An Optimized Algorithm to Select the Most Appropriate Gate Type for a Given Level Crossing in Sri Lanka

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Abstract- *The current railway system in Sri Lanka, there are 1687 Railway Level Crossings Systems (RLC) with three types of RLCs protection methods namely RLCs with barriers, RLC with bell and light, and unprotected RLCs. As per our observation, we identified that there is no decision criterion on identifying the most suitable RLC protection mode for different RLC environments in the current railway system and this leads to an increase in the collision rate of the road traffic and the train schedule. Therefore, as a solution in this work, an accurate prediction method is introduced based on the 'Regression Tree Analysis' method to identify the most appropriate component out of barriers or bell and light in a specific RLC.*

Keywords: Train Vehicle Unit, Regression tree analysis, Machine learning, RLC, Accidents, Level crossing

I. INTRODUCTION

In 1864 "rails" were introduced to Sri Lanka to transport tea from upcountry to Colombo port. The mainline was extended north to Kandy in the ancient capital of Anuradhapura and north to Kankesanturai and west to Talaimannar for the ferry link of the island to South India, to bring in Indian tea and rubber plantations, as well as to import rice and other foodstuffs not grown in adequate quantities indigenously. Sri Lanka Railway (SLR) is a government department that operates under the Ministry of Transport. It is the leading transport provider of transport services and the only rail transport organization in Sri Lanka. SLR operates under the General Manager of Railway (GMR), the GMR shall report to the Secretary Secretary-General of the Ministry of Transport. Currently, the Sri Lanka Railway operates and manages 1561 km of railway lines with a broad gauge of 1,676 mm, having 72 locomotives, 78 power sets, and a signaling network. In the current railway line, there are single track, double track, three tracks, and four tracks available throughout the route. Around 396 trains operate on Sri Lanka Railway line daily commutating passengers to their workplaces, taking the passengers to their respective destinations, including 67 long distance and 16 intercity trains, and transports approximately 3.72 million passengers per day (SriLankan Government ,2020).

The railway network consists of nine railway lines and it is given in Figure 01. They are Mainline (Colombo to Badulla), Matale Line (Peradeniya Junction to Matale), Puttalam Line (Ragama to Noor Nagar), Coastal Line (Colombo to Beliatta), Kelani Valley Line (Colombo to Avissawella), Northern Line (Polgahawela to Kankesanthurai), Mannar Line (Medawachchiya Junc. To Talaimannar), Trincomalee Line (Gal Oya Junc. to Trincomalee) and Batticaloa Line (Maho Junc. to Batticaloa).

Both the train passengers and the public have been quite concerned about the increasing trend of rail accidents in the past few years. As the railway track is unfenced, it is very much prone to accidents involving pedestrians, passengers as well as animals. There are many kinds of rail incidents and some of them are accidents at level crossings, accidents in railway stations, collisions on railways, derailments, and suicides. From the years 2018-2020 total of 1273 suicides have been taken place and a total of 552 accidents have been taken place (SriLankan Government ,2020).

There are two main types of level crossings in Sri Lanka called active and passive level crossings. Active level crossings can be categorized as manually operated barriers, electrically operated barriers, farm farm-type barriers, and bell and lights. Passive level crossings are the level crossings which doesn't provide any information whether the train is approaching or not. Only stop and giveaway signs are available.

In the current Railway system, there is are no specific criteria to determine what is the best protection method as such as Barrier, Bell, and Light or unprotected for a level crossing. They use parameters like "Traffic congestion, Train Density, Road type, number of accidents" to determine the protection method, or else the pedestrians should complain to the Sri Lankan Railway that the level crossing is unsafe for them to use.

This research will be a quantitative approach to the issue at hand where the primary focus is on building up a model to determine the protection type needed to the level crossing by using machine learning.

