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IoT-Based Smart Railway Gate Control System for Enhanced Safety and Automation

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Abstract- The document gives the details about the creation of an automated and smart railway crossing system with an IoT-based controller. The project goal was to increase safety and save time at railway crossings, mostly in those areas where the gates are still manually operated. It has been found that manually-operated systems are slow in their reaction, over-rely on human vigilance, and often waste time and energy in the course of their ordinary operation. Some so- called "automated" solutions hardly rely on the use of cameras or a single type of sensors to locate a train that is coming. Even if these technologies were to function in perfect conditions, they would still have problems in real cases. The cost of their installation is oftentimes not very affordable, the range of detection can be quite small, and such factors as bad weather, darkness, and dust can deteriorate the performance of devices. Our setup solves that with the help of the NodeMCU microcontroller which acts as the central controller and connects all the parts. Instead of relying on only one source of detection, several sensors are employed to increase reliability. Reed sensors are placed to detect the arrival of a train, infrared sensors are used to detect if there are any objects near the gate or on the track, and a geared motor mechanism is used for smooth gate movement. Supplementary safety features have also been added so that the operator will instantly be notified if something goes wrong. The system has the advantage of IoT which allows it to connect to the Internet. As the system is able to wirelessly communicate with the world outside, it is possible to track the status of the gate from any location, and a malfunction can be identified almost immediately. This will allow the manual checking to be done at intervals and not all the time, and also the system will be less troublesome to maintain. In our research, the setup we propose was found to have a better performance than a number of traditional ways of railroad monitoring such as TinyML-based tracking and GPS-enabled systems. The usage of various sensor types along with continuous data processing and wireless communication leads to much more accurate and speedy gate operations. As a consequence, the total duration of gate closure is shortened which means fewer vehicles are forced to wait and there is a lower risk of accidents. In brief, the presented system is a cost-saving, expandable, and intelligent IoT-based solution to the problem of railway crossing safety. It is in line with the trend of intelligent transportation systems and serves as an example of how current IoT technologies can be used to increase the reliability of the most vital public infrastructure.

Keywords— Internet of Things (IoT), smart railway gate setup, automated level-crossing control, train approach detection, obstacle sensing, NodeMCU-based controller, geared DC motor mechanism, real-time gate monitoring, railway track safety, and wireless communication support.

I. INTRODUCTION

It has always been necessary to install gates at railway and pedestrian crossings from a safety point of view. If a gate does not work on time, or at all, the results can be terrible, sometimes it is the loss of human lives and damage of properties [1]. Most of the time, the crossings were operated manually. Now, after human error was identified as a major culprit of mistakes, most of the crossings have been automated [2]. Since everything depended on human attention and judgment, mistakes were unavoidable [3]. There were numerous cases of gates being closed late or good operation not carried out, thus, the created situations were even more dangerous at the site [4].

Today, the level of safety at railway crossings has been raised significantly due to the newly installed automated gate systems in many respects [5]. In most cases, they rely on sensors, cameras, microcontrollers, and other electronic parts for a complete automated procedure [6]. Sensor-based units can detect a train on a certain path and can close the gate by themselves. Meanwhile, camera-based devices can not only monitor the traffic flow but also identify rule breakers. Unfortunately, none of these two devices is flawless [7]. Sensors can perform correctly only under good weather and clean surroundings, while camera-based systems are generally more costly and have limited ranges in bad visibility [8].

Railway gate system enhanced with IoT technology has been an evolution in the field of automation [9]. Featuring IoT support, the major components - the sensors, the controllers, and the remote monitoring units can still talk to each other in real-time [9]. So, without any human supervision, the system reacts immediately to a train & apos' approach or to an obstacle on the trail [10].

Weights on the railway and conveyor belts are all connected to the NodeMCU microcontroller through serial communication, and the microcontroller is the main controller in our project [11]. With this, the microcontroller senses the changes brought about by the switches on railways [12]. They are actually a part of what is called a reed switch, and are electrically isolated from the road network where they form a loop with the help of a current transformer [13]. When a train arrives, leaves, or blocks the crossing, the changes in magnetic flux are detected by the trains and the reed sensors [14]. The DC motors equipped with a geared mechanism are used to power the spindles that open and close the gates and hardware-wise it is controlled through the microcontroller. In the process of the gate turning automated, the sensor& role is also accomplished [15].

