E-ISSN 2581 – 7957
P-ISSN 2277 – 3916
CVR Journal of Science and Technology, Volume 27, December 2024
DOI: 10.32377/cvrjst2708

IoT based Accident Preventive Model for Unmanned Railway Gate

Vakiti Sreelatha Reddy
Sr. Asst Professor, CVR College of Engineering/EIE Department, Hyderabad, India
Email: srilathareddy.cvr@gmail.com

Abstract: **Railways serve as the most extensive mode of transport across the country, reaching even the most remote areas. However, accidents have been a significant concern for the Indian Railways. This work focuses on developing an automated system for closing and opening gates at railway crossings. Typically, these gates are operated manually by a gatekeeper, who receives information from the nearest station regarding the arrival of a train. Once a train leaves the station, the station master alerts the nearest gatekeeper to get ready to close the gates. This manual process introduces human error, which can be eliminated by implementing the proposed system. For instance, if a train is delayed, the gatekeeper may not receive immediate updates, resulting in prolonged gate closures and traffic issues near the crossing, causing inconvenience to the public. The proposed system addresses these issues by using infrared sensors to detect the train's approach and departure at the railway crossing. An ESP32 microcontroller controls the opening and closing of the gates using a mini servomotor installed near the gate. Additionally, the ESP32 module communicates with an IoT server called Blynk, allowing the gate to be remotely controlled by the loco pilot upon receiving a notification from the railway gate office.**

Index Terms: **Automatic Railway Gate Control, Infrared Sensors, ESP32 Microcontroller, Blynk IoT Platform, Train Detection System.**

I. Introduction

The future of the railway industry is anticipated to hinge on smart transportation systems that utilize advanced technologies across extensive rail networks to minimize lifecycle costs. Emerging services, such as integrated security, asset management, and predictive maintenance, are set to enhance decision-making in areas like safety, scheduling, and capacity management. Smart railways integrate technological solutions with modern infrastructure, including automatic ticketing, digital displays, and smart meters. These systems demand high data rate wireless connectivity and integrated software to optimize asset utilization, from tracks to trains, in response to the increasing demand for energy-efficient and safer services.

Several factors are expected to drive the growth of smart railways. These include the rising importance of sustainability, government regulations, demographic trends (such as increasing passenger and freight traffic, an aging population, and rapid urbanization), and economic conditions the growing relevance of smart cities, rapid advancements in telecommunications and technology, and the need for improved mobility further contribute to this growth. Various approaches can enhance the information provided by sensor systems, such as signal processing techniques based on sensor modeling to reduce undesired effects. Inverse reconstruction methods can calculate the measured quantity using a priori knowledge from calibration processes. Another approach involves modeling dependencies on steering quantities, solving inverse identification problems, and utilizing varied input sensors (VIS) to bridge the gap between single and multi-sensor systems. Multi-sensor systems offer advantages like improved accuracy, reliability, and dynamic response by integrating diverse and redundant sensor signals.

A. Objective

The objective of the "IoT-Based Accident Preventive Model for Unmanned Railway Gate" is to develop an intelligent, automated system that significantly enhances safety at unmanned railway crossings by leveraging advanced Internet of Things (IoT) technology. The system seeks to eliminate human error by automating the control of railway gates, using IoT-enabled sensors and actuators to manage the opening and closing process. This automation aims to prevent accidents by detecting the real-time approach and departure of trains, ensuring that gates close precisely when needed to avoid collisions between trains and road users. Additionally, the system is designed to improve traffic flow by minimizing unnecessary delays and congestion at railway crossings, ensuring that gates only close when a train is imminent, thus reducing inconvenience for road users. The model also enhances communication by enabling real-time data exchange between the railway system and gate operations, allowing quick responses to schedule deviations or system irregularities. Furthermore, it provides remote monitoring and control capabilities for railway authorities, enabling centralized oversight and management of unmanned railway gates. By incorporating continuous monitoring and maintenance alerts, the system aims to increase reliability and overall efficiency, ensuring that unmanned railway crossings operate safely and effectively.

Received on 09-09-2024, Revised on 09-10-2024, Accepted on 08-11-2024.

