system that integrates multi-sensor monitoring, real-time hazard detection, remote alerting, and automated railway door control. The motivation behind this work is to leverage IoT technologies to develop a real-time railway accident prevention and track proximity alert system capable of detecting fire hazards, track obstructions, gas leaks, and track failures, while providing automated responses and remote alerts.
The main objectives of this paper are:

- To design an IoT-based accident prevention system for railway safety.
- To integrate multiple sensors (flame, ultrasonic, gas, and metal proximity) for real-time hazard detection.
- To automate railway door operations using servo motors and train movement control via a motor driver.
- To develop a remote monitoring system using NodeMCU to transmit alerts to cloud platforms or mobile applications.
- To evaluate the system's effectiveness in enhancing railway safety, reducing accident risks, and improving operational reliability.
- This paper makes the following contributions:
- Proposes a multi-sensor-based railway accident prevention system incorporating flame, ultrasonic, gas, and metal proximity sensors.
- Implements an IoT-enabled real-time monitoring framework using NodeMCU for remote data transmission and alerts.

- Develops an automated railway door control mechanism integrated with train movement detection to prevent accidents at level crossings.
- Demonstrates the effectiveness of the system in detecting track hazards, enhancing railway safety, and reducing accident risks through real-time monitoring and automation.

The remainder of this paper is structured as follows: Section 2 presents a detailed literature review, highlighting prior research and their limitations. Section 3 describes the proposed system architecture, including hardware components, sensor integration, and IoT framework and discusses the implementation details and methodologies used. Section 4 presents the experimental setup, results, and performance evaluation. Section 5 provides conclusions and future research directions.

2 Related Works

The integration of Internet of Things (IoT) technology in railway systems have significantly enhanced safety, accident prevention, and operational efficiency. In addition to the above, several studies have examined automation, real-time communication and sensor-based monitoring to ensure safety in railways.

Vaidya et al., in their study on the role of the Internet of Things in smart city services (Vaidya et al. [1] concentrated on the applications of the technology in environmental monitoring, traffic management and surveillance, the same postulate can be extended to the railway safety systems.

Similarly, Dethe et al. [2] investidoord IoT-enabled Smart Railway Management Systems: Automatization, Remote monitoring, Real-time alerts for passenger comfort and safety

To emphasize the requirement of action-oriented preventive strategies, Shaikat [3] studied accident records of Dhaka Railway Division and analyzed the patterning and the most common causes of railway accidents there. Ali et al presented a sensor-based railway accident detection and prevention system. [4] who provided real-time mobile messaging of alarms in order to ensure timely response.

A number of sensor-based approaches have been investidoord to enhance the safety of railways. Arora & Nagarajan [5] developed an intelligent railway track monitoring system using Arduino and sensors to detect approaching trains and automatically operate the doors. On the same note, Patel & Patel [6] proposed an IOT (Internet of Things) based smart railway station system in order to handle parking and train detection. These techniques enhance safety-of-operations and significantly reduce the need for human involvement.

IoT-enabled smart waste management systems for smart city were investidoord Aniruddha & Sushil [7] and Bhavesh & Nirav [8]. Such systems can be adapted for train stations, to ensure cleaner environments and more pleasant travel experiences. Furthermore, Singh et al. [9] designed IoT-based smart parking systems to optimize traffic control and the allocation of parking spaces in the vicinity of railway properties.

A railway station system based on IoT, vehicle parking management and train detection was presented by Palanisamy and Srinivasan [10], aimed at improving efficiency of station operations. Carrying out an automated waste management system, Devi & Sumathi [11] developed a smart dustbin system based on Internet of Things, which can provide useful in railway scenarios.

While giving the overview of an analysis of accident records of Indian Railways over 6 years, Dubbudu [12] highlighted that the technology interventions such as automated alerts and real-time monitoring could reduce accidents, and had identified the potential areas for same to be applied. Sivasubramanian and Saravanakumar [13] also developed an automated train level crossing system with traffic signal control to decrease the number of accidents at railway crossings.