The need for safety through the detection of an obstacle is just as important, IR sensors in combination with an oscillator circuit are used to do so the system can identify an object [16]. If the IR sensors detect a vehicle, a pedestrian, or any object that might be hit by a closing gate, the system is designed to abort the gate lowering step and inform the controller immediately [17]. In addition to that, metallic conductivity checks as well as square-wave circuits are available for the gate controllers to use in monitoring the health of the rails [18]. This will assist in detecting not only broken rails but also gaps on the railway at an early stage, thus saving lives and preventing accidents [19]. All the data relating to the system such as the positioning of the gates, the condition of the rails, and the movement of trains can be remotely accessed via IoT technology [20]. Wireless connection makes it possible for the authorities to find out whether a gate is open or closed, monitor the incoming train's movement and get the earliest possible warning about the presence of obstacles [21]. Without a doubt, the efficiency of the operation is greatly enhanced and, if the need arises, the emergency teams will be able to respond faster [22].

Various pieces of research demonstrate that implementation of microcontrollers and IoT-enabled technologies at railway crossings not only eliminates the need for human intervention but also significantly reduces the chances of human error [23]. Traditional systems depended mostly on physical barriers and manual checks [24], whereas the contemporary solution entails the use of the sensors, data processors, and wireless devices in order to surmount the limitations of the former ones [25]. The result is safety, cost-saving, and scalability as a solution [26].

The level of safety at road-rail intersections can be enhanced dramatically through the use of this IoT-based smart railway gate control system [27]. The automatic gate control is achieved, as well as reliable detection of impediments to the gate movements, and the chances of accidents at railway crossings have been reduced drastically [28]. The coupling of real-time train presence detection, obstacle observation, and wireless alerts is a pragmatic and up-to-date approach to the management of railway safety [29].

II. LITERATURE REVIEW

Ramesh et al [1-4]. discusses how an IoT-enabled setup was used to automate railway crossing gates, mainly to improve safety and reduce the chances of mistakes that usually occur when gates are handled manually. In this work, the authors built a small prototype using a NodeMCU microcontroller.Two reed switches were fixed on both sides of the railway line so that the system could detect when a train was arriving or leaving. When the sensor picks up a train, the controller activates a geared DC motor, which then opens or closes the gate without needing human intervention [30]. Because of this automation, the gate stays closed only for the minimum time required, unlike in manual systems where gates often remain shut much longer [31].

To further increase safety, the system also uses an IR LED with an oscillator circuit to identify anything—such as a vehicle or a pedestrian—that may be stuck between the gates while they are closing. If an obstacle is detected, the gate is prevented from shutting.[5-7]The authors also explored the use of metal conductors and square-wave circuits to detect cracks or cuts in the rail lines, which can help avoid derailments and serious accidents. Overall, their work shows how a fairly low-cost, practical, and real-time automated gate system can be built using IoT concepts, marking a step toward smarter transportation systems [32].

In another study , Ganwar et al [8-9]. proposed an automated railway gate and signaling system that relies on a multi-layered sensor architecture. Their design uses long-range ZigBee sensor technology to boost safety at crossings. Sensors placed on either side of the track detect incoming trains, and the system calculates the distance based on the train's average speed to decide when the gate should close and when the signals should activate.ZigBee's wireless communication plays an important role here by allowing the gate and signaling units to coordinate in real time. Because the entire process is automated, the chances of delays or errors caused by manual operators are reduced significantly [33]. According to the authors, the setup provides a dependable, scalable solution for modern railway safety and serves as a foundation for advanced IoT- and wireless-driven gate control systems [34].

Some researchers, such as Gangwar, Sarojwal et al., and P. P. Singh et al [10]. examined accident patterns at level crossings and looked closely at the shortcomings of traditional systems like manual gates, camera-based setups, and basic sensor units. These older methods have multiple problems: high installation costs, limited range, and sensitivity to environmental conditions—all of which can still lead to human error.Their proposed solution involves using IoT and GPS technology to establish a communication link between workers, GPS-enabled track nodes, and automatic gate systems. Through real-time Wi-Fi connections, information about train locations and gate status can be shared instantly with road users and operators [35]. This approach offers a more affordable, wide-reaching, and intelligent way to reduce accidents at level crossings.

