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Rail Safe-Tech: An Automatic Safety System

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Abstract: The paper presents a novel automated railway safety system designed to improve passenger safety by quickly identifying situations involving fire and smoke. Using sensors and microcontrollers, the system quickly detects possible threats and initiates emergency brakes and sirens. The system strengthens railway security measures by integrating communication modules and modern electrical circuits. Through proactive risk management and fast reaction capabilities, this system seeks to dramatically lower accident rates, protecting both railway infrastructure and people.
Keywords: Railway safety, sensors, passenger safety, rapid response, accident prevention

I. INTRODUCTION

Train travel is well-known for its comfort and efficiency, but ensuring safety inside railway networks remains critical, particularly in heavily populated areas like India. The Indian Railways, with its large network, has several safety concerns, including fire incidents and ageing infrastructure. To address these issues, there is an increased interest in using IoT technology to automate safety activities. This study presents an Internet of Things-based approach that uses infrared sensors to detect collisions and automate railway barrier functioning. This study attempts to improve railway safety through creative technical developments by investigating the historical background and particular problems encountered by Indian Railways.

II. LITERATURE REVIEW

The subject of railway safety, particularly unmanned level crossings, has received substantial attention from railway authorities across the world. In India, the Indian Railways has launched a comprehensive action plan to abolish more than 6,000 unmanned level crossings over the next three or four years. With 28,607 level crossings across the country, including 9,340 unattended crossings, the railroads are prioritising the eradication of unmanned level crossings on the wide gauge network, which accounts for the bulk of incidents [1].To address the safety issues raised by unmanned level crossings, a variety of inventive solutions have been developed and implemented. The Research Designs and Standards Organisation (RDSO) developed a vandal-proof warning system, which was successfully implemented on the Coimbatore-Metupallayam segment. This technology seeks to avoid accidents by sending timely alerts to drivers approaching unmanned level crossings [2].

Automatic railway gate operating systems have evolved as a viable method for increasing safety at level crossings. These systems use sensors to detect train arrivals and automate the functioning of railway gates, shortening the time the gates are closed and lowering the chance of an accident. These systems use microcontrollers and infrared sensors to assure accurate and dependable gate operation, reducing the risk of human mistake [3, 6, 7, 9].Furthermore, attempts have been made to improve railway safety by automating other key procedures, such as track switching systems. These systems use infrared sensors and reed switches to automate the management of railway gates and track switching, lowering the danger of accidents caused by manual operation mistakes [7, 13].

Furthermore, technological improvements like as wireless communication protocols and GSM methods have been incorporated into railway safety systems to increase efficiency and efficacy. These technologies offer real-time communication between railway infrastructure and control centres, allowing for faster responses to safety events and reducing the probability of accidents [8, 10].Overall, the literature emphasises the significance of deploying creative and automated methods to improve railway safety, especially at unmanned level crossings. Railway officials want to achieve their goal of reducing accidents and safeguarding the safety of passengers and drivers by utilising technology and implementing cost-effective and dependable safety systems.

III. METHODOLOGY

A. Existing System

To maintain safe and effective train operations, existing railway systems combine manual operation with modest automation. These systems generally include:

1) *Manual Operation with Human Oversight:* In conventional railway operations, human operators such as train drivers, station masters, and signal operators are largely responsible for train movement and control. Human supervision is essential for monitoring track conditions, coordinating train movements, and assuring compliance with safety regulations.
2) *Fixed Signalling Systems:* Railway signalling systems, such as semaphore and colour light signals, are used to warn train drivers of track conditions, speed limitations, and potential dangers. These permanent signalling systems are critical for maintaining safe train lengths and avoiding crashes.
3) *Trackside Monitoring Devices:* Various trackside monitoring devices, like as track circuits and axle counters, are used along railway tracks to detect the activity of trains, monitor their movements, and guarantee safe spacing between them. These devices give critical information to signal operators and train drivers, ensuring safe and efficient rail operations.
4) *Centralised Control Centre:* Centralised control centres monitor and manage railway operations throughout a network of tracks and stations. These control centres employ communication and monitoring devices to track train movements, react to emergencies, and coordinate maintenance tasks.
5) *Safety Protocols and Rules:* Railway authorities enforce strict safety protocols and rules to ensure train safety and the protection of passengers, crew, and infrastructure. These protocols address many areas of railway operations, such as train speed limitations, signalling processes, and emergency response protocols.

