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EMERGENCY VEHICLE PRIORITY SYSTEM IN RAILWAY CROSSINGS

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Abstract : The efficient movement of emergency vehicles, such as ambulances, fire trucks, and police cars, is crucial in today's traffic landscape. Railway crossings, however, often present a significant challenge, causing critical delays due to train schedules and barrier closures, which can have serious consequences. To address this, we propose an "Emergency Vehicle Priority System at Railway Crossings." This system aims to minimize these delays through automation and seamless communication. The system uses RFID or infrared (IR) sensors to detect approaching emergency vehicles and sends this information to a central microcontroller. The microcontroller then processes the data and transmits a wireless signal (via LoRa, Zigbee, or GSM) to the railway signal system. Upon receiving this signal, the system holds the railway barrier closed for trains and opens it for emergency vehicles, ensuring they can pass without interruption. Once the emergency vehicle has safely crossed, normal train operations resume. This system reduces the need for manual intervention, improves traffic flow, and enhances coordination between road and railway networks, ultimately leading to greater public safety.

Keywords: RFID(Radio Frequency Identification) IR(Infrared radiation) LoRa(Long Range) GSM(Global System for Mobile Communication)

I. INTRODUCTION

Emergency response operations are fundamentally time-sensitive, where even momentary delays can have critical repercussions. A significant impediment to the swift passage of emergency vehicles, including ambulances, fire engines, and police cars, is the presence of railway crossings. The enforced waiting periods caused by lowered crossing gates, designed to facilitate train transit, frequently lead to substantial delays. These delays can compromise the effectiveness of emergency interventions and potentially result in adverse outcomes.

Current railway crossing infrastructure often lacks the responsiveness necessary to accommodate the urgent needs of emergency services. This report details the development of an intelligent system designed to prioritize the passage of emergency vehicles at railway crossings. The system employs advanced detection and communication technologies to dynamically adjust crossing operations, thereby reducing delays for emergency vehicles and improving overall response times.

The implementation of such a system has the potential to substantially improve public safety, reduce property damage, and save lives. This report outlines the design and functionality of a solution that addresses the need to minimize delays and enhance the efficiency with which emergency services can respond to critical situations.

II.LITERATURESURVEY

[1] The research conducted by Borning Lius, Abiodun Okunola, and Loveth Goodness [1] **delve into a Smart Road Infrastructure System (SRIS)** as a solution to enhance road safety and accelerate emergency response by seamlessly integrating real-time sensor networks, artificial intelligence (AI), and the Internet of Things (IoT) to address the issues of delayed accident detection and slow emergency vehicle movement. Their proposed SRIS leverages advanced technologies such as computer vision, edge computing, deep learning, high-resolution cameras, LiDAR sensors, accelerometers, and V2X communication modules to swiftly gather data, detect accidents, assess their severity, and make rapid decisions. Furthermore, the system incorporates AI-powered traffic control mechanisms capable of generating "green waves," thereby enabling emergency vehicles to navigate intersections with greater ease. Simulations conducted within the research suggest that the SRIS holds the potential to substantially decrease accident response times and concurrently enhance overall traffic flow. The authors also emphasize the role of predictive analytics and cloud-based systems in ensuring the system's seamless and adaptable operation across diverse urban settings. Ultimately, this smart infrastructure presents a scalable approach to tackling transportation challenges, promising significant

benefits, including faster emergency responses, reduced traffic congestion, and the creation of safer urban environments.

[2] The study by Helfy Susilawati and colleagues [2], titled **"Design of a Road Marking Violation Detection System at Railway Level Crossings,"** introduces an innovative solution to combat traffic violations and congestion at railway crossings, especially when vehicles illegally enter restricted lanes during gate closures. The proposed system combines IoT technology and computer vision techniques to detect, document, and penalize such violations. It uses a Raspberry Pi 4, ultrasonic sensors, webcams, and image processing algorithms, activating only when the railway gate is down. The system employs the Single Shot Detector (SSD) algorithm for real-time vehicle classification and Optical Character Recognition (OCR) to capture license plate information. When a violation occurs, an audible warning is issued, and the vehicle's license plate details are logged in a central database for enforcement. The study reports an average recognition delay of 0.554 seconds for cars and 0.702 seconds for motorcycles, with OCR accuracy at 64.45% under ideal conditions. Unlike previous research focused on infrastructure improvements or train detection, this system aims to correct driver behavior by actively issuing penalties in real time. While environmental factors like lighting and weather affect accuracy, the system shows promise as a practical, affordable solution to improve discipline at crossings, reduce congestion, and enhance road safety. This work highlights the integration of IoT, machine learning, and surveillance to create more efficient and accountable transportation systems.