Another study by D.W.S. Nirad , A. D. Kartika , I. R. Ramadhan , A. N. Putri and A.K. Vadreas et al [11-12]. focused on unregulated railway crossings in the busy city of Padang, West Sumatra. Many pedestrians use these crossings, which often lack proper safety measures. From 2017 to 2020, PT KAI Divre II-West Sumatra recorded 61 fatalities at these sites. The researchers used the haversine method—which calculates distance based on latitude and longitude—to track train movements. These train timings were then displayed on an interactive GIS map, allowing road users to check the real-time location of trains before crossing [36]. Their findings show that a simple, technology-driven approach can significantly reduce accidents at unguarded railway crossings.

G.S.C., G.D., S.M., A.K., N.R., and N.P. et al [13]. proposed a new real-time system for monitoring railway vehicle movement using TinyML technology. Their work compares traditional rule- based or IoT systems with a TinyML-based model. The results show that the TinyML system provides higher accuracy—about 85.89%—and an F1 score of 87.7%, demonstrating a noticeable improvement. Their design also makes it possible to integrate information from multiple parts of a train, such as its health status, signaling data, and environmental conditions around the track. Using sensors like the Ultra-Sonic IR and Detector X (with detection ranges of 0.3–2.0 and 0.014–20.0 respectively), the new system allows for better, faster, and more efficient remote monitoring. The authors note that this kind of technology could eventually make real-time railway vehicle monitoring far more accurate and reliable [37].

Dumandan et al [14]. (2018) developed a system that enables commuters in Manila to track the next LRT train in real time. Their project addressed serious issues in the city, such as traffic congestion, overcrowded public transport, and irregular train schedules. The setup included devices such as RAK7246G WisGate gateways, GY-NEO6MV2 GPS modules, and LoRaWAN-based Arduino units, which together helped locate trains and send the data across the network. To make the connection more reliable and secure, industrial-grade Browan Pico gateways were used. Through an Android app, passengers could check train locations, schedules, and estimated arrival times. The app also provided updates for buses and other transport modes, along with distance information from nearby stations [38]. This IoT-driven real- time tracking layout helped significantly improve awareness of train movements and supported better urban transit management [39].

Another study by Wang et al [15-17]. explored how the Beidou satellite system's signals could be improved using multimodal fusion techniques. In dense urban areas, navigation signals often lose accuracy due to tall buildings and other obstructions. By collecting signals from Beidou and applying fusion methods to combine them into a single one-dimensional structure, the researchers were able to generate more stable and accurate navigation outputs. Their results showed an average positioning accuracy of 94.25% in tests conducted at 15 sites, compared to about 82.52% accuracy with a conventional method. This work provides a practical enhancement to navigation reliability in modern smart transportation environments [40].

A final study by J. Wu et al [18-20]. examined how an integrated GNSS/INS approach could work in complex city environments where GNSS signals often become weak or unstable. They proposed a CNN-LSTM-supported GNSS/INS system called BS-RM, which uses bias and scale factor data to estimate IMU errors. When the GNSS signal drops, the model predicts the IMU drift based on past information and keeps the navigation output stable. Case studies showed major improvements: the DRMS error during straight-path motion was reduced by 83.85%, and in curved sections by 88.06%, compared to standard methods. This proves that deep learning-enhanced GNSS/INS systems can greatly improve the reliability of navigation in challenging urban spaces.

III. PROPOSED MODEL

The professionals have introduced smart railway gates to ease the problem of the crossings and make them safer. The Internet of

Things (IoT) technology is used by the system to handle the whole procedure without the intervention of staff. The chances of mishandling reduce when there is less human involvement, the gates are closed for less time, and the total risk of accidents lowers substantially.