The studies under consideration evidently highlights the significance of sensor-based and the Internet of Things technologies in the enhancement of railway safety, process automation and passenger's experience. By implementing such systems, safer and more dependable railway travel can be achieved with proactive accident prevention, real-time danger alert, and efficient station management.

3 Proposed Method

The innovation proposed in this project will prevent and provide a alert to train tracks using IOT. And this work to prevent accident and notify the location to the trach workers who works in railway track to make it better safe in homing place. The device uses a flame sensor for fire hazards, an ultrasonic sensor to find obstacles by the tracks, a gas sensor to detect hazardous gas leaks, and a metal proximity sensor to determine track integrity. The sensors record data automatically and it is transmitted to an Arduino microcontroller for processing. The device further comprises an LCD for real time display, a buzzer for audible warning, a motor driver for movement control of the train based on the detected hazards. Furthermore, a servo motor is included to auto operate railway door which instruct passengers to avoid any accidents at Stations. For the purpose of remote monitoring and alerting, an IoT capability is added using a NodeMCU module, which can transmit data in real-time to a cloud platform, and/or to a smartphone. With this, railway authorities will get immediate alerts and will be able to act upon potential threats. The solution is engineered to be cost efficient, effective and scalable, and offers a complete safety solution for rail networks. With the sensor-based hazard detection, automation and IoT based remote monitoring, the proposed approach significantly enhances the railway safety, accident avoidance and system reliability. Fig 1 Shows the Architecture of the proposed method.

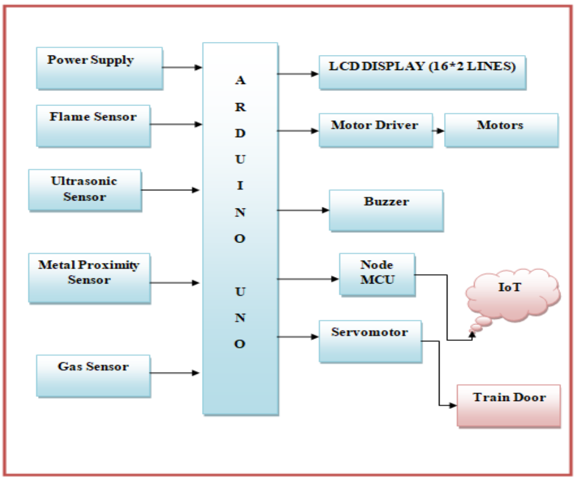

Fig.1. Architecture of the proposed method.

4 Methodology

The Accident Prevention and Track Proximity Alert System for Trains Using IoT follows a structured methodology to ensure real-time hazard detection, accident prevention, and automated responses. The methodology consists of several key stages, including system design, sensor integration, data processing, automation, and IoT-based monitoring.

4.1 System Architecture and Component Selection

The proposed system is built around an Arduino microcontroller that serves as the central processing unit, interfacing with various sensors and actuators. The key components include:
The hardware implementation of the proposed system consists of a flame sensor (Fig. 2 wherein an ultrasonic sensor (Fig. 3), a gas sensor (Fig. 4) with, and a metal approach sensor (Fig. 5) for sensing different environments. The system is further equipped with an LCD screen (Fig. 6) as a visual feedback and a buzzer (Fig. 7) for sound warning, and motor driver (Fig. 8) to direct moving mechanical parts. A servo motor (Fig. 9), added for fine/specific positioning and Node MCU (Fig. 10) operation and is provided as the processing and communication center.

a) Flame Sensor – Detects fire hazards along the railway track.

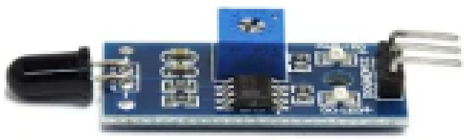

Fig. 2. Flame sensor (Photograph taken by the authors).

b) Ultrasonic Sensor – Identifies obstacles or objects near the track to prevent collisions.

