Design of Automated Unmanned Railway Level Crossing System Using Wheel Detector (Sensor) Technology

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DECLARATION

The undersigned declares that as this own results, the literature, and tools used can be identified. Results in the achieved thesis may be used for the purposes and tasks of the university awarding institution free of charge, subject to any restrictions on encryption.

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ABSTRACT

It has been concluded that level crossings of rail and roads pose potential danger to roads users in railway industry. Due to ever increasing number of vehicles daily, it was concluded that using automated technique at level crossing can be useful for the safety of traffic. Level crossing protection is the consequence of having level crossings on a railway line. Generally, the railway level crossing requirements are determined by the type of technology used in order to provide a fail-safe system.

The main aim of this thesis work is develop an automated level crossing system that would prevent accident between trains and road users. From the railway level crossing point of view, the requirement to be met by such protections is quite simple: it has to stop all road users before passing of a train. A special attention is paid on wheel sensor which is used to detect the train accurately, direction and speed of the train are monitored in the process. Two wheel sensor are used located before (Strike-in point) and also after (Strike-out point) the level crossing. On the other hand, the proposed system comprises of other warning devices such as automatic barrier, LED flashing lights and the alarm device. MicroLok II is used as the controller to execute all the signals and programs.

Barrier closing time will be optimized based on the type train and their speed. Implementation of new technology will significantly improve safety at level crossing without building the capacity of road infrastructure. In this work, the application potential technique to secure rail road crossings is explained in details. By the use of the train detection system, it is the best possible control of the level crossing.

Keywords: Level crossing, Strike-in point, Strike-out point, wheel detector, Sensor

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LIST OF ABBREVIATIONS

(a) **RFID –** *Radio Frequency Identification*
(b) **GPS –** *Geographical Positioning System*
(c) **ROB** – *Railway Over Bridge*
(d) **RUB** – *Railway under Bridge*
(e) **AVL -** *Automatic Vehicle Location*
(f) **GIS** – *Geographical Information System*
(g) **SELCAT -** *Safer European Level Crossing Appraisal and Technology*
(h) **TPS** - *Train Protection System*
(i) **ATP** – *Automatic Train Protection System*
(j) **UWCs** – *User-Worked Crossings*
(k) **GHZ** – *Gigahertz*
(l) **EU** – *European Union*
(m) **US** – *United State*
(n) **SOC -** *System on Chip*
(o) **STS -** *Supervisor Track Section*
(p) **LC –** *Level crossing*
(q) **FPGA -** *Field Programmable Gate Arrays*
(r) **ITS –** *Intelligent Transport System*
(s) **V2V –** *Vehicle-to-Vehicle*
(t) **SCATS** - *Sydney Coordinated Adaptive Traffic System*

CHAPTER 1: INTRODUCTION

1.1 Introduction to level crossing

Railway is considered as one of the cheapest and safest mode of transport worldwide. Therefore, safety is one of the crucial aspect when it’s come to railway operation everywhere. With the ever increasing population, the railway industry always encounter many problems due to technical and human errors, especially at level crossings. The Level crossing is a cross-sectional area where rail track and roadway intersect each other (Figure 1). In most cases, level crossing remains unattended mostly in rural and remote areas. Hence, such intersection requires constant human coordination and monitoring on everyday basis. The level crossing is divided into two type’s namely manned and unmanned level crossing. Manned level crossing is further grouped into classes’ ‟A‟ Class, ‟B‟ Class and “C‟ Class. On the other hand, unmanned level crossing is grouped into C‟ Class, D‟ Class [74].

Almost every year there are accidents/collisions reported at level crossing. In Europe, more than 1200 accidents are recorded each year with more than 200 fatalities at level crossing. Of all the road infrastructures, level crossing is considered as one of the most dangerous spot. As a matter of facts, 29% of accident occurs in railway infrastructure happen at level crossing [1]. In most cases, accidents happened due to carelessness of commuters and vehicle operators towards passive road signs or probably because of bad weather conditions.