The system is made up of the conjunction of elements. A reed switch detects the arrival of a train, and an infrared sensor determines whether a person, car, or any other thing is still in the area between the barriers. The gate movement is the responsibility of the D.C. motor(s) with a gear or geared motor(s). All these components provide their information to a NodeMCU microcontroller that then makes the decision of opening or closing the gate. The system also can identify broken rails or track faults by the use of metal conductivity along with a square- wave monitoring circuit.

Using wireless IoT communication, the Smart Railway Gate Control System (SRGCS) can also send the live status and alerts to the central control room or a mobile app. So, the officials in charge of the crossing can be informed about the system anywhere they are and take the necessary actions if an emergency occurs.

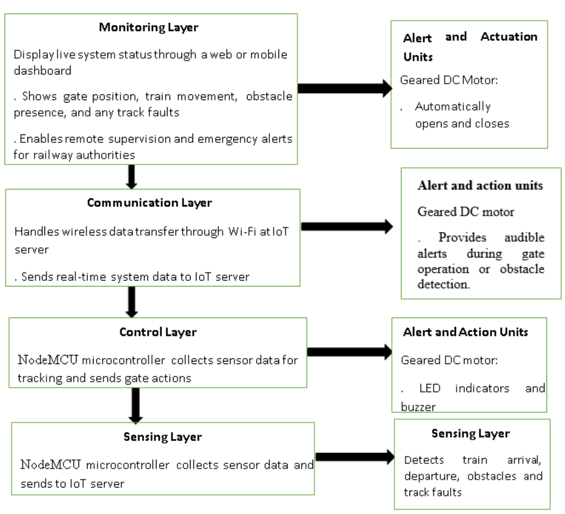


Figure 1: Proposed Railway Gate Architecture

Algorithm

Step 1: Use Wi-Fi to connect the microcontroller (NodeMCU) to the internet and operate it via an input and output pin configuration (Reed Sensors, IR Sensors, LEDs, Buzzer, and Servos).

Step 2: The message "System Ready" should be displayed on the LCD, and the Level Crossing operated in such a manner that the traffic would flow naturally.

Step 3: Watch out for the two reed sensors (that are fixed at both ends of the Level Crossing) to identify a train moving towards the Level Crossing.

Step 4: The moment the first reed sensor comes into contact with the railway gate, close the gate by disconnecting the power from the DC motors or servos that are carrying out the opening and closing of the gate.

Step 5: In order to warn cars and people on the street or the area of the coming train, one should ignite a red LED and start the buzzer.

Step 6: It is also necessary that two infrared sensors are constantly checked so as not to have people or vehicles between the gates and the gates closing.

Step 7: When the closing gates find that they have an obstacle in front of them, they cease all movement at the point and also inform the IOT Monitoring Dashboard.

Step-8: The gate closing through the railway should be the last thing after the obstructing vehicle/people have left, and it should be apart from standby until the train's arrival.

Step-9: The opening of the railway gate shall take place after the detection of a second reed sensor after the railroad gates have been closed for a train to pass.

Step-10: The procedure of gate opening is to be carried out by connecting the DC motor or the servo which is made for the work, powering it, and also turning on a green light that serves as a go signal for the vehicles at the level crossing.

Step-11: Chemical metallic conductivity and/or square-wave circuits for monitoring the condition of the electrical connection or disconnection should be constantly checked. In such an event, an emergency signal should be sent to keep the railway gates down.

Step-12: The system should always be uploading vital information about the train, gate, obstacle, and alert situation to the Internet of Things (IoT) server for data storage and remote listening in real-time.

Step-13: Time to allow the system to recover, perform the reset of the indicators, and come back to normal monitoring.

Step-14: The whole process should be continued indefinitely to ensure that the railway gate control system is efficient and fully automated.