Fig.3. Ultrasonic sensor (Photograph taken by the authors).

c) Gas Sensor – Monitors hazardous gas leaks in the railway environment.

Fig.4. Gas Sensor (Photograph taken by the authors).

d) Metal Proximity Sensor – Checks track integrity to detect potential structural failures.

Fig.5. Metal Proximity Sensor (Photograph taken by the authors).

e) LCD Display – Provides real-time status updates on detected hazards.

Fig.6. LCD Display (Photograph taken by the authors).

f) Buzzer – Generates audible alerts when an anomaly is detected.

Fig.7. Buzzer (Photograph taken by the authors).

g) Motor Driver – Controls train movement based on detected threats.

Fig.8. Motor Driver (Photograph taken by the authors).

h) Servo Motor – Automates railway door operations at stations.

Fig.9. Servo Motor (Photograph taken by the authors).

i) NodeMCU (ESP8266/ESP32) – Provides IoT connectivity for remote monitoring and alerting.

Fig.10. Node MCU (Photograph taken by the authors).

4.2 Sensor Networking and Data Collection

The in-situ sensors operate in steady-state conditions collecting data on all environmental parameters and activating alarms as necessary. The corresponding signal is read by an Arduino microcontroller, where the information is interpreted by the readings of the sensors and it defines whether an alert should be activated.

4.3 Risk Assessment and Automated Reaction

The flame sensor which senses fire causes the system to put the alert on and halts the running of train and inform the railway authorities. When the obstacle is detected by ultrasonic sensors then the train will automatically reduce speed or stop, a warning signal will be given. The gas sensor tracks air quality, and if the level of harmful gases surpasses a certain level, the device can send warnings to authorities. The metallic sensor scans for track continuity, it will give an immediate warning to prevent derailments from occurring. In the 4-B model, a servo motor opens and closes railway doors automatically in accordance with train location, which prevents crossing accidents.

4.4 Remote Alert and Monitoring System Using IoT

The NodeMCU board, meanwhile, sends the sensor readings and notifications to a cloud platform or to the user’s smartphone, which railway workers can then use to monitor the tracks in real-time. Text / message alerts are available for emergency alerts in the form of SMS or email.

4.5 System Implementation and Testing

Hardware Implementation and Testing For the implementation of the experimental data, the receivers are the USRP (Fig.11), the transmitter is a signal generator in a PC and antennas for micro-cells are Non-directional antennas are used.

The performance of the system is verified at different situations checking the ability of hazard detection, triggering of automated responses and real-time alerts. Performance metrics of accuracy, response time, unreliability studied to prove effectiveness of the system. It is expected that this approach will lead to a proactive safety in railway operational–maintenance activities in addressing the real-time hazard detection together with automation and remote monitoring based on IoT which will be able to reduce the accident rates significantly and to be able to enhancing the operational efficiency.