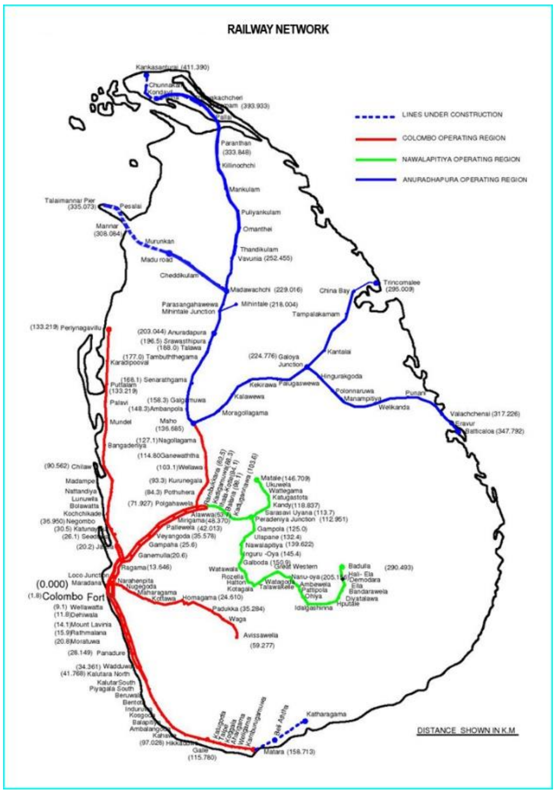

Figure 01: Railway network of Sri Lanka (SriLankan Government ,2020)

II. RELATED WORK

In the early days, the probability of collision of trains sharing the same track was small because there were fewer number of trains and a considerably long-time gap between two trains kept the risk of collision low. Therefore, in the present railway system, having a proper and accurate signaling system is a must because the train density and the trains are scheduled very frequently. Unlike vehicles on roads, trains cannot be steered away to stop collisions. It is confined to the railway track and even taking a bend at high speed will derail the train and end up in disaster (Tan, 2019). The evolution of the railway signaling system was initiated by mechanical systems, which led to Multiple Aspect Colour Light Signaling System (MAS) to Communication Based Train Control (CBTC) (Jayasundara, 2019). The current system was upgraded in the most effective, feasible, cost-effective, and easily manageable way for Sri Lanka by using Q-type latch relays. Latch relays were used in this system to acquire safety interlocking with a lesser number of relays compared to the existing system (Jayasundara, 2019).

A Block system can be described as a system that prevents a train from entering a specific sector of the railway track until the train that is already within that particular sector leaves. These block systems can consistently record distance intervals between trains. In the modern railway system, block signaling has been upgraded into Automating Block Signaling (ABS) (Britannica, 2011). A fixed block signaling system is an artificial separation between train can be created between train using fixed block signaling by separating the track into small blocks, which determines the distance between two trains. This will avoid train collisions and provide safety. Even though this provides safety, it challenges the signal engineers when designing the size of the block as it should be designed for optimum headway and safety concurrently (Ali, 2019).

There are two main types of level crossings. They are active level crossings and passive level crossings (Amarasingham et al. 2017; Fambro et al. 1998). All the countries in the world have both protected and unprotected railway crossings. Despite the traditional railway systems, the developed countries also have many advanced high-speed railways transportation methods such as light rail system, monorail system, metro system, maglev train, and high-speed trains (Britannica 2013; Britannica 2012;Paranirubasingam 2018; Regulation 2007).

A general understanding of the key circumstances and other contributory factors for having a protected RLC is provided by the study of deaths from railway-related accidents. Since the number of RLC injuries and events is troubling, the need to introduce policies which that contribute to improving the protection at RLCs which will reduce the injuries and accidents, has risen (Nedeliakováa et al. 2015). Improving the standard of protections used in RLCs can be accomplished either by decreasing the risk of an accident or by reducing the effect of incidents, or by integrating them. Protection enhancement is expensive, but it is a necessary expense that cannot be eliminated or be neglected (Pyrgidis 2016; Weerakoon 2011).

To avoid disturbance in the circuit track, the researchers have proposed and designed an online monitoring system and management platform for monitoring railway signal infrastructure. This focuses on a simulation-based approach using optical fiber sensing for supporting a threshold analysis aimed at identifying the maximum number of trains to be operated on a line for the given the related infrastructure. The proposed design by the group of researchers can perform signal processing, chart display, acousto-optic alarm, user authority. This project is based on the graphical programming language labVIEWLabVIEW, the obtained results from this show that the basic signaling equipment for monitoring and managing railway systems can transmit data correctly and steadily. Thereby it is proven that this design is resulting in convenient and ideal for operations (Ma et al. 2018).

III. METHODOLOGY

The project was started with the initiative of Increasing the reliability of the existing Bell and Light protection system through an optimized algorithm to select the most appropriate Gate type for a given location in Sri Lanka Railway. The primary concern of the Railway department officials is to safeguard the train passage of the commuters. Over the years, there have been drastic measures taken by the department to ensure the safety of the commuters. Therefore, fatal accidents that the commuters have been subjected to over the years have been diminished. But with the increasing complexity of railway networks due to the development throughout the country, there has been a trend of commuters getting into accidents, some of which are fatal. Most of these accidents occur near the railway level crossings. Due to the nature of these accidents, it is tough to regulate and prevent such incidents. Therefore, a way to reduce these accidents has to be found in a methodical and systematic manner.