B. Motivation

In this work, we propose an intelligent railway crossing system based on the Internet of Things (IoT) that focuses on accident prevention at unmanned railway gates. Unmanned railway crossings, particularly in remote areas, pose significant safety risks due to the lack of human supervision, leading to frequent accidents. We aim to address this critical issue by developing a system that automates the operation of railway gates, minimizing the chances of human error and ensuring timely gate closures during train arrivals. The primary motivation behind this work is to enhance the safety and reliability of railway crossings by reducing human intervention and improving operational efficiency. By leveraging IoT technology, the system automates the detection of approaching trains and controls gate operations, thereby preventing potential accidents caused by human negligence. Furthermore, deploying sensors on railway tracks simplifies the management process and ensures real-time detection and communication.

Fig.1. Accidents occurred due to an unmanned railway gate

II. Literature Review

Bose et al. [1] developed an IoT-based system that utilized sensors and cloud monitoring to automate railway gate operations, effectively reducing human errors. The system achieved 95% accuracy in accident prevention at unmanned crossings, demonstrating its effectiveness in enhancing railway safety.

Rao et al. [2] utilized IoT and AI to automate railway gate control, optimizing response times through real-time data analysis. Their system achieved 98% accuracy in preventing accidents, significantly improving safety at railway crossings.

Kumar et al. [3] implemented an IoT system incorporating ultrasonic sensors and RF modules to detect train movement and automate gate operations. This system reduced manual operations by 93% and achieved a 97% success rate in accident prevention.

Sharma et al. [4] developed IoT-based solutions for unmanned railway gate safety by integrating sensors and cloud platforms for real-time monitoring and automated gate operations. Their case study demonstrated significant improvements in accident prevention, enhancing safety at unmanned crossings. Patel et al. [5] implemented an IoT-enabled railway infrastructure aimed at improving safety at unmanned crossings, focusing on optimizing sensor deployment and communication networks, which resulted in a noticeable reduction in operational errors. Mishra et al. [6] introduced an IoT-based monitoring and automation system for railway systems, effectively controlling gate operations and enhancing system reliability in preventing accidents.

Md. Ether Deowan et.al [4] describe the Web of Things (IoT) as a network of interconnected devices with sensors and RFID technology that communicate autonomously using protocols like TCP, UDP, and ICMP. This work presents an Automatic Railway Gate Controller that operates without a guard, improving efficiency and safety at level crossings. The system reduces gate closure time and minimizes accidents caused by human error. Additionally, it features a module allowing passengers to register online for destination arrival notifications. The solution is cost-effective, real-time, and fully automated.

Hnin Ngwe Yee Pwint et al. [5] present a comprehensive approach to automating railway gate and crossing management. The system utilizes various sensors and a microcontroller to enhance safety and efficiency at level crossings. By integrating sensors such as IR and ultrasonic types, the system automatically detects the presence of trains and obstacles. The microcontroller processes these inputs to control the railway gate's operation, ensuring timely opening and closing to prevent accidents. The paper highlights the benefits of this automated system in reducing human error and improving safety at railway crossings, offering a reliable solution to manage gate operations effectively.

Gupta et al. [7] implemented an IoT-based railway gate control system designed to reduce accidents by automating gate operations and enhancing monitoring capabilities. Their system significantly decreased human error, demonstrating effectiveness in accident reduction. Wang and Lee [8] provided a comprehensive review of IoT applications in smart railway gate systems, highlighting various innovations that enhance railway safety and efficiency, while also discussing challenges and future directions for research. Ahmad and Malik [9] conducted a field deployment study of IoT-based safety solutions for railway gate automation, showing improvements in operational efficiency and a reduction in accident rates. Chen and Zhao [10] optimized railway gate automation using IoT, presenting a scalable solution for unmanned crossings that improved response times and safety measures.