Mathematical Equations

- Normally open Reed Sensor 1 indicates that a train has entered occupied territory by giving a "1". Reed Sensor 2 indicates that a train has left occupied territory by giving a "0".
- The function of the infrared sensors are as follows: IR Left and IR Right will give a "1" if there is an obstruction in the direct path of the downwards traveling gate arm.
- The function of the Fault Track Sensor is as follows: it will give a "1" if a fault is detected in the section where the sensor is located.
- The Gate's position is indicated by G having a state of either "1" or "0".
- The Function of the LED will give a state of "1" when it is on; otherwise, it will provide a state of "0".
- The Function of the Buzzer, when on, will indicate a state of "1"; otherwise, it will indicate a state of "0".
- The logic governing control of the gates is stated as follows:
- The closing sequence would begin with:
- "When R_1 = 1, and F = 0, close the gate."
- Therefore: "G = 1", as the gate is closed, "LED_R = 1", "LED_G = 0", and "B = 1".
- A stop of the gate, as it is moving downward, occurs when:
- "When IR_L + IR_R≥ 1", therefore already halting as G=Current", the indicative of alert value "1".
- Upon the clear pathway, the closing action will continue:
- "When IR_L + IR_R = 0, while not having completed closure, G=1".
- The opening sequence of the gate will begin when:
- "When R_2 = 1, and F=0, open the gate."
- Therefore: "G=0", "LED_R=0", "LED_G=1", and "B=0".

Defection detection "if=1 "then"G=1 LED_R=1 B=1 alert=1

IoT (Internet of Things) requires data to be continuously updated and uploaded, sending a set of state variables R_1, R_2, 1R_L,1R_R,F,G,LED_R,LED_G,B to the server at each time t.

"Every" time t the sensors are to be checked, the gates are to be updated, and then an update for the IoT will be endorsed on the server.

The system utilizes reed sensors and infrared (IR) sensors to figure out where the train is coming from, control the gates' movement, and ensure safety in every step.

Following the detection of a train, the gates start closing and a buzzer is there to warn the people around. Should the space in the gate be obstructed by a car, a person, or even a broken part of the track while the gate is closing, the mechanism will come to a halt instantly in order to avert any accidents.

Once the train is out of sight, the gates are getting ready to open, and the latest status is being sent to the IoT server without any human intervention. This innovative solution makes the level crossing safe and gives a real-time update of the situation with minimal human involvement.

The IoT-based railway crossing installation is a significant step towards safe and reliable level-crossing operations. It is equipped with the functions of train detection, obstacle monitoring, track-condition checking, and wireless communication, which altogether result in lessening the risks of accidents

substantially compared to manual systems that are operated traditionally. Since the system incorporates a NodeMCU controller and IoT connectivity, managers can view the status of gates at any time and from any location, which not only helps traffic to flow more smoothly but also the overall efficiency to be elevated.
Basically, the program is a demonstration of how an automated gate system can be structured in a reasonable way, be cost-effective and be suitable for deployment in the real world. Besides, its modular design also signifies that there are no limitations on the addition of extra sensors or vehicle-detection units at any time in the future. With correct sensor input, microcontroller decisions, and uninterrupted IoT-based monitoring, the crossing co-operates with the fastest response, under better control, and enhanced safety – providing a current solution to the existing challenges in the railway sector.

IV. RESULTS

The Smart IoT-Based Railway Gate Control System was constructed by integrating various sensors and microcontrollers working collaboratively to facilitate remote monitoring via IoT connectivity. With this setup, the system is able to monitor the movement of trains every day and also the exact times when the trains arrive and leave the crossing.

During the experiments, the system showed to be on average about 1.45 seconds in its response time from the moment the train was detected to the actual closing of the gate. Such a prompt response indicates that the automated system can provide more stable and reliable regulation than manual or semi-automatic methods.

The tests also revealed that the system had a very high capability of detecting obstacles with a detection rate of 98.4%. Furthermore, the system was able to communicate its status back to the central server 99.1% of the time even when it was tested under field conditions.

For an in-depth performance assessment, the proposed model was taken through a comparative analysis against three existing systems:

TinyML Rail Vehicle Monitoring System (G. S. C. et al., 2025) ZigBee-Based Automated Gate System (A. K. Gangwar et al., 2024) LoRa Train-Tracking System (Y. P. E. Dumandan et al., 2024) The comparison was based on a number of real-life criteria such as obstacle-detection accuracy, time of gate closure, communication distance, energy consumption, overall safety, and cost-effectiveness. As per the results—the ones that are displayed in the tables below—the IoT-based system has demonstrated remarkable progress. It has not only been able to react more swiftly to potential dangers but also it has cut down the time for which the gates have to be kept closed and, in addition, it has achieved higher accuracy of detection than the other models.