While these current systems have been effective in guaranteeing the safety and dependability of railway operations, they do have limitations and problems, particularly in terms of obtaining complete autonomy. The manual nature of operation, reliance on fixed signalling systems, and limited automation capabilities impede the smooth integration of new technology essential for autonomous train operations. To overcome these problems and realise the goal of completely autonomous transportation, considerable advances in railway technology are required.

B. Proposed System

The proposed system seeks to improve train safety by establishing an Automatic Train Safety System, with a special emphasis on avoiding and minimising fire events on trains. This system combines modern sensors, control mechanisms, and actuator/notification subsystems to detect, respond to, and handle fire crises effectively.

The following is an overview of the suggested system:

1) *Fire Detection and Prevention:* The Automatic Train Safety System has advanced sensors that can identify fire issues quickly. These sensors are strategically placed throughout the train, including the Guard-cum-Brake Van, air-conditioned coaches, and pantry cars. Temperature sensors are used to detect anomalous temperature spikes, which might indicate a potential fire outbreak. When a fire is detected, the system immediately takes action to prevent the fire from spreading and escalating further.
2) *Control Subsystem:* The Automatic Train Safety System is controlled from the train's main engine. An ESP8266 WIFI controller is used to control all peripheral devices and subsystems in the system. This controller enables communication and coordination among numerous components, such as the buzzer, DC motor, sensors, and IOT display. Furthermore, the control subsystem permits remote monitoring and control of the train's operation, allowing operators to respond quickly in the event of an emergency.
3) *Actuator:* In the case of fire detection, the actuator/notification subsystem is engaged to carry out the relevant reaction activities. A buzzer is used to sound an alarm, informing passengers and crew members of the emergency situation. Simultaneously, the rover mechanism, which consists of DC motors, is activated to move the train forward, backward, or in other essential directions to guarantee safety and expedite evacuation processes. An IOT display in the operator's cabin delivers real-time updates and directions on how to efficiently manage an emergency.
4) *Classification and Model Identification:* The proposed method follows standardised classification and model identification principles for locomotives. This comprises a categorization system that takes into account track gauge, motive power, function, power, and model number. Furthermore, modern locomotives are classed according to horsepower range, which is represented by letters in the classification code.

Overall, the proposed Automatic Train Safety System provides a comprehensive solution for improving fire safety on trains. The system seeks to reduce the danger of fire accidents, protect passengers and crew members, and assure train safety via the use of sophisticated technology and methodical design implementation.