In exploring this avenue, we conducted interviews, surveys and went through a plethora of literature in this context to find out what are the most common factors that are needed to be considered when installing the level crossing protections. As the preliminary step for this project, it was required to identify the factors that affect the decision decision-making of installing the protection method for an existing level crossing. The expected outcome of this is to show the most optimum type of level crossing to be installed by the Sri Lankan Railway.

The information required for this project was gathered by conducting the interviews with railway officials, distributing questioners, contacting research centers, interviewing a guard who operates a barrier, and surveying other related research articles and other data and systems in foreign countries. Considering all the data collected, 11 main factors have been identified which can be utilized to develop the algorithm. After gathering data Train Vehicle Unit (TVU) was calculated using the following formula in Eq. (1) which calculates the total train and vehicle units passing a level crossing per.

$$TVU = \text{no.of train units} \times \text{no.of vehicle units} \times 24 \quad (1)$$

When the data is plotted on a time-plot containing missing data, gaps emerge on the plot where missing data occurs in the data set, which results in data acquisition failures in both input and output signals. In order tTo handle outliers, a boxplot has been used. If there are a lesser number of outliers, the data set is kept as it is because data will not be biased. If there is a higher number of outliers, those outliers must be removed because if not, the data will be bias.

Generally, using the correlation analysis method the strength of the relationship between the factors can be identified. If there is a high correlation between two or more variables, it means that they have a strong relationship among the factors else the correlation relationship is weak, which states that the variables hardly relate to each other. Therefore, in this project, Spearman's correlation is used since the chosen variables do not follow the assumptions of linearity, interval or ratio level, and bivariant normal distribution. The main goal of the project is to build up a model that makes a prediction with a given set of uncertain data and this is called “supervised learning”. Regression and classification are the two main methods used in supervised learning where the regression method predicts a continuous measurement for the observation and, the classification method allocates a class from a finite set of classes. This work is focused on predicting and observation of

continuous dependent variables/data and regression analysis is the best method to use.
Considering the correlation analysis, it exhibits that all factors that have been chosen do not always have a strong positive or negative relationship with the response variable as the data is scattered. Despite having a weak relationship between two factors and not having a linear relationship, the variables show equal importance in developing the model. Hence, the Linear regression model doesn't fulfill the necessary requirements. If this model is used, factors with weaker relationships have to be dropped out of the considering factors. Even though there is no mathematical correspondence between some aspects, it is not feasible to drop those factors as they might contribute to the development of the model.

Based on the background domain knowledge and set of intensive simulations the regression trees (RTs) model is identified as the most suitable model for this project since the considered response variables/factors are dependent and continuous. In the RTs analysis, the cvpartition function is used to randomly partition the set of data of specified size. Using this partition, it is possible to create test and training sets to validate a mathematical model using cross-validation. In order tTo build up this model, the cross-validation method is chosen since the gathered data set is small. Cross-validation is carried out to eliminate overfitting and underfitting of data and a K-fold cross-validation partition is used with K = 10 to carry out the model. In this partitioning process, the data set is randomly divided into 10 folds approximately with the same number of entries and approximately 10% of total entries are included in the test set.

Based on the observation of the carried out correlation analysis and the details are given in Tan (2019) and Jayasundara (2019), 10 main factors which can be utilized to develop this model were identified. Gate mechanism which identifies the unmanned/manned gates, number of accidents at unmanned/manned level crossings, Train Vehicle Unit (TVU), visibility conditions, signaling system, alarm system, vegetation, number of tracks, road bendy, and communication system are the factors that have been chosen to utilize the model. Using the selected features, sets of different numbers of features were fed into the model at a time and the results were obtained. To choose the most suitable result following parameters from Eq. (2) to Eq. (7) were considered. Where y_i is actual response value of the model, $i \in 1,2,\ldots,n$ and $\hat{y_i}$ is the value estimated by the regression model. $\bar{y}$ is the mean response.

