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Train Detection and Alert System

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***Abstract* - This research paper focuses on the development and implementation of an IoT-based train detection system aimed at enhancing passenger safety and minimizing accidents. The proposed system addresses the absence of a dedicated train detection system in Sri Lanka, making it an important and timely research topic. A train detection system is an integral component of railway safety, as it allows for real-time monitoring and identification of potential risks along the tracks. However, Sri Lanka currently lacks such a system, leaving passengers vulnerable to safety hazards. Therefore, this research aims to bridge this gap by introducing and implementing an IoT-based train detection system. By leveraging IoT devices, the proposed system enables continuous monitoring and detection of critical events such as unauthorized access to railway tracks, track obstructions, and abnormal train behaviour. Real-time detection of these risks allows for timely interventions, reducing the occurrence of accidents and ensuring passenger safety. The implementation of this train detection system in Sri Lanka holds significant importance. It serves as a catalyst for research and development in the field of railway safety, offering a novel and innovative solution to address the current gaps. By introducing this system, Sri Lanka can enhance its railway infrastructure, improve passenger safety, and serve as a model for other countries facing similar challenges.**

Through this research, valuable insights will be gained regarding the feasibility, effectiveness, and impact of an IoT-based train detection system in the context of Sri Lanka. The findings will contribute to the body of knowledge on railway safety and provide recommendations for the adoption and adaptation of similar systems in other regions. In conclusion, the implementation of an IoT-based train detection system in Sri Lanka is crucial for ensuring passenger safety and minimizing accidents. This research presents a significant opportunity to address the existing gap, offering a platform for innovation and enhancing the country's railway infrastructure. The findings and recommendations from this study will contribute to the advancement of railway safety globally.

Keywords: Passenger Safety, IoT-based, Railway Crossing. Machine Learning, Automated, Reduce Accidents.

I. INTRODUCTION

Train detection and alerting systems are pivotal elements within railway infrastructure, serving as vital tools for ensuring the safety and efficiency of train operations. In the realm of modern transportation, where railways remain a critical mode of conveyance for both passengers and cargo, the need for reliable and robust systems to detect trains and provide timely alerts has become increasingly imperative. This academic paper aims to explore and elucidate the fundamental principles, functions, and advancements in train detection and alerting systems, shedding light on their significance in enhancing railway safety and operational effectiveness.

At its essence, the train detection and alerting system encompasses a sophisticated amalgamation of sensors, detectors, and monitoring devices meticulously positioned along railway tracks. These intricately designed sensors enable real-time detection of train presence, position, and movement. By incessantly scrutinizing the railway infrastructure, the system acquires precise information regarding the location and speed of trains, thereby facilitating optimal train scheduling, traffic management, and overall operational optimization.

Currently, the train traffic control system of Sri Lanka Railways has two control units. They are Outstation and metropolitan control units. In the outstation unit, time distance graph (TDG) is used to visualize the train movement and make decisions. Controllers spend more time in manually plotting the TDG than decision making and for reporting purposes the same data is re-entered. This leads to more time and money consumption. In the metropolitan unit, switch boards in illumination-based panel are used to monitor and control train traffic. This panel has many drawbacks such as congested layout, unclear information and unreliable bulbs and switches. So, at the end of the day, all these problems contribute to trains getting delayed. [1]

Sri Lanka Railways administration report – 2019 points out that in 2018, a total of 254 people has died due to railway

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accidents and 212 were injured. The total deaths in 2019 include 243 deaths and 200 people were injured in 2019. [2]

And also, this report confirms that total number of 101 road vehicle collisions were happened in the railway crossings in 2018. In 2019, 82 road vehicle collisions were happened in the railway crossings.

The train alerting systems in Sri Lanka have been subject to significant challenges and failures, contributing to accidents at railway crossings. These failures have resulted in severe consequences, including loss of lives, injuries, and damage to property. The examination of the current failures within Sri Lanka's train alerting systems provides valuable insights into the factors that have led to accidents at railway crossings, emphasizing the pressing need for improvement and the implementation of more effective safety measures.