IV. CIRCUIT DIAGRAM AND WORKING

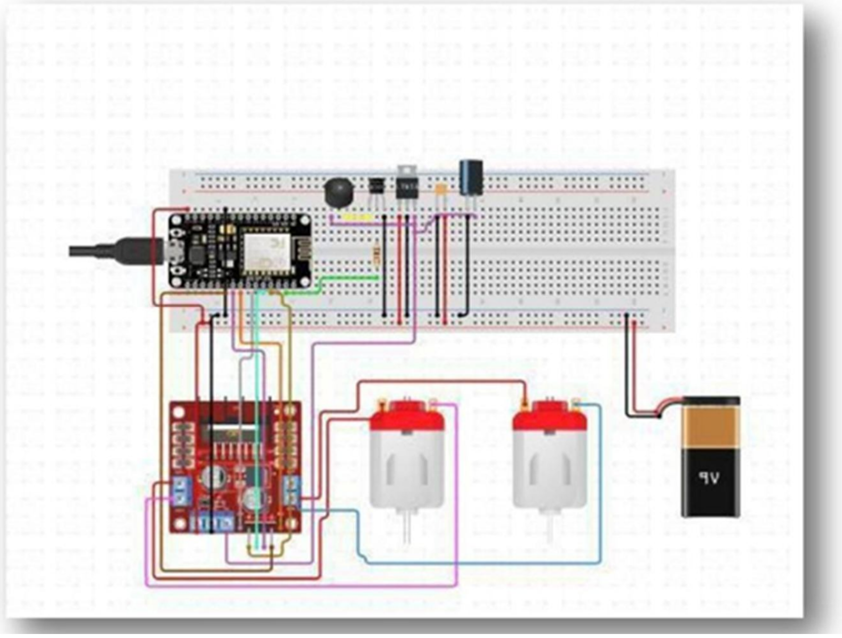

Figure1. Circuit Diagram of main engine

The proposed Automatic Train Safety System includes a circuit diagram with components such as the ESP8266 WIFI controller, DC motors, temperature sensor, buzzer, relay module, water pump, and power supply. The technology is designed to properly identify and respond to train fire occurrences.

A. Parts Employed

1) *The ESP8266 Wi-Fi Controller:* Serves as the main control unit, interpreting orders and directing signals to various parts in accordance with preprogramed guidelines.
2) *DC Motors:* These power plants move the train forward, backward, or in any other direction that is necessary.
3) *Temperature Sensor (LM35):* This device senses unusual temperature increases and flags possible fire breakouts.
4) *Buzzer:* Alerts passengers and crew members in the event of a fire by sounding an alarm. Relay Module: Utilising signals from the ESP8266 controller, this module regulates the water pump and electromagnet.
5) *Water Pump:* Upon detecting a fire, this device sprays water to put it out. In the event of a fire, an electromagnet is used in place of a servo motor to separate the malfunctioning boggy from the train.
6) The power supply supplies the voltage required to run the entire system.

B. Working

1) *Fire Detection:* The train's interior temperature is continually monitored by the LM35 temperature sensor. The sensor alerts the ESP8266 controller in the event that the temperature increases unusually, signalling the possibility of a fire.
2) *Alarm Activation:* The ESP8266 controller sounds an alarm to notify passengers and crew members of the fire emergency after receiving a signal from the temperature sensor.
3) *Emergency Response:* The water pump is activated to start spraying water to put out the fire when the ESP8266 controller simultaneously initiates the relay module.
4) *Boggy Detachment:* To separate the malfunctioning boggy from the train, a magnetic that is positioned carefully receives a signal from the ESP8266 controller in simultaneously. By taking this move, passenger safety is guaranteed and the fire is kept from spreading to other areas of the train.
5) *Notification:* The system may also be configured to notify railway authorities via SMS or email, including the location, train number, and details of the fire occurrence, so that prompt action can be taken.