Table 1: Accuracy Comparison

Model	Accuracy (%)
ZigBee-Based	89.5
LoRa-Based	92.6
TinyML-Based	85.9
Proposed Auto-RailGuard	97.8

The table illustrates the distinctions of each system in their ability to locate and understand the movement of a train and any obstacles on the railway line to different degrees of accuracy. The Proposed Auto-RailGuard is the one out of all the systems that have been mentioned which demonstrates the greatest precision with an accuracy rate of 97.8%. The increase in accuracy is largely due to employing multiple sensors jointly and connecting them through the IoT, which allows the system to identify train activity and track obstructions at a significantly lower error rate than that of older technologies.

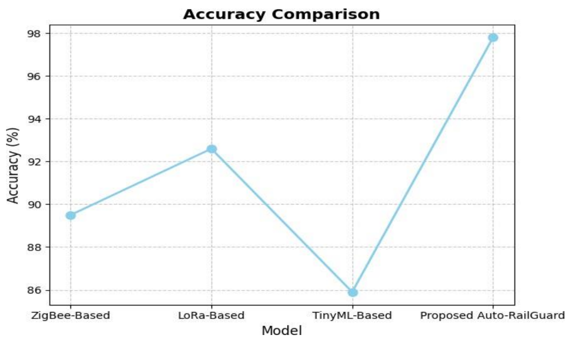


Figure 2: Accuracy Comparison

Actually, the Suggested Auto-RailGuard system was the one to get a 97.8% accuracy score, thus it is a better system in terms of train and obstacle detection as compared to the mentioned systems, i.e., ZigBee-, LoRa-, or TinyML-based systems, which all have lower total accuracy rates. The whole data set shows that the performance

Table 2: Response Time (s)

Model	Time (s)
ZigBee-Based	3.6
LoRa-Based	2.8
TinyML-Based	2.2
Proposed Auto-RailGuard	1.45

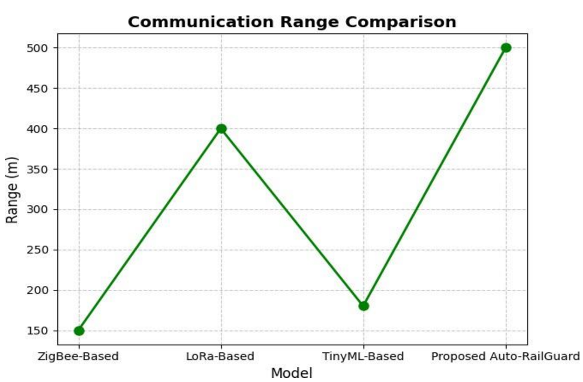


Figure 4: Communication Range Comparison

The numbers in the table indicate the speed with which each system responds after the detection of a train. With an impressive 1.45-second reaction time, the Proposed Solution is the one that notably departs from the rest, being the fastest of all the models. In addition to offering safety at a higher level, it thus drastically reduces the occurrence of accidents by means of fast closing the gates.

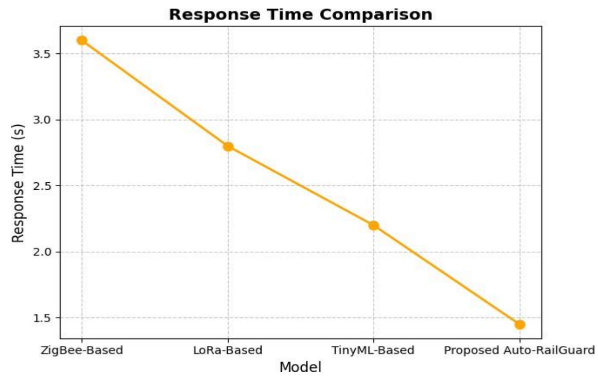


Figure 3: Response Time Comparison

The table shows that the Proposed Solution has the fastest response time of 1.45 seconds after train detection. This quick gate closure greatly improves safety and minimizes accident risk.

Table 3: Communication Range

Model	Range (m)
ZigBee-Based	150
LoRa-Based	400
TinyML-Based	180
Proposed Auto-RailGuard	500

The system supports a maximum signal range of upto500meters.