Figure 1: Typical level crossing [9]

In this paper, the author emphasizes on the system consist wheel detector sensor technology to be used at the railway level crossing to minimize and mitigate accidents occurrence. First of all, closing and an opening time of the gate will be reduced. Secondly, improve infrastructural capacity to accidents at level crossing.

Commuters and roads users have to give right of way to the trains at level crossing in accordance to technical specifications. The fact that railway has low coefficient of adhesion between its wheel and rail which makes it hard to stop immediately leading to long braking distance. According to article [90], a new system type like intelligent railway system may be created and developed with regards to safety and security in railway industry. It's worth noting that it should be of user friendly, economical, efficient, safe, easy to use and sustainable type of system. It can be done by incorporating artificial intelligence (AI) in the existing system for future development of railway industry.

The combination of road and rail traffic where they intersect led to accidents if there is no proper infrastructural implementation. With the increase in the number of road transport, both in urban and suburban areas, improving road safety and road capacity became the biggest concern at the level crossing. Level free has been always a solution especially when it's come to capacity improvement. But this somehow failed since not all the crossing can be changed to level free like overpass or underpass because it's generally impossible or perhaps spending much investments in improving the condition. In this regards, building and level crossings maintenance is required, which must be equipped with safety installations to prevent level crossing accidents. These level crossings are called protected level crossings [66].

The number level crossing is said to be decreasing at the rate of about 2% every year in [37]. Even though the number of level crossings in operation is shrinking, the number of level crossing with protection system which consist 50% approximately of the total number of level crossing is still huge.

Accidents in Railway industries are classified depending on the causes, results etc. These types of classifications help researches to study and find possible solution in preventing the occurrence same accidents in future. When the train collides on the track from opposite direction is called head on collision. On the other hand, when train on same track facing the same direction collides is called posterior collision. Derailments are caused by merely straight track, sharp curves; mishap of a train, or on a junctions; the place wherever two tracks diverges into one or one diverges into two [37].

1.2 Objectives of the research

The objectives of this thesis is to develop an "automated railway level crossing system" to replace the present deployed system in the railway industry. The system consist of wheel sensors which can be implemented easily inroads especially at level crossings. With the increase of vehicles daily, it has become more difficult to manually operate the gate and its time consuming at level crossing. As a result, often accident occurs and many people become injured badly and sometimes it become very serious when people died due to this type of accidents. This project can help us to reduce accidents in the society by introducing automatic railway level crossing.

The main aim of this thesis is to improve safety, minimizes travel time and increase capacity of Infrastructures. This type of improvements are advantageous to health, economy and to the environment. Hence, reduced time delay at level crossing and saving travel time are the main objective of Intelligent Transportation Systems (ITS). Parameters such as day, time, weather, season and other undetermined circumstance such as accidents, special occasion, road maintenance and construction are the major contributor to traffic load.

Besides that, the usage of guards (personnel) to physically control (open/close) the gate involves heavy use of manpower which directly contributes to inefficient because sometimes it take much time. This often creates a traffic jam especially during peak hours and as a result, road users end up being late for work. In addition to that, the guards are forced to endure extreme weather conditions such as intense heat and also light drizzles just to enforce the current entry system.

1.3 History of railway level crossing

In the past, flagman were used at level crossings to give signal on the approaching train. This was done by waving a red flag to direct commuters to off clear the rail tracks. Later, manual and electrical barriers were introduced as gates to obstruct commuters from entering the railway track. The gates are swung across the railway width to allow road users to enter the track at any time. In August 27th, 1867, J. Nason and J. F. Wilson were the first US researchers to be awarded a patent of crossing gates in Boston [21].

Sometimes later when motor vehicles appeared after, this type of barrier were barely used. Further, the need for livestock barrier also diminished dramatically later. In most countries, fully gated level crossings were replaced with weaker but more-visible barrier and relied upon road users by obeying to the warning signals (as shown in figure 2). In Britain, the first automatic level crossing was introduced February 5, 1961. During the early days of Mania Railway, the right of way was given to the rail traffic simply because train cannot stop easily compare to road users [22].