[3] The research conducted by Ajay Jethva, Shekhar Parmar, and Parag Savsani [3] **focuses on improving traffic flow and safety at rail-road crossings,** with a particular emphasis on ensuring emergency vehicles can pass through unhindered. This study, based at the "Chobari Fatak" in Junagadh, Gujarat, an area critical due to its proximity to hospitals, presents the PERC Assist system, which uses retractable bollards and surveillance cameras. The bollards automatically rise when railway gates close, clearing a path for ambulances and other emergency responders, while the vehicles are verified using license plate recognition. In-depth traffic analysis, including counts, speed measurements, delays, and accident data, helped inform the development of the system. The solution integrates traffic signal management, gate operations, and real-time surveillance, ensuring that emergency vehicles can swiftly pass even in busy traffic. Ultimately, PERC Assist seeks to reduce emergency response times, alleviatecongestion, and improve overall traffic safety.

[4] The paper by Darren Espinoza, Galal Ali, and Tarawneh [4], in their research titled ***"AI-Based Hazard Detection for Railway Crossings,"*** **explore** how artificial intelligence can enhance safety at railway intersections by reducing collisions involving vehicles, pedestrians, and trains. They introduce a computer vision approach using Convolutional Neural Networks (CNNs) to automatically identify hazardous conditions at crossings. Their system was trained on a diverse dataset of images captured under varying lighting and weather conditions from live camera feeds positioned at different railway locations. The authors followed a meticulous process of collecting, cleaning, and labeling these images before using Tensor Flow and Keras frameworks to train their CNN model. Designed with over 10 million parameters, the network was capable of detecting multiple types of hazards simultaneously—such as stalled vehicles, approaching trains, pedestrians, animals, and malfunctioning gates or warning lights. During testing, with 80% of the data used for training and 20% for validation, the model showed high levels of accuracy, particularly in identifying critical obstructions like vehicles on the tracks. The study suggests that such AI-driven detection systems could offer a scalable, cost-effective solution for continuous monitoring of rail crossings and could be integrated with technologies like Positive Train Control (PTC) to further reduce accident risks. While the model performed well overall, the authors recommend expanding the dataset to improve detection of less frequent events such as animal crossings or rare pedestrian scenarios. This research represents a forward-looking contribution to transportation safety, demonstrating the real-world potential of AI in developing smarter, automated hazard detection systems for railways.

[5] The research by Kajat Sartono, Martin Djamin, and Suryadi [5], in their study titled ***"Design and Construction of Automatic Railway Crossing Gate Control Using Proximity and Infrared Sensors Based on Omron CP1E E30-SDRA PLC,"*** propose an automated system to improve safety at railway crossings by reducing dependence on manual operations. Acknowledging that many accidents are caused by human error and inadequate infrastructure, the authors developed a model using proximity and infrared sensors linked to an Omron CP1E E30-SDRA PLC to control gate barriers, alarms, and LED indicators. The system detects an approaching train, activates warnings, and lowers the gate, then reopens it once the train has passed, all without human intervention. The use of infrared sensors enhances performance in low-visibility conditions, while the PLC ensures precise and reliable operation. The researchers followed a detailed process involving literature review, component selection, system design, and prototype testing, with voltage readings confirming the system's stability. Their findings demonstrate that integrating non-contact sensors with PLCs provides a reliable, low-maintenance, and scalable solution for railway safety. The study not only contributes to safer railway crossings but also shows potential for broader applications in traffic automation and infrastructure modernization.

[6] The study by Zhao, Fan, Li, Gebreyohanes, Wang, and Mo [6] explore the safety challenges that emerge when high-speed trains engage in emergency braking on curved rail tracks, a condition far more complex than braking on straight segments. In their study, titled ***Dynamic Behavior of Railway Vehicles During Emergency Braking on Curved Tracks*,** the researchers developed a coupled rigid–flexible dynamic model that merges both vehicle mechanics and braking system responses. This model wasn't just theoretical—it was tested against actual field data, lending credibility to its outcomes. One of the standout findings from their research is the significant rise in lateral vibrations and the intensity of wheel–rail forces during emergency stops on curves, both of which threaten train stability. Particularly telling were two indicators: the derailment coefficient and the wheel load reduction rate, both of which showed increased risk under such conditions. The study points out that curves with tighter radii and inadequate super elevation worsen these effects, suggesting that careful track design is more than just a formality—it's a safety necessity. A unique aspect of their approach lies in how they modeled braking components like calipers and discs with flexibility, leading to a more realistic representation of braking forces. This sets the research apart from earlier work that tended to isolate either vehicle dynamics or braking systems, rather than looking at their combined effect. Their conclusion is clear: both the design of the track and the behavior of the braking system must be considered together if high-speed rail travel is to remain safe. The insights provided in this study could be especially valuable to railway engineers and planners looking to minimize risk while optimizing performance on complex rail networks.