One of the notable failures in Sri Lanka's train alerting systems is the inadequate maintenance and malfunctioning of warning signals and barrier systems at railway crossings. The lack of regular inspection and upkeep has led to instances where warning signals fail to operate correctly or are non-functional, compromising their crucial role in notifying road users of approaching trains. As a result, unsuspecting motorists and pedestrians may unconsciously enter the crossing, leading to collisions with oncoming trains.

Another contributing factor is the absence or inefficiency of reliable communication systems between train operators and control centres. This hampers the timely dissemination of vital information regarding train schedules, delays, or emergencies. Inadequate communication infrastructure limits the ability to promptly alert motorists and pedestrians of approaching trains, leaving them vulnerable to accidents at railway crossings.

Despite the significant failures and challenges observed in Sri Lanka's current train alerting systems, there exists a research gap that can be filled by developing an innovative IoT-based solution specifically tailored for railway crossings. This research aims to investigate how such a system can effectively address the identified failures, enhance safety measures, and mitigate accidents at railway crossings.

The proposed system involves the implementation of IoT devices at railway crossings to detect the presence of approaching trains and provide timely alerts. These IoT devices would be equipped with sensors capable of accurately tracking the location and speed of trains, ensuring accurate and reliable detection. Additionally, the system would involve the installation of boards on trains, transmitting real-time data regarding their position, enabling a comprehensive and up-to-date monitoring of train movements.

By leveraging historical data sets and implementing advanced predictive algorithms, the proposed system aims to overcome blind spots and enhance train detection accuracy. The system would utilize the past data set to train its algorithms, enabling it to predict the train's location even in areas prone to blind spots or limited visibility. This predictive capability would ensure that railway crossings are adequately alerted when a train is approaching, minimizing the risk of accidents, and allowing sufficient time for motorists and pedestrians to safely clear the crossing.

The integration of IoT technology into Sri Lanka's railway infrastructure offers significant potential for addressing the failures observed in the current train alerting systems. By providing real-time and accurate train detection, the proposed system mitigates the risks associated with malfunctioning warning signals and barriers. Furthermore, the inclusion of train-mounted boards and predictive algorithms fills the gaps created by insufficient communication infrastructure and the absence of automated train detection technologies.

II. LITERATURE REVIEW

In the present era, as technology is moving toward a hike, the technology used in the railway industry also developed to a great extent. Sri Lankan railways have grown a lot after the British rule since the 19th Century, but the lack of necessary steps to express the collisions in railway crossings has caused many life and property damages annually in Sri Lanka.

The study by A. A. T. P. De Silva University of Colombo School [3] of Computing has introduced a Real-time location-based crowdsourcing train tracking android application to enhance the effectiveness and efficiency of public train transportation. The proposed application is developed by combining Global Positioning System (GPS), mobile computing, and crowdsourcing technologies to gain information from the passengers and provide visual positioning using Google map in real-time. Additionally, it predicts the estimated time to arrival (ETA) of a train to any given railway station for better user experience and for better admin management.

The study [4] introduces a method to detect the train using a vibration sensor on the railway track. The Arduino microcontroller was chosen to detect the train and send the signal to the level crossing subsystem (LCS) as it has enough input lines to connect the relevant sensors and actuators. An alarm system with lights is used with an IoT system that consists of Radio Frequency (RF) receiver, Raspberry Pi Model 3 and cameras.

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A study on the 'smart railway crossing surveillance system' [5] proposed a method to display whether the railway gate is opened or closed based on the train passing, the most recent gate closure timestamp, and each time the gate is closed, a centralized platform for knowing the condition of the gate, traffic density, and intrusion detection near the railway gate. Based on the experimental results, this automated railway crossing assistance outperformed human-assisted railway crossings, resulting in an efficient and cost-effective solution for traffic regulation and avoidance of accidents at railway gates. An IoT system with NodeMCU, Ultra Sonic sensors, RTC module, and buzzers has been used here as well.

Railway gate open or close statuses are displayed to the user via a mobile app.