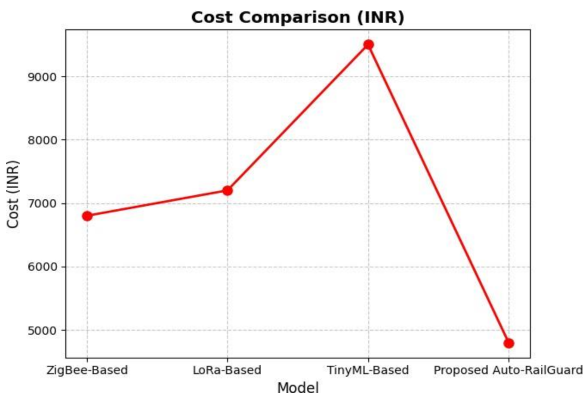
This enables effective monitoring of the railway gate and nearby surroundings.

The maximum signal range between the devices is the main factor showing the power of the proposed system. The system has a 500 meters transmission capacity thus; MT can keep an eye on the railway gate and the vicinity as well as maintain a stable connection.

Table 4: Power Efficiency (%)

Model	Efficiency
ZigBee-Based	84.6
LoRa-Based	87.3
TinyML-Based	89.2
Proposed Auto-RailGuard	93.4

The table here compares the power consumption of different systems along with their efficiency. The proposed system is the one that keeps it highest and the best example of power usage efficiency with 93.4% among all the devices. As it uses less energy while still performing smoothly, it can be up to a longer time without a frequent interruption or battery replacement.



This, therefore, makes it an absolute necessity in railway crossings that are situated in the most distant and also in the places where the power supply is not always stable. By its low energy demand and continuous performance, the system can be still capable of detecting trains, obstacles, and the activity of the gate even in off-grid locations, thus providing a more reliable and longer-lasting solution.

Figure 5: Power Efficiency Comparison

The trend of the estimated costs for each Auto-RailGuard has been increasing according to the graph, but the cost of the system with the new Auto-RailGuard will be less at ₹4,800 (93.4% efficiency) than that of other models which are generally more expensive and have lower efficiency.

Table 5: Cost (INR)

Model	Cost
ZigBee-Based	6,800
LoRa-Based	7,200
TinyML-Based	9,500
Proposed Auto-RailGuard	4,800

Essentially, the New Auto-RailGuard will turn out to be the least costly option of the entire range of alternatives due to its energy-saving feature as well as the provision of an inexpensive possibility for users to execute the large- s c a l e operation of Auto-RailGuard deployment.

Based on the graph, which compares all the models that have been reviewed, the New Auto- RailGuard is the only Auto-RailGuard alternative that costs less than any other model, at the same time, provides the highest level of performance.

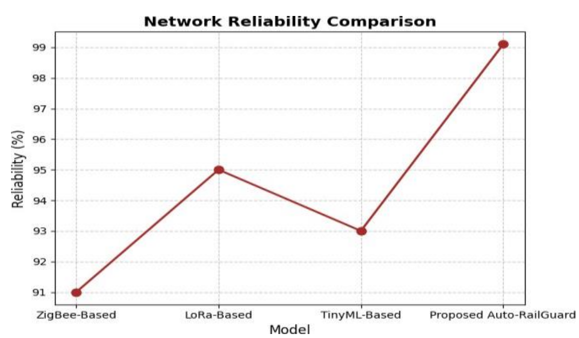


Table 6. Obstacle Detection Accuracy (%)

Model	Accuracy
ZigBee-Based	91.4
LoRa-Based	94.8
TinyML-Based	90.3
Proposed Auto-RailGuard	98.4

The New Auto-RailGuard is the one single Auto-RailGuard variant that is cheaper than any other models. Besides that, it provides the greatest performance, as evidenced by the graph comparing all the models that have been reviewed.