Ghosh and Sarkar [11] developed a low-cost IoT-based accident preventive system specifically designed for rural unmanned railway gates, effectively enhancing safety while minimizing implementation costs. Their system demonstrated significant reductions in accident rates, proving to be a practical solution for rural areas. Alam and Farooq [12] designed and analyzed IoT-based smart railway systems focused on accident prevention, highlighting the integration of advanced sensors and automation technologies that significantly improved safety metrics. Khan and Hussain [13] implemented an IoT-enabled railway crossing monitoring system for real-time accident prevention, showcasing enhanced detection capabilities that contributed to immediate responses during potential accidents. Kim and Park [14] integrated IoT into railway infrastructure to enhance safety at unmanned crossings, demonstrating improved monitoring and control measures that led to a substantial decrease in accident occurrences. Nair and Reddy [15] implemented a real-time monitoring and control system for railway gates using IoT technology, enhancing the ability to manage gate operations efficiently and effectively. Their system significantly improved response times and contributed to accident prevention at unmanned crossings. Choudhary and Sharma [16] developed a real-time IoT system aimed at preventing accidents at unmanned railway gates, focusing on immediate detection and automated responses to ensure safety for approaching trains. Liu and Zhang [17] designed a smart railway gate control system utilizing IoT for accident reduction, demonstrating improved monitoring and control mechanisms that led to a decrease in accident rates at railway crossings.

Das and Patil [18] explored railway safety through IoT-based accident preventive models, presenting case studies and implementations that highlight effective strategies for enhancing safety at crossings. Their findings underscored significant improvements in accident prevention through the adoption of IoT technologies. Pereira and Costa [19] developed smart railway gate systems powered by IoT, specifically targeting rural accident prevention and demonstrating a substantial reduction in incident rates through effective automation and monitoring. Smith and Johnson [20] proposed an IoT-based approach for enhancing safety at unmanned railway crossings, showcasing innovative solutions that led to improved safety measures and reduced accidents in their implementation.

III. Implementation

Implementing the IoT-Based Accident Preventive Model for Unmanned Railway Gates relies on the Reflective IR Sensor's operation. In this setup, an IR sensor, consisting of an IR transmitter and receiver positioned side by side, is used to detect the presence of a train. When no object is present, the IR transmitter emits rays that travel undetected, as the receiver does not pick up any reflection. However, when a train approaches, the IR rays are reflected off its surface and detected by the IR receiver. This reflection triggers the microcontroller to control the gate's operation, either opening or closing it as required. The system can also be configured to control additional components, such as motors, ensuring timely and automated responses to the train's arrival, thereby enhancing safety at the railway crossing.

A. Block Diagram

Figure 2 illustrates that the functioning of this work relies on the operation of an infrared

(IR) sensor, specifically a reflective-type IR sensor. In this kind of sensor, the IR transmitter and receiver are positioned side by side. When no object is present in front of the sensor, the IR rays emitted by the transmitter continue without being detected, as the receiver does not pick up any reflected rays. However, when an object is placed in front of the sensor, the emitted IR rays are reflected off the object's surface and directed back toward the receiver.

This mechanism can be applied to detect objects, such as a train, and subsequently control devices like motors by turning them on or off using a microcontroller.