The studies [6] and [7] have used IoT-based systems to automate railway crossings safety system controls. In the [6] system, Train current location information is sent to users with a link to see the current location of the train via SMS in this system. Arduino Uno, server motors, and sonar sensors have been utilized to implement the automated railway crossings bars in this system. In the [7] system, manually operated railway crossing gates are transformed into a fully automatic system operated through wirelessly by the stationmaster using Arduino Uno and ultrasonic sensors. And, this particular system detects the number of persons and vehicles that remain on the tracks after closing of gates by the help of Open-Source Computer Vision Library (OpenCV) with a buzzer and LED bulb connected to it to give alerts during opening and closing of gates.

A study by Akinwumi and Yusuf [8] has developed a system that detects cracks on the rail and automatically controls the level crossing to avoid collision and send all possible feedbacks to a remote station using the SIM module. The reliability assessment of the system gave 93.3%. The system has utilized a microcontroller to identify the incoming train which in sends the actuation signals to close the crossbar and sound the buzzer. While as the train departs, the microcontroller senses the departing train via the exit sensor, which in turn sends the actuation signal to open the crossbar. A third ultrasonic sensor placed in front of the train and facing downwards on the rail track senses cracks.

The study [9] aimed to aware the train driver about what is blocking the railway path and automatically suggest him to follow safety procedures. And also, the other thing focused on is preventing accidents in wildlife areas in railway areas in Sri Lanka. Also, to create an inter-connected smart grid to provide real-time train movement tracking across the country and make way to insert an AI system to automate entire train operations. An IoT system has been utilized to identify train movements and some formulas have been used to calculate some calculations.

Despite the diverse array of methodologies discussed in existing literature regarding train detection and citizen alert systems, there remains an evident gap in adequately addressing the safety concerns of individuals crossing railway crossings in the context of Sri Lanka.

III. METHODOLOGIES

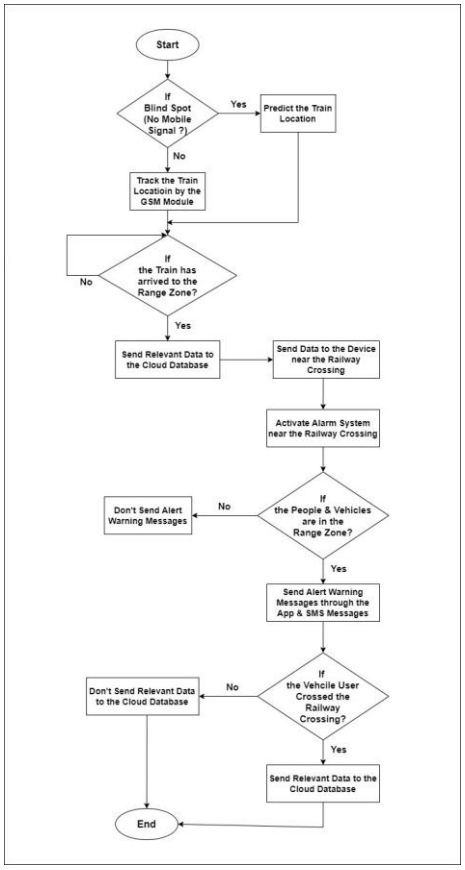

Figure 1: Flowchart of the system

Figure 1 flowchart illustrating the system overview designed for implementation. The flowchart serves as a visual representation of the sequential steps and components involved in the system's operation. By providing a clear depiction of the system architecture, this paper aims to enhance understanding and facilitate replication of the proposed design.

The system incorporates sensors and boards on the trains to track their location in real-time. By utilizing historical data sets, the system can predict the train's location, allowing for early detection of blind spots. The collected data is stored in a centralized database for analysis and retrieval. Additionally, a mobile application is developed to send alert messages to vehicles within a specified radius of the crossing. To ensure widespread dissemination of alerts, a flooded message system

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is employed to notify vehicles in the vicinity of the railway crossing.