[7] The study by Iftekharuzzaman and his co-authors [7], in their study titled ***"Visualization of Renewable Energy Powered Automatic Railway Crossing Systems in Bangladesh,"*** propose a sustainable and technology-driven approach to enhance safety at railway level crossings. Recognizing the frequent accidents at manually controlled crossings throughout Bangladesh, the researchers designed an automated system that operates independently of the national grid by using renewable energy. Their model integrates infrared (IR) sensors and Arduino Uno controllers to detect approaching trains and manage boom barriers automatically, significantly improving operational reliability. A distinctive aspect of this study is its hybrid power setup, which combines solar panels, wind turbines, and backup generators to ensure uninterrupted functionality regardless of weather conditions. The authors employed simulation tools such as Homer Pro and Proteus to evaluate system efficiency, optimize energy output, and calculate the Levelized Cost of Energy (LCOE), ensuring the solution remains both cost-effective and reliable. Lithium-ion batteries were chosen to maintain around-the-clock operation, and sensitivity analysis was conducted to accommodate seasonal variations in solar and wind energy availability. The system not only addresses safety concerns but also aligns with Bangladesh's broader sustainability goals and international environmental commitments, such as those outlined in the Paris Agreement. By integrating IoT-based control mechanisms with eco-friendly energy solutions, the study presents a scalable and forward-thinking infrastructure model capable of reducing accidents and minimizing carbon emissions. The proposed solution is especially relevant for deployment in both urban and rural areas where conventional energy access may be inconsistent. This research contributes significantly to the discourse on green transportation infrastructure and demonstrates how renewable energy and automation can be leveraged together to build safer, smarter railway systems.

[8] The study by Gintautas Bureika, Marek Komaiško, and Virgilijus Jastremskas [8], in their research titled ***"Modelling the Ranking of Lithuanian Railways Level Crossing by Safety Level,"*** examine the risks associated with railway level crossings across Lithuania and propose a structured method to assess and prioritize them based on safety. Their study identifies that nearly 30% of railway-related transport accidents occur at these crossings, underscoring their significance in national transport safety. To address this, the researchers developed a logistic regression model that evaluates 337 crossings by calculating accident probabilities using key variables such as visibility conditions, traffic intensity of both trains and vehicles, crossing width, train speed, and the categorization of the crossing itself. Drawing from both local and international accident data, they highlight the strong influence of human error and inadequate infrastructure—like poor signage or limited visibility—as major contributors to risk. The methodology also incorporates global best practices, including tools like ALCAM from Australia and the Π–tool framework, to enhance the robustness of their model. The result is a risk-based ranking system that identifies high-priority locations needing immediate safety upgrades. The study stresses that such assessments should be revisited annually to remain effective, given evolving traffic patterns and infrastructure changes. Furthermore, the authors advocate for simple, budget-friendly improvements, such as low-cost warning systems, to boost safety in vulnerable areas. Despite Lithuania having relatively fewer incidents than many European nations, the research emphasizes that certain crossings still present serious risks. Their interactive model is designed to support decision-makers in scheduling inspections and allocating resources more efficiently. Ultimately, this work contributes a valuable, data-driven framework for improving railway crossing safety and guiding targeted interventions where they are needed most.

[9] There search paper by Prof. Bharath Bharadwaj B S and his team [9], in their study titled ***"Automated Railway Monitoring System,"*** explore the use of IoT-based technologies to improve safety and efficiency at railway level crossings. Their work focuses on creating an automated gate control mechanism that utilizes Arduino Uno boards, ultrasonic sensors, and servo motors to manage barrier operations without human intervention. The system is designed to detect approaching trains using sensors and respond by lowering or lifting the gate accordingly, reducing unnecessary closure time and helping ease traffic congestion. Unlike traditional manually operated gates, this setup operates through an event-driven logic, triggering actions only when required, which enhances both safety and system responsiveness. The researchers also review earlier developments involving infrared sensors and remote monitoring to place their solution within the broader context of railway automation advancements. Through practical testing, the team demonstrated that their design is not only reliable and responsive but also affordable and scalable for widespread use. The model shows strong potential to reduce accidents at unmanned crossings and improve overall traffic flow near railway lines. In addition, it addresses common drawbacks of manual systems, such as human error and delayed gate operation. By combining basic yet effective components with responsive logic, the study offers a practical approach to modernizing railway safety systems, particularly in regions where manual crossings are still prevalent.