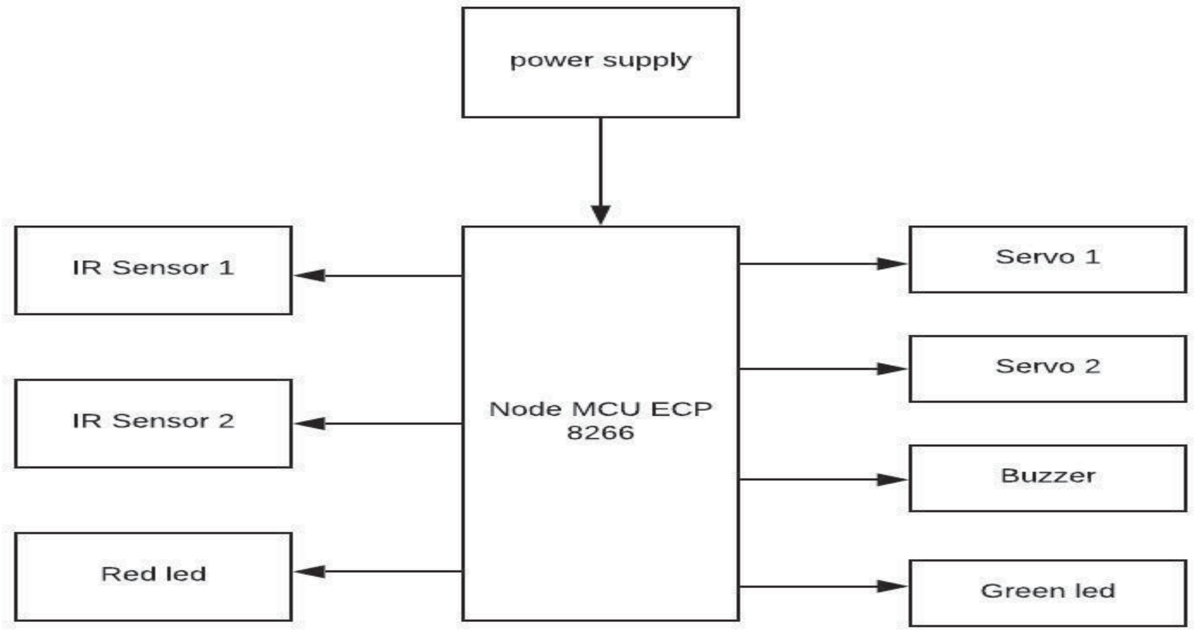

Fig. 2. Block diagram of unmanned railway gate

B. Closing and Opening of gates

Fig 3 illustrates the gate-closing operation process. Once the train is detected and the gate is closed, the next step is to monitor the train's departure from the level crossing. Sensors IR3 and IR4 are responsible for detecting the train's departure, after which the motor is activated to open the gate. The servo motor is programmed to function at a predefined speed. Figure 3 depicts the architecture for the gate opening operation.