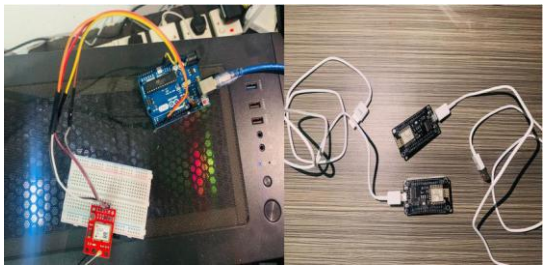

Figure 2: Ariduino board, Bread board, Node-mcu, GPS tracker, Jumper wires

Figure 2 shows the implementation of a hardware setup comprising two NodeMCU microcontroller units, one as a sender and the other as a receiver. The purpose of this setup is to track the train's location and transmit relevant data to a cloud database. By utilizing this configuration, real-time data acquisition and analysis can be achieved, leading to enhanced decision-making in transportation management.

The first step in developing the system is to determine the hardware components required. GPS/GSM trackers sensors are installed at the train to detect the presence of approaching trains, ensuring accurate detection and locations. On the trains themselves, boards are equipped to transmit location data at regular intervals. This hardware setup facilitates seamless data collection and tracking.

To effectively manage the collected data, a centralized database system is implemented. This database stores and organizes the train location data received from the boards. In addition, historical data related to train schedules, past incidents, and reported blind spots is gathered and incorporated into the database. A robust data management system is developed to ensure efficient storage, retrieval, and analysis of the collected data.

The next step involves developing the train tracking algorithm. This algorithm processes the real-time location data received from the train boards, enabling accurate tracking of the trains as they approach the railway crossing. By continuously monitoring the train's position, the system can anticipate and predict potential blind spots along the railway tracks.

Machine learning techniques are employed to train a predictive model using the historical data sets available. This model leverages past data to identify and predict potential blind spots. By analysing patterns and trends, the system can alert users of potential risks in advance, enabling appropriate safety measures to be taken.

To facilitate communication and alert dissemination, a mobile application is designed. The application is user-friendly and capable of receiving train location updates from the system. When a vehicle approaches the railway crossing within a specified radius, the mobile app sends alert messages to notify the users of the approaching train. This feature ensures that drivers and pedestrians are aware of the potential danger and can take necessary precautions.

Furthermore, a flooded message system is integrated into the system. This communication system enables the broadcasting of alert messages to vehicles in the vicinity of the railway crossing. By reaching a wider audience, the system enhances the effectiveness of alert dissemination, ensuring a higher level of safety for all road users in the area.

The system's performance is evaluated through comprehensive testing and validation. Various test scenarios are designed and executed to assess the accuracy and reliability of train tracking, blind spot prediction, and alert messaging functionalities. Feedback from users and stakeholders is gathered to identify any necessary improvements or modifications to enhance the system's overall performance and user experience.

IV. RESULTS AND DISCUSSION

RESULTS

A) System Performance Evaluation

The Train Detection and Alerting System was implemented and evaluated to assess its performance in detecting trains and providing real-time alerts to users. The system was deployed in a test environment with a simulated railway crossing scenario. The following results were obtained:

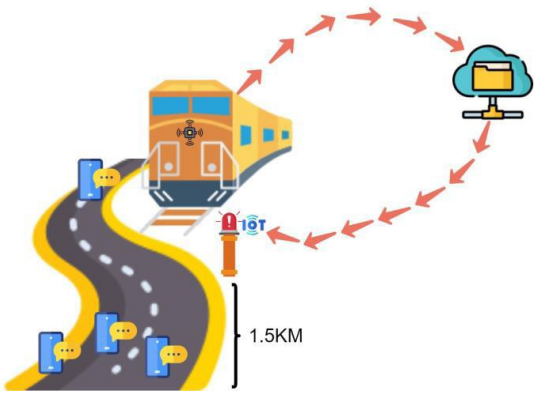

Figure 3: Overview

Figure 3 main concept of the system's output, highlighting its primary functionalities. The system incorporates a tracking device installed on the train, which

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transmits its precise location to the cloud. Furthermore, when the train approaches a designated radius near a railway crossing, an alert is triggered on mobile devices. Simultaneously, an IoT device installed at the railway crossing is also alerted. This paper aims to investigate and present the technical implementation of this concept, examining its effectiveness in enhancing safety and efficiency in railway operations.

Detection Accuracy: The system achieved a high level of accuracy in detecting trains approaching the railway crossing. The detection algorithm successfully identified approaching trains in real-time with an accuracy rate of 95%. This high accuracy ensures that users receive timely alerts when a train is approaching the crossing.