Figure 2: Cross buck stop sign and line [14]

When it comes to warning systems at railway level crossings, signs are used as passive warnings or active automatic warning devices such as boom gates, flashing lights and alarms [31]. Level crossings with active warning systems has fewer accidents compared to the one with passive warning system [12].

1.4 An Overview of Automatic Barriers

Automatic Half Barrier (AHB) the most used level crossing use today. In 1992, quarter of the level crossing was AHB recorded with 41% of accidents and 57% of fatalities [76]. It is almost the same as AOCL with the speed limit of 160 km/hour [75]. In most cases, signalman are used to control the level crossing. Other than that, there are other three major types of barrier:

- ✓ Occupation/Private Crossing or Rural Barriers are normally used in very rural areas with a line speed limited to 15km/hour. The road user confirm from the signalman whether it’s safe to cross or not. In some cases, they use small miniature Stop Lights to warn the user about the oncoming train.
- ✓ Automatic Open Crossing Locally Monitored (AOCL) are used where the track line has a speed limit of 90 km/hour. This is determined by criteria such as line speed, trains number and traffic volume satisfy criteria. The crossing sequence is initiated 10 seconds after the train comes in the track circuit section. They uses alarm and traffic light as the warning devices.
- ✓ Manually Controlled Barriers (MCB) with Closed Circuit Television (CCTV) for remote viewing with a speed limit of 160km/hour. They also use signalman like AHB to operate at the crossing when the train is approaching. Everything is monitored in the signal box.

1.5 Railway safety in Europe

In 2012-2014, about 2000 railways infrastructure related accidents were recorded in EU member states significantly. This types of accidents range from collision of trains, derailments, level crossing accidents etc. (figure 3). It's further reported that accident to person is toping up the list followed by level crossing accidents. In Europe, railway collision/accident happens on weekly basis causing significant delay and disruption in the railway industry [37].

However, the fatalities number has declined and showed a downfall trend in type of railway accident except the level crossing accidents. The continuous road traffic in Europe contributes to the increasing accidents at level crossing. This could be the fact that commuters are less vigilant at such crossing but it's one the major threat to the railway industry as it disrupt the railway operation in most cases [37].

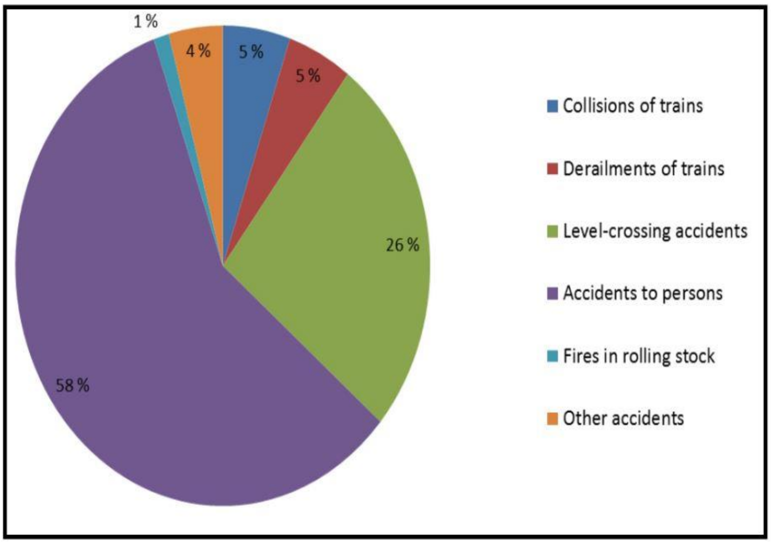

Figure 3: Breakdown of significant accidents per type [18]

1.6 Railway accident costs analysis

The cost of Accident with regards to serious injuries and fatalities, delay costs, infrastructure or material damage costs and environmental economically affect the railway industry. The cost of fatalities has the most significant economic impact to the Europeans member's economy. In 2014, it's further estimated that value of 1.4 billion Euro was used in prevention of casualties. However, the total costs of material damage and delay were 103 million Euro and 71 million EURO respectively [37].