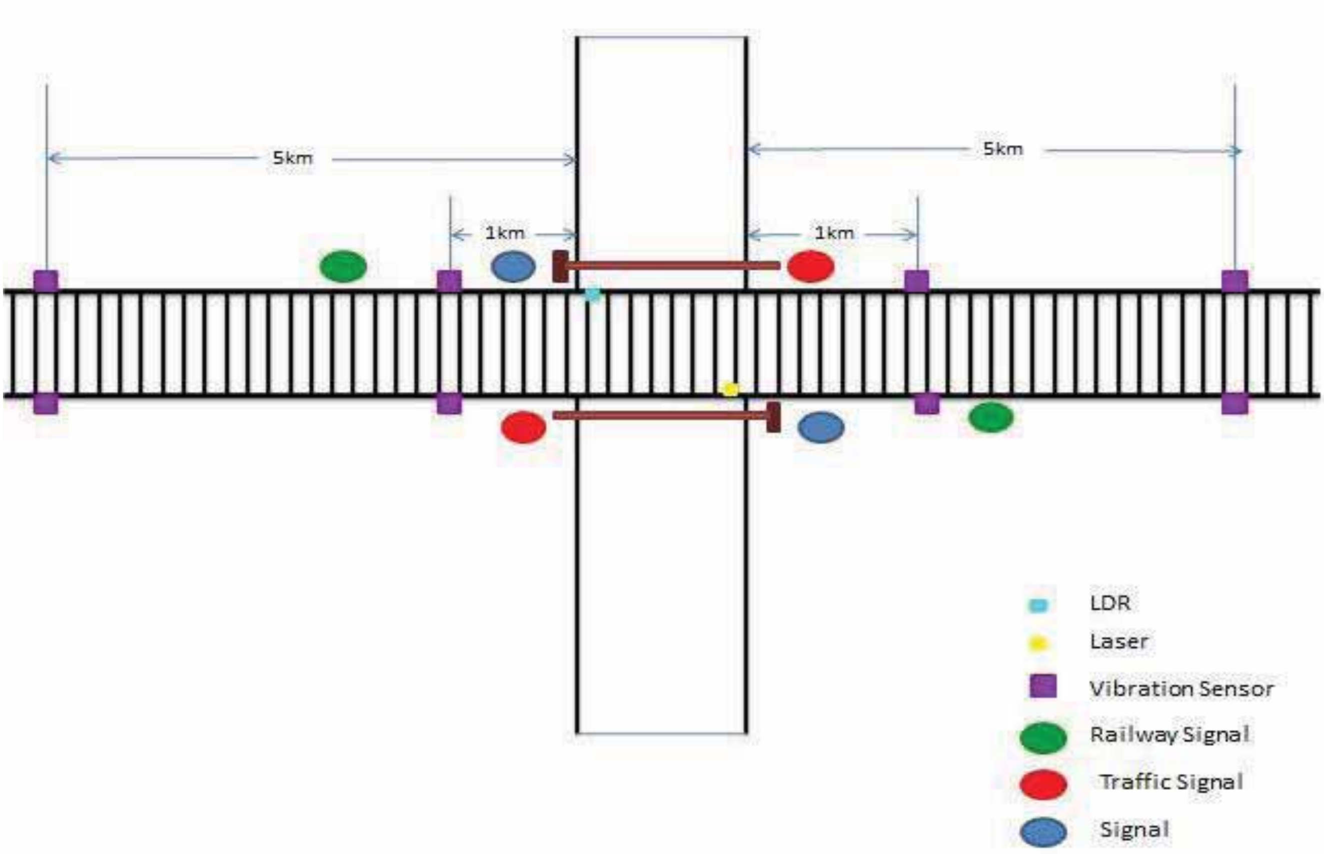

Fig. 3. Gate operation process

IV. Results

Figure 4 shows the hardware setup of the proposed system, which has been successfully implemented as a working model replicating a real-world level crossing. The key components utilized in the model include an 80 cm diameter railway track, a toy train, four IR sensors, a stepper motor to operate the gate, four LEDs for traffic signals, and a buzzer to signal the arrival of the train.

Gate Operation

An IR sensor is positioned 30 cm from the level crossing, and another is placed 5 cm away. When the toy train passes the first sensor, a yellow LED illuminates, warning traffic that the gate will soon close. Upon detection by the second sensor, located 20 cm from the level crossing, the buzzer sounds, the motor fully closes the gate, and the signal changes to red. The buzzer continues to ring until the train has fully passed the level crossing. When the departure is detected by another sensor placed 20 cm beyond the crossing, the motor is activated to reopen the gate.

Obstacle Detection

An RF module is placed on the train to detect any obstacles on the track. If an obstacle is present, a signal is sent to the control room, and the train’s movement is adjusted accordingly based on the obstacle detection.

This model effectively demonstrates the automatic operation of gates at a railway crossing and includes safety mechanisms like obstacle detection.

E-ISSN 2581 – 7957 CVR Journal of Science and Technology, Volume 27, December 2024
P-ISSN 2277 – 3916 DOI: 10.32377/cvrjst2708