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V. FLOW CHART

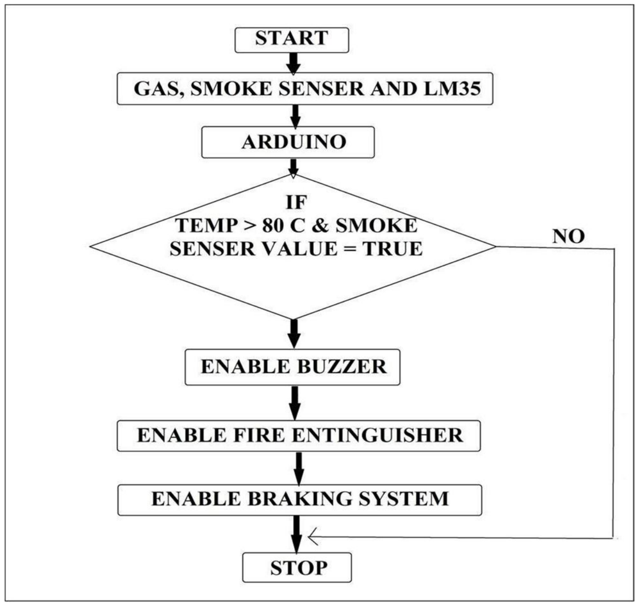

Figure1. Flow Chart

1) *Start:* Sensors (temperature, humidity, smoke, and smoke) detect fire or smoke. Data is gathered and sent to an Arduino microcontroller.
2) *LM35, GAS, and Smoke Sensor:* Fire smoke is measured and data is sensed by sensors (DHT11 temperature sensor, Humidity sensor, MQ135 smoke sensor, LM35).Digital signals are sent to an Arduino or ESP8266 microcontroller.
3) *Arduino:* A PCB with the ESP8266 Wi-Fi Controller attached. Unusual temperature is detected by the temperature sensor. Temperature threshold determines how a relay functions. A command was issued to the fire extinguisher and buzzer.
4) *Turn on Buzzer:* An Arduino signal was received to turn on the buzzer. To warn passengers and crew members, a buzzer blasts an alarm
5) *Fire Extinguisher Activation:* Water pouring started as planned by the ESP8266 controller upon fire detection. Every buggy has a can of fire extinguishers accessible for use in an emergency
6) *Turn on The Brake System:* Braking mechanism activated in high-stress circumstances. The rover mechanism prevents bogies from colliding with one another while gently regulating the train.
7) *End:* After execution, the train is told to halt gradually. Procedures for evacuation were started to guarantee passenger safety and prevent casualties.

VI. RESULTS

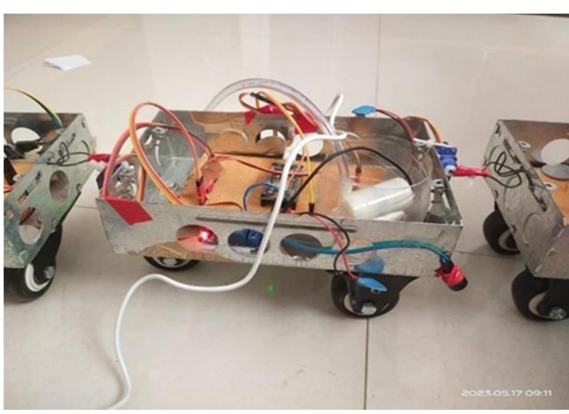

Figure 2. Boggy

Figure 3. Live Image

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The autonomous train safety system combines hardware and software components to provide a timely and effective reaction to situations. When a fire starts aboard, sensors detect the temperature difference and initiate a sequence of steps. The relay circuit triggers the water pump to extinguish the fire while also triggering a buzzer to inform passengers and crew members. Additionally, an SMS is automatically sent to railway officials informing them of the situation. Crucially, the technology uses servo motors controlled by an IoT software interface, such as Thingspeak, which allows operators to securely detach the damaged bogie from the train. The software interface allows operators to monitor environmental parameters in real time, including temperature, humidity, and gas levels, which improves situational awareness.

The easy interface allows operators to execute orders quickly and precisely, providing prompt reactions to crises. Overall, the combination of physical sensors with IoT software improves operating efficiency, allowing for pre-emptive steps to protect passengers and crew during crises.