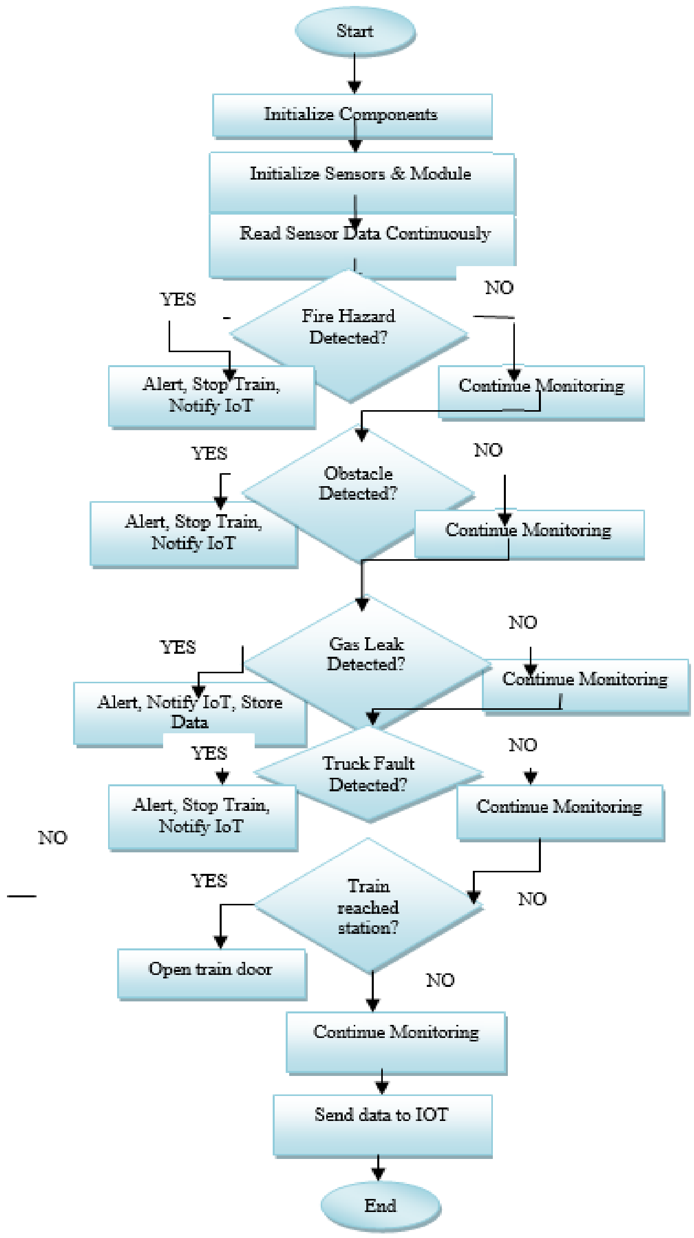

Fig. 11. Implementation Flow chart.

A. Algorithm

Step 1: System Initialization

1. Start the system and initialize the Arduino microcontroller.
2. Initialize all sensors, actuators, and communication modules (Flame Sensor, Ultrasonic Sensor, Gas Sensor, Metal Proximity Sensor, LCD Display, Buzzer, Motor Driver, Servo Motor, and NodeMCU).

Step 2: Continuous Sensor Monitoring

3. Continuously read data from the Flame Sensor, Ultrasonic Sensor, Gas Sensor, and Metal Proximity Sensor.
4. Store the sensor readings and process the data for analysis.

Step 3: Fire Hazard Detection

5. If the Flame Sensor detects a fire:
    - Trigger buzzer alert and display warning on the LCD.
    - Send an emergency alert to railway authorities via IoT.
    - Stop train movement using the Motor Driver.

Step 4: Obstacle Detection

6. If the Ultrasonic Sensor detects an object within a predefined distance:
    - Trigger buzzer alert and display warning on the LCD.
    - Reduce train speed or stop the train to prevent collisions.
    - Send real-time alert to railway monitoring personnel.

Step 5: Gas Leakage Detection

7. If the Gas Sensor detects hazardous gas levels above a threshold:
    - Trigger buzzer alert and display warning on the LCD.
    - Send an emergency alert to railway authorities via IoT.
    - Log the gas levels to the cloud for monitoring.

j) Step 6: Track Integrity Check

8. If the Metal Proximity Sensor detects a track break or misalignment:
    - Trigger buzzer alert and display warning on the LCD.
    - Send an immediate alert to railway maintenance teams.
    - Stop train movement to prevent derailments.

Step 7: Automated Railway Door Control

9. If a train approaches a level crossing:
    - Activate the Servo Motor to close the railway door.
    - If the train has passed, open the door automatically after a predefined time.

Step 8: IoT-Based Data Transmission

10. Transmit all sensor data and alerts to the cloud platform using the NodeMCU module.
11. Display real-time alerts on a mobile application or web dashboard for remote monitoring.

k) Step 9: System Loop and Continuous Monitoring

12. Repeat steps 3-11 continuously to ensure real-time safety monitoring and hazard detection.

Step 10: Emergency Handling and Manual Override

13. If an emergency override is activated:

- Allow manual control of the train and railway doors.
- Send override status to the monitoring system.