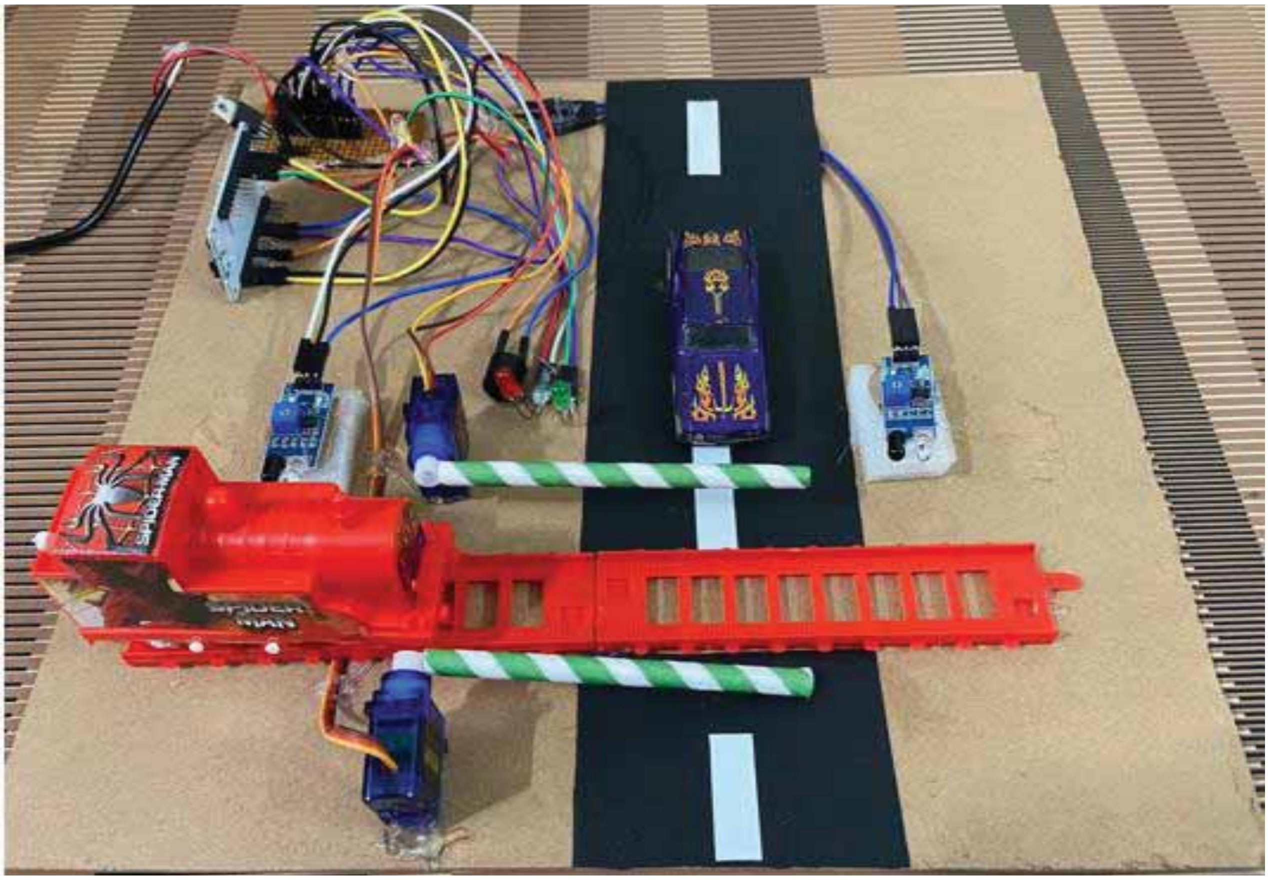

Fig. 4. Hardware Setup of the system

Figure 4 illustrates that when the train approaches the gate, the gate is closed by the operator upon receiving a notification. Using this setup, the gate automatically reopens after the train has passed, helping to prevent accidents. This system integrates both hardware and software components. Two IR sensors are positioned near the gate to detect the arrival and departure of the train. A mini servo motor enables automatic gate control, while the Node MCU, GPS module, Blynk software, and a fire sensor are used to detect any fire occurrences on the train.The buzzer serves as an alert system to notify both passengers and the loco pilot in case of fire.

One IR sensor is placed 30 cm away, and another is positioned 5 cm from the level crossing. When the toy train passes the first sensor, a yellow LED illuminates, signaling to traffic that the gate is about to close.Upon detection by the second sensor, located 20 cm from the crossing, the buzzer activates, the gate fully closes, and the signal changes to red. The buzzer continues to sound until the train passes a sensor located 20 cm beyond the crossing, indicating the train's departure. The motor then reactivates to reopen the gate.

Condition 1: Fig 5 shows that when the train is approaching, IR sensor 1 detects the signal and sends the information to the Blynk

software, indicating that the gate is ahead. This triggers the automatic closure of the gates.

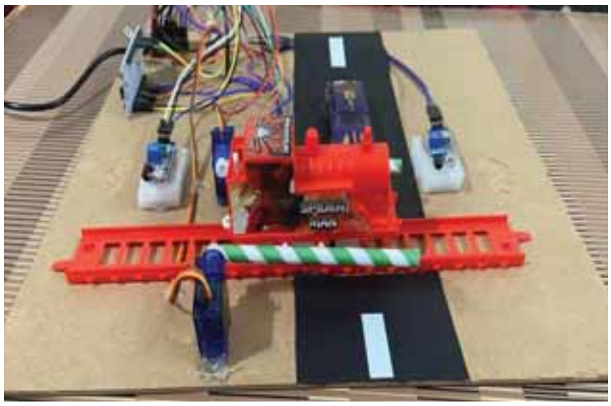

Fig.5. Gates are Closed

Condition 2: Fig 6 shows that when the train departs, IR sensor 2 detects the train leaving and sends the signal to the Blynk software, prompting the gates to open automatically.