$$Root\ Mean\ Square\ Error(RMSE) = \sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i - \hat{y}_i^{\,2}} \quad (2)$$

$$Total\ Sum\ of\ Squares(SST) = \sum_{i=1}^{n} y_i - \hat{y}_i^{\,2} \quad (3)$$

$$Sum\ of\ Squares\ Error(SSE) = \sum_{i=1}^{n} y_i - \overline{y^2} \quad (4)$$

$$R^2 = \frac{SST-SSE}{SST} \quad (5)$$

$$Mean\ Squares\ Error(MSE) = \frac{1}{n}\sum_{i=1}^{n} y_i - \hat{y}_i^{\,2} \quad (6)$$

$$Mean\ Absolute\ Error(MAE) = \frac{1}{n}\sum_{i=1}^{n} y_i - \hat{y}_i^{\,2} \quad (7)$$

To perform analyzationanalysis, the model has been trained by feeding training data, and then it can be tested by using test data. In addition, simulated results are analyzed and used as a method for better understanding and improving the performance and reliability of the structures where the simulation is often commonly used to validate the accuracy of the designs. In validation, the identification of the acceptability of the built model is important. In this situation, the software should be modified to fit the features of the current system and the effects of the model can be compared to those of the actual system. To check the validation in this model rMetrics parameters with training data and test data are compared to check the accuracy.

IV. RESULTS AND DISCUSSION

From the questionnaire carried out, it was shown that most of the accidents happen at the unprotected level crossings due to the carelessness of the pedestrians or road vehicles. And also, it was revealed that most of the responders had faced failures at level crossings often.

When finding the correlation, it is observed that there is a strong relationship between Accidents versus Gate type, and Train vehicle unit versus gate type. The reason behind the observation was that there is a high probability of happening an accident in unprotected RLC as well as the high value of TVU impact on the selection of Gate type to be Protected most of the time. The correlation between the response variable and 'visibility' is calculated as 0.5595, which is important that visibility of rail track along both sides of RLC and also whether rail track is bendy or not, was measured and correlation is calculated which does not show a strong relationship, but it is essential to consider the fact that, no line of sight with train can lead to accidents. The same procedure was applied to other predictive variables and checked an impact on the response variable.

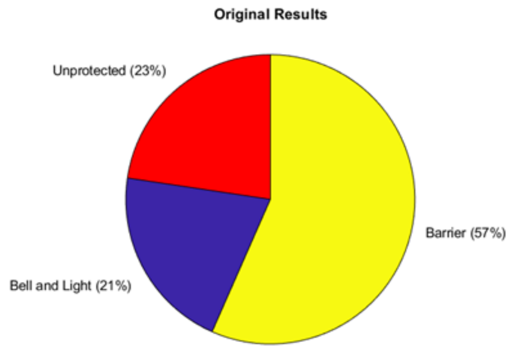

Figure 02: Original Results

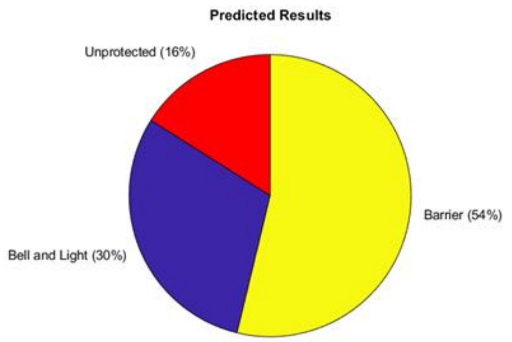

Figure 03: Predicted results

It is observed, there is a significant improvement in unprotected RLCs turned into bell and light protection. This results in a smaller number of accidents and also there is a decrease in the percentage of barrier protection, where the model predicts the existing barriers should be bell and light. It is identified that with more training data, the results can be further optimized to get a highly accurate decision.

V. CONCLUSION AND RECOMMENDATIONS

In Sri Lanka, the safety of RLC becomes the most essential concern since RLC deaths are reported throughout the year. Based on the conducted qualitative assessments it is identified that most railway accidents occurred in RLC due to the unprotected RLC and the carelessness of vehicles/passengers. Further, it is founded that there was no proper justified quantitative metric or thorough statistical analysis based on accident/incident data to convey the need for an appropriate type of gate to protect the RLCs in the current Sri Lankan railway (SLR) system. Therefore, in this work, we implemented an optimized model which can predict the most appropriate gate type for a given RLC and this is beneficial to SLR to make the decision on which gate protection to be installed. This result not only in reduction of railway accidents /collisions and may save many human lives while preventing the material/economic losses due to disruption of train operations and shutdown of road traffics. It is quite apparent that a larger database with the appropriate data is beneficial in creating a well appropriate model.

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