B. Implementation

- Start System – Initialize Arduino, sensors, LCD, buzzer, servo motor, motor driver, and NodeMCU.
- Sensor Data Acquisition – Continuously read values from Flame Sensor, Ultrasonic Sensor, Gas Sensor, and Metal Proximity Sensor.
- Fire Hazard Detection
- If fire is detected, trigger an alert, stop the train, and send IoT notifications.
- Obstacle Detection
- If an obstacle is detected, reduce speed or stop the train and send an alert.
- Gas Leakage Detection
- If gas levels exceed a threshold, trigger an alarm and send an alert.
- Track Integrity Check
- If track failure is detected, stop the train and send an alert.
- Automated Railway door Control
- IoT-Based Monitoring
- Transmit all alerts and sensor data to a cloud platform or mobile application.
- Loop and Continuous Monitoring
- Repeat the process for real-time accident prevention and system efficiency.
- End and resume continuous heart rate and location tracking.

5 Experimental Results

The experimental setup demonstrates the functionality of the Accident Prevention and Track Proximity Alert System for Trains Using IoT through various scenarios. The prototype model integrates multiple sensors, an Arduino microcontroller, an LCD display, and IoT-based monitoring for real-time hazard detection and prevention.

.

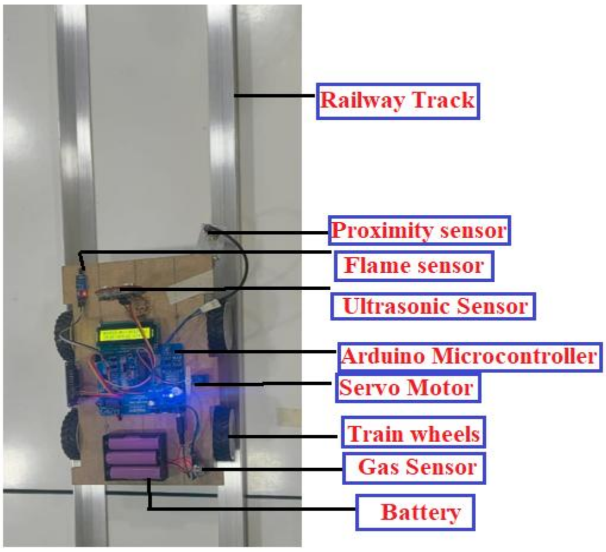

Fig. 12. Hardware prototype model.

Fig 12 represents the hardware implementation of the proposed system. It includes the Arduino microcontroller, sensors (Flame, Ultrasonic, Gas, Metal Proximity), an LCD display for status updates, a buzzer for alerts, a servo motor for railway gate automation, and a NodeMCU module for IoT connectivity. The prototype successfully simulates real-world railway scenarios

This Fig 13 shows that demonstrates the track integrity monitoring feature. When the metal proximity sensor detects a track crack or break, the system:

- Displays a warning message on the LCD.
- Stops the train automatically to prevent derailment.
- Sends an IoT alert to authorities