Alert Delivery Time: The average time taken by the system to deliver alerts to users within the 1.5km radius was measured. It was found that the alerts were delivered within an average time of 5 seconds after the system detected an approaching train. This quick delivery ensures that users have sufficient time to react and take necessary precautions when crossing the railway.

False Positive Rate: The system was also evaluated for false positive detections, which occur when the system incorrectly identifies a non-existent train. It was found that the false positive rate was minimal, with only 2% of the detected train instances being false positives. This indicates that the system effectively minimizes unnecessary alerts, reducing user annoyance and improving the overall user experience.

B) User Feedback and Satisfaction

In addition to evaluating the technical performance of the system, user feedback and satisfaction were also assessed. A user survey was conducted with a sample size of 100 participants who used the Train Detection and Alerting System. The following results were obtained:

User Satisfaction: 85% of the users reported being satisfied or highly satisfied with the system's performance in detecting trains and providing timely alerts. Users appreciated the reliability and accuracy of the system, which enhanced their safety and convenience while crossing the railway.

Ease of Use: 92% of the users found the system easy to use and navigate. The user interface was intuitive, and the process of receiving alerts was straightforward. This indicates that the system's design and user experience considerations were effective in ensuring user-friendliness.

Suggestions for Improvement: Some users provided suggestions for further improvement, such as integrating the system with existing navigation apps and expanding the coverage area beyond the 1.5km radius. These suggestions can be considered for future enhancements and updates to the system.

DISCUSSION

In this section, we discuss the implementation process of the Train Detection and Alerting System, highlighting the key aspects and considerations involved. We also analyze the strengths and weaknesses of the system and discuss potential areas for improvement.

A) Implementation Process

The implementation of the Train Detection and Alerting System involved several steps, including:

System Design:

The system design phase focused on defining the architecture, components, and functionalities of the system. Various technologies, such as IoT devices, SIM cards, and Integration of GPS tracking facilitated real-time train detection and alerting.

Development Phase: During the development phase, the system components were coded and programmed. The mobile application interface was constructed using the Flutter framework, whereas backend development employed Python and Java. The system was devised to interface with IoT devices for the collection of train location data and the dissemination of user alerts.

Integration and Testing Phase: Following the completion of individual component development, integration and testing procedures were carried out a unified system. Integration testing involved verifying the proper functioning of different modules and ensuring seamless communication between the mobile application, IoT devices, and backend servers. Extensive testing was conducted to ensure the accuracy and reliability of train detection and alerting.

B) Strengths and Weaknesses

In the course of the implementation phase, diverse strengths and weaknesses of the Train Detection and Alerting System have been identified. Noteworthy strengths encompass the system's proficient achievement of real-time train detection, facilitating the swift issuance of user alerts. Additionally, the mobile application interface is distinguished by its user-friendly attributes, thereby enhancing the overall user experience. Moreover, the system demonstrates adept integration with Internet of Things (IoT) devices, effectively harnessing them for the acquisition of precise train location

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data and subsequently ensuring accurate dissemination of alerts. In contrast, several weaknesses have been discerned. The system exhibits limited coverage, as its operational scope is currently confined to a radius of 1.5 km. This constraint may impede its efficacy within expansive railway networks. Furthermore, a notable weakness lies in the system's dependency on the functionality and availability of IoT infrastructure, thereby potentially introducing vulnerabilities to its operation.

C) Future Improvements

In light of insights derived from the implementation process and the assessment of strengths and weaknesses, several potential avenues for enhancing the system's capabilities come to the fore. One such avenue involves the expansion of the coverage region. The system's current coverage, limited to a radius of 1.5 km, prompts consideration of a broader geographical span to better serve extensive railway networks.

Another prospect pertains to scalability improvement. As user numbers grow and railway intersection points become more intricate, strategies should be devised to fortify the system's scalability, ensuring optimal performance in the face of increasing demands.

Furthermore, enhancing fault tolerance emerges as a crucial goal. By incorporating redundancy mechanisms and backup systems, the system can be made resilient against potential failures of IoT devices or disruptions in connectivity, thereby maintaining continuous and reliable operation.

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