[10] The study by Ke-jun Long and his research team [10] explored how to give emergency vehicles faster access through intersections without severely affecting the flow of everyday traffic. Their work, titled "**A Collaborative Control Framework: Achieving Emergency Vehicle Priority While Minimizing Negative Impact on Ordinary Vehicles at Signalized Intersections,"** introduces a dual-approach system aimed at solving this urban traffic challenge. The system combines a temporary lane setup called a Dynamic Emergency Lane (DEL), which creates space for emergency vehicles, with a coordinated signal adjustment phase known as the Emergency Priority Phase (EPP). This strategy helps ensure that emergency vehicles can move efficiently during congested conditions while still allowing regular traffic to flow with minimal interruptions. Unlike older systems that often stop or delay general traffic completely to prioritize emergency access, this framework tries to maintain a better balance between both needs. Additionally, the researchers included an eco-driving feature that helps reduce fuel usage and encourages more stable driving patterns for non-emergency vehicles. Through simulations, the system showed strong results — reducing delays for emergency responders and slightly improving travel conditions for regular drivers, especially under high traffic volumes. Compared to conventional models like greedy preemption and fuzzy logic systems, this collaborative setup performed more effectively across various traffic scenarios. The study highlights how well-planned coordination of lanes and signals can create smarter, more responsive urban traffic systems. Overall, this research presents a realistic and scalable model that cities could adopt to improve emergency response times without significantly disrupting daily commuting, making it a valuable contribution to modern transportation planning.

III.PROBLEM IDENTIFICATION

- Emergency vehicles face dangerous delays at railway crossings due to closed barricades.
- Lack of an automated priority system results in poor communication and slow response times.
- Train operators are unaware of approaching emergency vehicles ,causing further delays.
- These situations increase accident risk and worsen traffic congestion.
- A smart, automated system is urgently needed to ensure safe and timely passage.

VI.APPLICATION

- **Emergency Vehicle Traffic Management:** Ensures ambulances, firetrucks ,and police vehicles get priority at railway crossings, reducing delays.
- **Prevention of Accidents**: Automatically stops train movement when an emergency vehicleis detected, preventing collisions.
- **Smart Railway Systems**: Integrates with smart city infrastructure to improve railway crossing safety and efficiency.
- **Reduced Human Intervention**: Eliminates the need form annual gate operations and signaling, ensuring faster response times.
- **Improved Public Safety:** Helps in quicker medical emergency responses by allowing ambulances to pass without waiting.
- **Efficient Traffic Flow:** Prevents unnecessary congestion railway crossings by intelligently managing signals.
- **Scalability for Future Use:** Can be expanded to work with AI and IoT-based traffic control systems for better automation.
- **Energy and Cost Savings**: Reduces fuel consumption for emergency vehicles by minimizing idle time at railway crossings.

V.CONCLUSION AND FUTURE SCOPE

It is implementing an Emergency Vehicle Priority System for railway crossings significantly enhance the efficiency and safety of emergency response operations by reducing delays . caused by closed railway gates. By integrating technologies such as sensors, GPS, wireless communication, and intelligent control systems, the priority system ensures that emergency vehicles are detected in advance and that railway gates can be managed accordingly without compromising rail traffic safety. This system not only accelerates emergency vehicle trans it during critical situations butal so helps in minimizing congestion and potential accidents near railway intersections. Overall, it represents a vital advancement in intelligent transportation infrastructure, contributing to faster emergency response times and improved public safety.

- **Integration with Smart City Infrastructure**: The system can be part of larger Intelligent Transportation Systems (ITS), working with smart traffic signals, real-time surveillance, and automated traffic management. Communication between emergency vehicles and city traffic control centers can be fully automated.

- **IoT and AI-based Enhancements:** Use of IoT sensors and AI prediction models to detect and predict emergency vehicle arrival more accurately.

  AI can optimize the crossing gate operations based on real-time data(trainspeed,distance,emergencyvehicleurgency)

- **V2X Communication (Vehicle-to-Everything):** Emergency vehicles can directly communicate with railway crossing systems using V2I (Vehicle-to-Infrastructure) protocols.
  Future railway systems may have direct wireless links with emergency fleets for faster responses.

- **Priority-based Train Management**: In highly critical cases (ambulance with critical patients, fire brigades to big fires), trains could be slowed slightly if safely possible, giving emergency vehicles faster clearance.

- **Data Analytics for Optimization**: Overtime, data collected from such systems could beused to analyze bottle necks, improve the design of crossings, and further reduce emergency delays.

- **Autonomous Emergency Vehicles**: As autonomous (self-driving) emergency vehicles become reality ,systems could automatically communicate route and crossing statuses to them without human intervention.

- **Block chain for Secure Communication**: Block chain can beused to create secure,tamper-proof logs of emergency crossings and priority decisions for accountability and post-event analysis.

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