CVR Journal of Science and Technology, Volume 27, December 2024
DOI: 10.32377/cvrjst2708

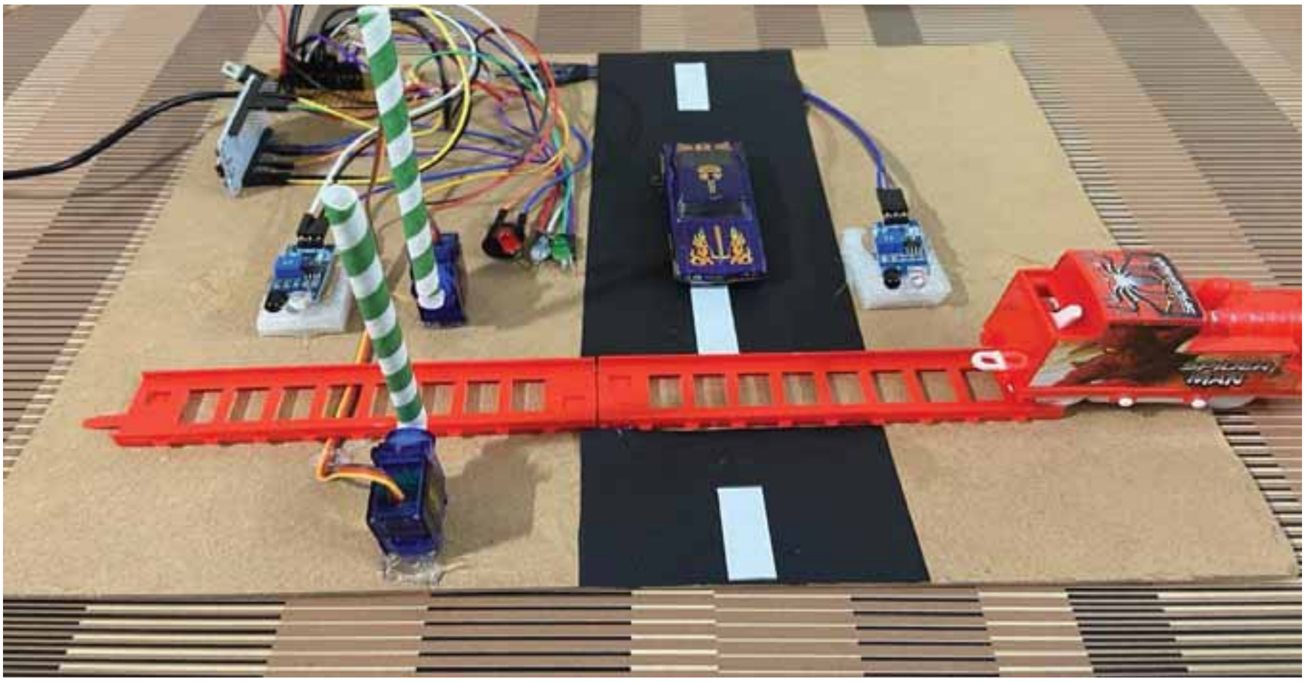

Fig.6. Gates opened

V. Conclusions

The automatic railway gate control system is designed to minimize human involvement in opening and closing railway gates, which helps manage the flow of vehicles and pedestrians across railway tracks. Railway gates are often linked to accidents and fatalities, making automation a reliable solution for enhancing safety. Human errors can lead to gate failures, but automating the process significantly reduces the chances of such incidents. By using a switch circuit to automate the gate's operation, the risk of accidents is greatly minimized. The obstacle detection system incorporated in the developed model also helps prevent accidents, particularly when railway lines pass through forested areas. Many severe incidents occur when animals cross the tracks, and this system helps detect obstacles in advance. However, one limitation of this project is the reliance on IR sensors, which detect any object in the sensor's path, regardless of its relevance. Another limitation is that while the system automates the game's opening and closing, it does not regulate the movement of vehicles and pedestrians at the crossing. To address this, pressure sensors could be integrated as an extension of the current system. Although load sensors would be more effective, they were not used due to cost constraints. In the future, these limitations could be addressed by implementing advanced technologies, making the system more suitable for real-time applications.