1.7 Managing and infrastructural safety at level crossings

1.7.1 Train Protection System

There are various different types of train protection systems (TPSs) installed in Europe offering different functionalities and providing different level of safety assurance. Among all, automatic train protection system (ATP) is so far considered to be the most effective technical measure of which infrastructural managers can implement to reduce the risk of collisions, accident, and derailment on mainline railways. This system applies obedience to signals and speed restrictions by supervision, including automatic stop at signal along the railway track [18].

1.7.2 Sign types at Level crossing

Rudin-Brown et al [55] did a research to find out the effectiveness of flashing lights together with mechanical barriers and standard traffic lights. However, the study found out that level crossing with traffic lights would not give better safety benefits compared to the one with flashing lights and boom barriers. Due to the high rate of violations at passively controlled level crossings, they recommend to upgrade level crossings with passive to active traffic control devices. Further, about 72% of drivers reported that they prefer flashing lights compared to traffic lights.

1.8 Factors contributing to collisions at level crossings

There is no single reason for level crossing collisions and near misses occurring. Contributing factors can include [9]:

- People, especially road users and the extent to which they obey the law and respond appropriately to the circumstances of the moment
- Vehicles and infrastructure, including speed limits, the design of vehicles, and the design and condition of level crossings and level crossing environments
- The overall management of road-rail interfaces, including coordination between service providers, the allocation of resources, and the ways in which knowledge is applied to enhance safety.

1.9 Outline of the thesis

This thesis report consists of total of 4 chapters in total. Chapter 1 gives a broader introduction to level crossing in general, safety concerns and types of level crossing.
Chapter 2 begins with short brief (review) on a number of automatic railway gate system with advanced technology were invented to prevent accidents at a level crossing. Whereby further elaborated on pros and cons of such research systems.

Chapter 3 Introduces the methodology of the proposed technology mainly Wheel detector (sensors) discussed in brief about its uses in daily life, railway sector, in particular, and limitations etc.

Chapter 4 System Design and Implementation where the working principles, system block diagram are discussed to allow the reader to get a clear understanding of the entire system. This chapter will also give information for a proper and easy usage of the application. Then, the mathematical formulation of the model is provided where the minimum closing time is calculated.

CHAPTER 2: LITERATURE REVIEW

2.1 Review of existing system (related research)

In the past, there are quite a number of automated level crossing with advanced technology that were invented to prevent accidents at intersection. To date, studies are still going on to improve safety at level crossing. There are many studies carried out and systems developed based on different technologies to promotion the operation of railway industry without endangering the society.

The recent railway accidents are raising safety concerns in the society as well as in some other part of the world. Accidents can take place anywhere. Even the most advanced technology can't ensure accident free and 100% safe working conditions. But scientific investigation can be used just to make incremental improvements to a theory, process or the existing system. The occurrence of catastrophes could be reduced by making such investigations to find out the reasons and take necessary actions to avoid recurrence of such incidents. This has inspired many to work on the improvement of the prevailing railway for the betterment of humanity. Out of the many systems, relevant research papers and document were conducted for reviewed in detail.

2.1.1 Automation monitoring of railway transit by using RFID technology

Michal et al [47] presented the possibility of using RFID technology by railway transport monitoring. The first part of the article describes the application of RFID technology in the railway industry of Slovak. Further, describes the principle of information system and design involved in electronic way-bill. The only related problem in the railway transit is about transferring many information such as waybill, technical condition of the wagon, date of the maintenance and repairs, etc. nevertheless, there is still hope of using RFID technology. The introduction of RFID technology enhance the concept of collecting data automatically. Tracking wagon location and car information collection will be much easier.

Ilie-Zudor et al [48] narrated about the main types of RFID tags and readers, introduction to the principles of RFID technology. They emphasize on the type of frequencies the uses and systems applications. Further discussed the pros and cons in fields of applications. Even if there are number of RFID technologies currently used in the industry, its diffusion and exploitation require technical and security issues to be solved ahead of time. Nonetheless, researches are busy working on this limitation issues to reach its maximum safety and reliability usage in the industry.