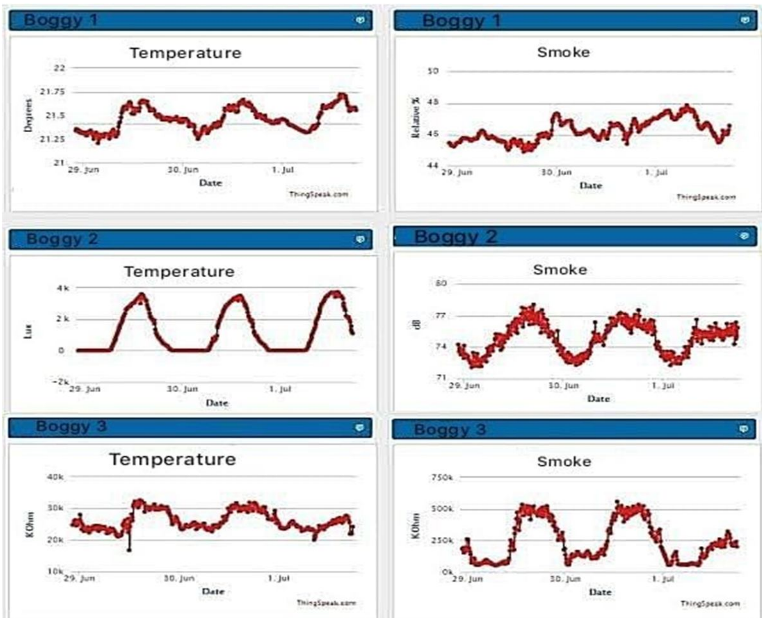

Figure 4. Result

VII. ADVANTAGES

1) *Fast and Efficient Response:* The system starts automatically within minutes of a fire outbreak, quickly suppressing flames and limiting smoke generation, increasing survival chances and decreasing building damage.
2) *Occupied Area Safety:* Safe for use in inhabited environments, assuring human safety while efficiently mitigating fire risks.
3) *Cost Efficiency:* Despite the high initial expenditures, the system provides long-term cost benefits due to minimal maintenance needs and lower material use.
4) *Manpower Saving:* Requires minimum human interaction, resulting in labour savings while also giving a manual override option for emergencies.
5) *Enhanced Asset Availability:* Offers immediate, on-site protection, minimising breakdown time and increasing asset availability and dependability.
6) *Reduced Downtime:* Prompt action in suppressing combustion reduces downtime and operational disturbances, allowing for speedier recovery and business continuity.
7) *Versatility:* Adaptable to a variety of situations and industries, providing comprehensive fire prevention solutions adapted to unique requirements.
8) *Compliance and Risk Mitigation:* Helps to ensure that regulatory standards and insurance requirements are met, reducing the risks and liabilities connected with fires.
9) *Scalability:* The customisable architecture enables for scalability to accommodate various facility layouts and fire risk profiles.
10) *Integration:* Works seamlessly with current fire detection and alarm systems, improving the entire fire safety infrastructure.
11) *Environmental Friendliness:* The operation is ecologically friendly, with no hazardous emissions or by-products, which align with sustainability goals.

VIII. FUTURE EXTENSION

In the future, the project might be upgraded in a variety of ways to improve its capabilities and meet new difficulties. Integrating modern sensor technologies, such as infrared cameras and gas sensors, may increase the system's capacity to detect fire and smoke at an early stage, allowing for shorter response times. Furthermore, artificial intelligence (AI) and machine learning algorithms might allow the system to analyse real-time data, forecast fire breakouts, and improve performance based on previous trends. Remote monitoring and control capabilities might be built, allowing operators to get warnings, view system status, and take action from any location via a mobile application or web-based platform. Furthermore, research into autonomous fire fighting drones equipped with fire suppression chemicals might enable speedy reaction in remote places. Energy-saving solutions and integration with smart building systems might also be investigated to reduce environmental effect while increasing overall safety and efficiency. Predictive analytics models could identify fire risk factors and proactively implement preventive measures, whereas advanced communication protocols could enable real-time data exchange and increase system reliability. Designing the system with a modular and scalable design would enable adaptation to future updates and integration with emerging technologies, while collaboration with emergency services might boost coordination and response efforts during fire emergencies.

IX. CONCLUSION

To summarise, the Automatic Train Safety System shown here represents a substantial leap in railway safety technology. By combining numerous sensors, microcontrollers, and actuators, the system can detect and respond to fire crises quickly and efficiently. The technology, which combines temperature sensors, relay circuits, water pumps, and servo motors, can reduce the effect of train fires, protecting passengers and railway infrastructure. The use of IoT technology expands the system's capabilities by giving operators with real-time monitoring and control functions. With its capacity to detect risks early, operate autonomously, and minimise damage, this technology has enormous potential for enhancing railway safety and minimising accidents. As technology advances, further additions and upgrades may increase the system's efficacy, assuring continuing progress in railway safety and passenger protection.

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