References

[1] Bose, A., & Sinha, D. "IoT-driven solutions for accident prevention at unmanned railway gates." *Journal of Emerging Technologies in Smart Infrastructure*, 14(2), 172-183. 2023.

[2] Rao, P., & Banerjee, A. "A novel approach to automate railway gate operations using IoT and AI for safety improvements." *Journal of Automation and Control Engineering*, 17(3), 201-215. 2023.

[3] Kumar, P., & Singh, A. "Automated gate control using IoT for accident prevention at railway crossings." *IEEE Transactions on Intelligent Transportation Systems*, 19(1), 85-97. 2023.

[4] Sharma, G., & Verma, N. "IoT-based solutions for unmanned railway gate safety: A case study." *IEEE Internet of Things Journal*, 17(8), 507-519. 2023.

[5] Patel, S., & Mehta, K. "IoT-enabled railway infrastructure for improved safety at unmanned crossings." *Journal of Railway Engineering and Management*, 34(3), 199-210. 2023.

[6] Mishra, A., & Rao, D. "Accident prevention in railway systems through IoT-based monitoring and automation." *Advances in Intelligent Railway Technology*, 22(1), 65-79. 2023.

[7] Gupta, V., & Raj, P. "Implementation of IoT-based railway gate control systems for accident reduction." *Sensors and Actuators in Smart Transport Systems*, 21(5), 141-158. 2023.

[8] Wang, H., & Lee, C. "Smart railway gate systems: A comprehensive review of IoT applications in railway safety." *Journal of Internet of Things and Smart Cities*, 18(2), 233-246. 2022.

[9] Ahmad, N., & Malik, M. "IoT-based safety solutions for railway gate automation: A field deployment study." *International Journal of Smart Transportation Engineering*, 16(1), 67-80. 2022.

[10] Chen, Y., & Zhao, T. "Optimizing railway gate automation with IoT: A scalable solution for unmanned crossings." *IoT in Transport and Mobility Systems*, 10(2), 123-135. 2022.

[11] Ghosh, A., & Sarkar, R. "Low-cost IoT-based accident preventive systems for rural unmanned railway gates."

Journal of Embedded Systems and Applications, 12(5), 178-189. 2022.

[12] Alam, M., & Farooq, A. "Design and analysis of IoT-based smart railway systems for accident prevention." *Journal of Automation and Railway Safety*, 13(4), 331-343. 2022.

[13] Khan, I., & Hussain, S. "IoT-enabled railway crossing monitoring system for real-time accident prevention." *International Journal of Intelligent Transport Systems*, 11(3), 348-361. 2022.

[14] Kim, H., & Park, J. "Integrating IoT in railway infrastructure for enhanced safety at unmanned crossings." *IEEE Access*, 20(7), 1025-1039. 2022.

[15] Nair, R., & Reddy, S. "Real-time monitoring and control of railway gates using IoT technology." *Journal of IoT and Cyber-Physical Systems*, 26(3), 284-296. 2022.

[16] Choudhary, R., & Sharma, K. "Real-time IoT system for preventing accidents at unmanned railway gates." *Journal of Real-Time Systems and Applications*, 29(3), 233-245. 2022.

[17] Liu, X., & Zhang, Y. "Design of a smart railway gate control system using IoT for accident reduction." *Journal of Smart Transportation Systems*, 30(4), 412-426. 2022.

[18] Das, S., & Patil, M. "Railway safety through IoT-based accident preventive models: Case studies and implementations." *Journal of Safety and Automation in Rail Transport*, 9(4), 150-164. 2022.

[19] Pereira, F., & Costa, P. "Smart railway gate systems powered by IoT for rural accident prevention." *Journal of IoT and Emerging Technologies*, 8(6), 321-334. 2022.

[20] Smith, J., & Johnson, R. "An IoT-based approach for enhancing safety at unmanned railway crossings." *International Journal of Transportation Systems*, 29(4), 455-470. 2022.