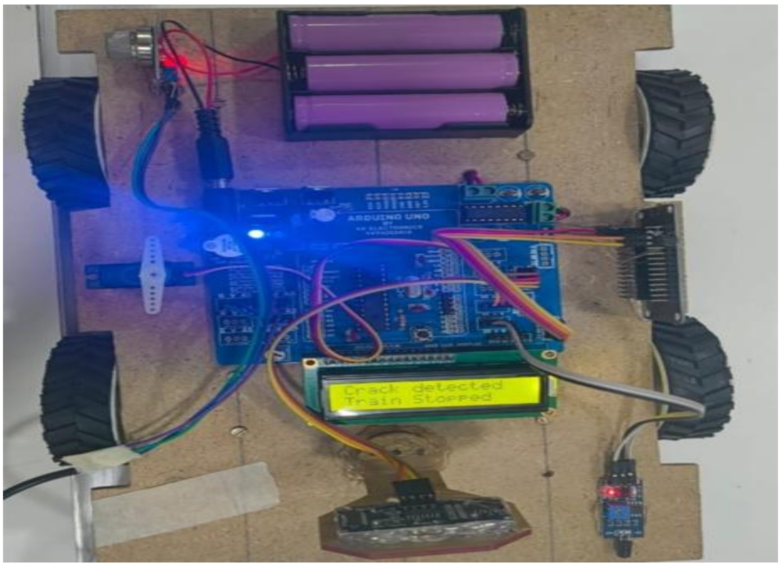

Fig. 13. LCD shows that train stopped when Crack Detected

The system's obstacle detection functionality is validated. When the ultrasonic sensor detects an obstacle within the set range:

- The LCD displays a warning message.
- The train is stopped automatically to prevent a collision.
- A buzzer alert is activated, and an IoT alert is sent.

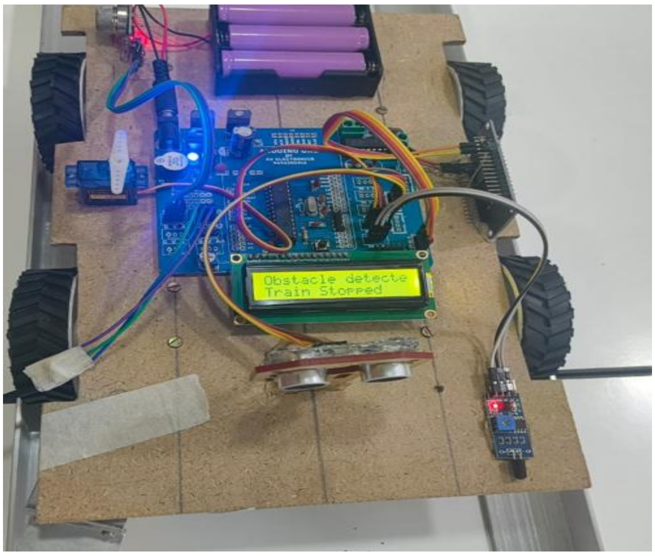

Fig. 14. LCD shows that train stopped when obstacle Detected.

Fig 14 shows LCD shows that train stopped when obstacle Detected To test fire hazard detection, the flame sensor is exposed to a flame source. The system responds as follows:

- The LCD displays a "Fire Detected" warning.
- The train halts immediately for safety.
- An alert is sent to railway personnel via the IoT module.

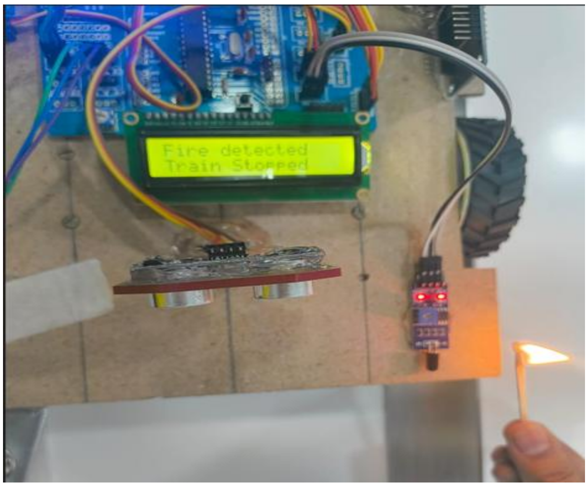

Fig. 15. LCD shows that train stopped when Fire Detected.

Fig 15 shows LCD shows that train stopped when Fire Detected and Fig 16 shows that the train stopped when Gas Detected. The system's ability to monitor air quality is evaluated using the gas sensor. When toxic or flammable gas is detected:

- The LCD displays a warning message.
- The train stops automatically to prevent exposure risks.
- An IoT alert is sent, allowing remote monitoring.