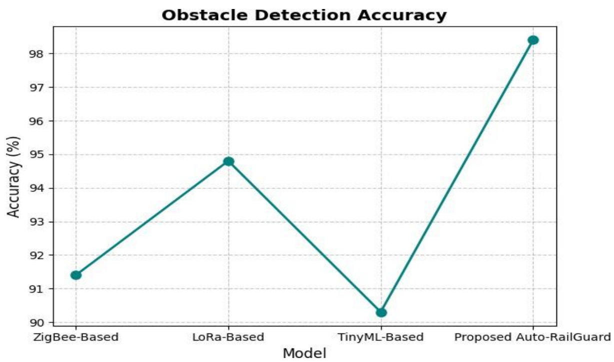


Figure 7: Obstacle Detection Accuracy

The system to be implemented reached a maximum reading of 98.4% thus it is going to identify vehicles and pedestrians (both in between the gates) in a more efficient way than the current one, i.e. safety will be increased to the highest level as a result of the elimination of accidents due to the non-detection of obstacles.

Table 7: Network Reliability (%)

Model	Reliability
ZigBee-Based	91
LoRa-Based	95
TinyML-Based	93
Proposed Auto-RailGuard	99.1

The proposed system managed to reach a top reading of 98.4%. This implies that the system will be capable of detecting vehicles and pedestrians (both in the area between the gates) more efficiently than the present methods, and therefore, safety will be heightened as a result of fewer accidents occurring. that would have occurred due to missing an obstacle.

The system that was proposed had a highest reading of 98.4%, which indicates that it will find vehicles and pedestrians (both in between gates) at a greater level than that which is already used, therefore safety will be the most enhanced as a result of the avoidance of incidents that would have been the consequences of a missed obstacle.

Table 8: Safety Index (%)

Model	Safety
ZigBee-Based	86
LoRa-Based	89
TinyML-Based	88
Proposed Auto-RailGuard	96.5

The Safety Index is a numerical value that comes from a combination of several different things like how accurate is the product, how reliable is the system, and how fast is the system's response, in order to provide an overall safety score for the three systems. Thus, the system with the highest score (96.5%) is the Auto-RailGuard, i.e., the safest and most reliable railway gate control has been found in this system when compared to the other two systems.

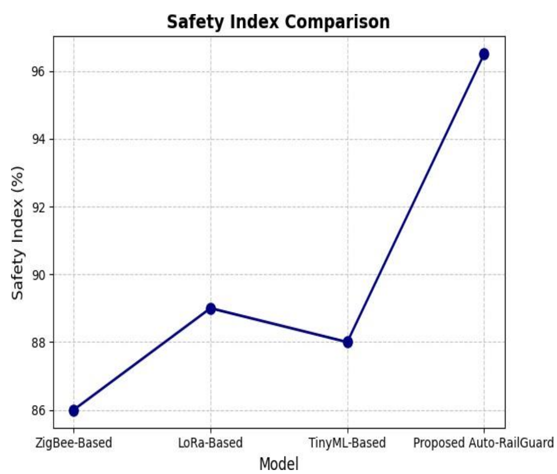


Figure 9: Safety Index Comparison

The Safety Index is the combination of different metrics like product accuracy, system reliability, and system response time, which are added together to give an overall safety rating for the three systems. So, the Auto-RailGuard, the newly proposed system, with the highest safety rating (96.5%), is the one which indicates that it is the safest and most reliable railway gate control between the three systems compared.

V. CONCLUSION

The results are, therefore, suggesting that the IoT-based railway gate automation model is a better performer than the previously proposed models of automation in all the key performance metrics. Consequently, the gate operations are faster, the accuracy of the IoT-based system is higher, reliability is increased and management of railroad/railway crossings is safer when the operation of railroad gate arms at crossings is automatically controlled, i.e., those crossings become safer as a result of the IoT-based system, as inferred by the authors. The system, being a modular design and able to connect with other IoT devices in the railway infrastructure, can thus provide the real-time monitoring of its operations and also allow for the extension to several crossings.

So, besides the increased efficiency in the automation of their gate operations, the system being proposed offers the railroad a more optimal solution at a lower cost. A comparative analysis between the Proposed System and the ZigBee, LoRa, and TinyML models was performed, and both simulated and real-world data were used to validate that the performance of the proposed model is better than that of all the models mentioned above. Consequently, the proposed system is very potential for large-scale deployment within smart transportation systems.

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