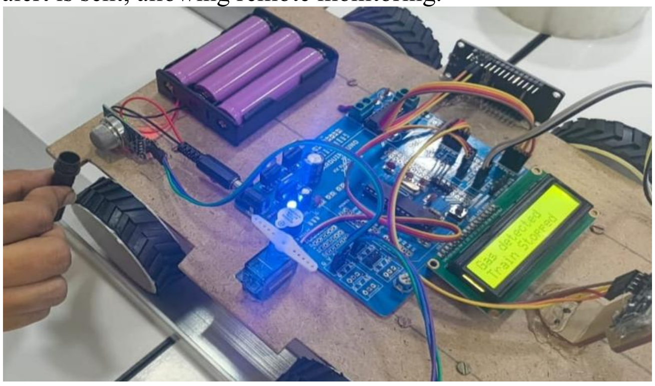

Fig. 16. LCD shows that train stopped when Gas Detected.

This Fig 17 showcases the real-time monitoring capabilities of the system. The IoT dashboard displays live sensor data, including:

- Track integrity status
- Obstacle detection status
- Fire hazard and gas level readings
- Train status (Running/Stopped)
- Historical logs for analysis and decision-making

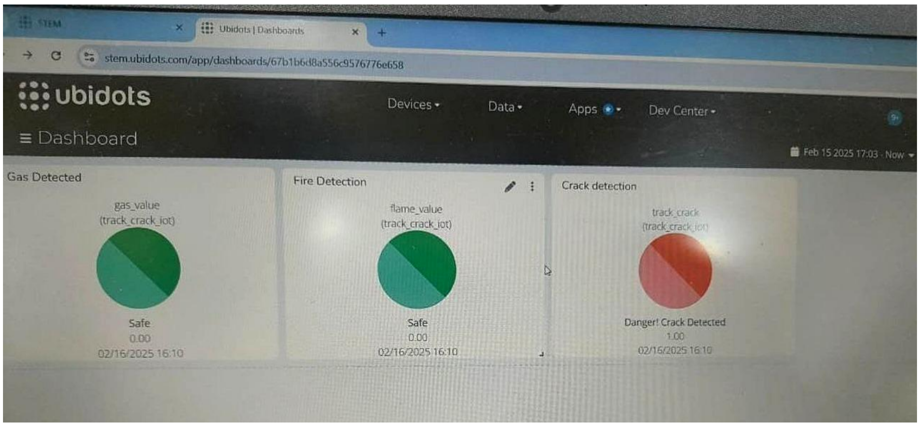

Fig. 17. Data Visualizationin in IOT Dashboard.

This Fig 18 highlights the automated alert system. When a hazard is detected, the NodeMCU module sends an email notification to predefined railway personnel. The alerts include:

- Type of detected hazard (Crack, Obstacle, Fire, Gas)
- Time and location of the incident
- Recommended action for response

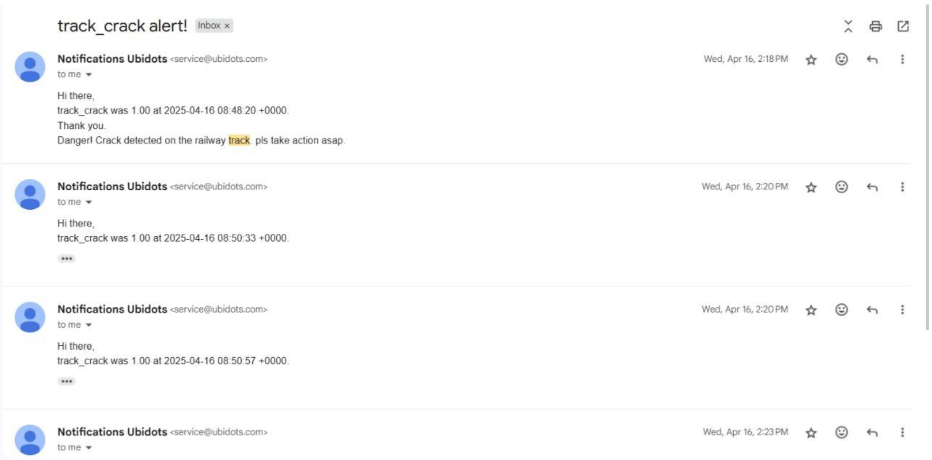

Fig. 18. Received Mail Alerts from IoT.

6 Conclusion and Future Scope

The Accident Prevention and Track Proximity Alert System for Trains Using IoT successfully integrates sensor-based hazard detection, automated response mechanisms, and IoT-based real-time monitoring to enhance railway safety. The hardware prototype and experimental results demonstrate that the system effectively detects fire hazards, obstacles, track cracks, and gas leaks, preventing potential accidents by automatically stopping the train and alerting railway authorities. The LCD display, buzzer alerts, and IoT-enabled notifications ensure immediate response and intervention. Furthermore, the automated railway gate control mechanism improves safety at Stations by preventing unauthorized access. By leveraging IoT technology, this system enhances real-time monitoring, data visualization, and remote access, ensuring timely decision-making for railway operators. The successful implementation of this model shows the potential for reducing railway accidents, improving passenger and railway infrastructure safety, and increasing the operational efficiency of train systems. Although the proposed system demonstrates significant improvements in railway safety, further enhancements can be explored. Integration with GPS and AI for Predictive AnalyticsImplementing GPS tracking and AI-driven predictive analytics can help identify high-risk zones and suggest preventive measures before an accident occurs.

References

[1] Ankita Jadhav, Pallavi Bhangre , Snehal Gaikwad, Amol Deshpande " Railway Track Security System",” International Journal of Engineering Research & Technology”, March 2015.

[2] Ali, M. R., Rehman, O. S., Ullah, F., & Ahmed, S. (2023). "Sensor-Based Smart Railway Accident Detection and Prevention System for Smart Cities Using Real-Time Mobile Communication." Springer.

[3] Chellaswamy C, Balaji L, Vanathi A, Saravanan L " IoT Based Rail Track Health Monitoring and Information System", 2017.

[4] Aniruddha, B. S., & Sushil, U. K. (2016). "Smart Garbage Monitoring System Using IoT." IEEE.

[5] Dewangan R., Pratibhadevi U. (2016). "Automatic Accident Control System on Railway Tracks, IJARECE.

[6] Narayan A., C C., P N. (2020). Prevention of Railway Accidents by Automatic Gate Control and Fire Detection using IoT, IJERT.Devi, P. V., & Sumathi, V. (2021). "Design and Implementation of Smart Dustbin System Using IoT." Springer.

[7] Dubbudu, R. (2016). "Accidents in Indian Railways – Review of the Last 6 Years." Factly.

[8] Sivasubramanian, T., & Saravanakumar, R. (2011). "Automated Train Level Crossing with Traffic Signal Control." IEEE.

[9] Zhang Jie1, Shao Liping, "Railway Safety Monitoring Architecture Based on Internet of Things","Journal of Logistics, Informatics and Service Science", 2014.

[10] Fatima Imdad, Muhammad Tabish Niaz and Hyung Seok Kim, "Railway Track Structural Health 2015Monitoring System"," International Conference on Control, Automation and Systems",2015.

[11] Dudley, S., Siddiqui, H. U. R., & Raza, M. A. (2022). "IoT Based Railway Track Faults Detection & Localization Using Acoustic Analysis." IEEE.

[12] N S., Hasane A. (2013). Prevention of train accidents using wireless sensor networks, IJERA

[13] T T., R M., R S., M V. (2020). Obstacle Detection In Railway Track Using IOT, IJCRT

[14] Narayan A., C C., P N. (2020). Prevention of Railway Accidents by Automatic Gate Control and Fire Detection using IoT, IJERT.

[15] N. A., R N., S S., R P. (2017). Implementation of Railway Track Crack Detection and Protection, IJECS.