Tam et al [26] conducted a research using FBG sensor to measure temperature and strain of the rail placed at different critical location. The sensors are installed on the side of the rail and also under the train carriage. The sensors provide information regarding the train status, temperature, deformation status of the rail axle vibration, axle and brake temperature. Based on the result, they found out that FBG sensor are the most effective tool for monitoring the rail healthy condition.

2.1.2 IR-Based Automatic Railway Gate Control System

The system comprises of microcontroller, motors, and sensors. The sensors installed on the track side near to the level crossing detect the train when it arrives (shown in figure 4). When the train is arriving from either side, the sensor detects the train and signal are then sent to control room. When the train arrives, at the same time IR transmitter senses and generates a signal; IR receiver receives the signal and generates an interrupt signal [8], [11], [41] and [43]. The motor rotates to the clockwise direction but it changes to the opposite direction when the interrupt signal is generated from the microcontroller ends. This system has the advantage of being cheap and simple with the disadvantage that it is slow and IR sensor gets affected by weather conditions [8].

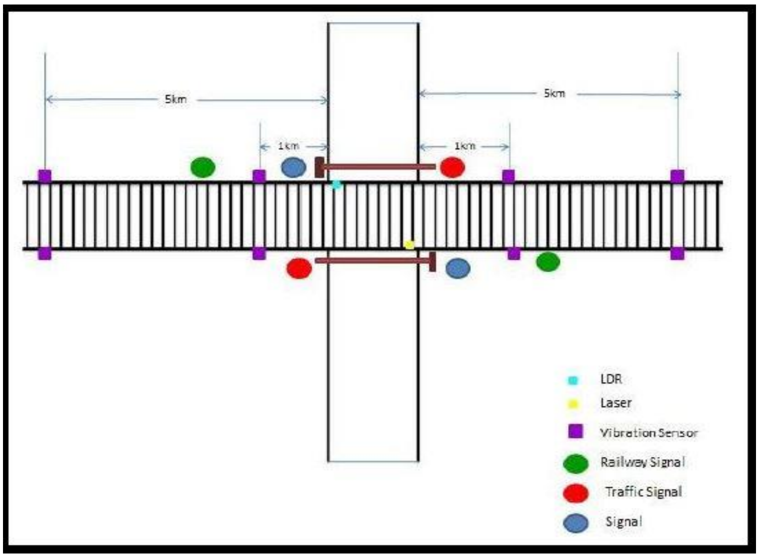

Figure 4: Architecture diagram [8].

2.1.3 Railway over Bridges (R.O.B.) and Railway under Bridge (RUB)

The proposed ROB plays a major role in traffic control system because it's more efficient and effective. The frequent closings of railway cross results in heavy traffic congestion increases time delay at level crossing and sometimes accident occur frequently. Building or constructing a Railway over Bridges (R.O.B.) is one the solution that was implemented and it's still used nowadays to prevent accidents at the unmanned level crossing (Figure 5). This solution is known to be reliable but it also has its downfalls such as financial issues, political barriers and time-consuming. In this regard, constructing a bridge takes years to complete and one has to invest a huge amount of money taking into consideration of bigger cities/towns with many level crossings. Further, education is hence required to alert commuters about the seriousness of accidents at the rail level crossing. Railway over Bridge is easy to implement and cost effective compared to other traditional methods [6].

Figure 5: ROB in cutting (Single Line) [39]

2.1.4 An Inductive loop automatic railway gate crossing system

This system uses the inductive loops that are buried along the rail track of the railway. The impedance changes whenever a material with magnet comes near to the loop. The electromagnetic theory is used in this case. The two coils are placed on both track sides. If the train passes by the section, the medium between the cores is changed and the induced voltage also gets changed. A magnetic flux is generated around it. The amplifier is used to amplify the changes and then compared using the comparator. Such information will give will notify if there's a train on the track. Once the train passes the track circuit, the flip-flop is used to give steady state signal. The disadvantages of using inductive loop detections are high cost of installation and maintenance, one have to delay the traffic during installation, obstacle detection system using newel methods [42], [46], and [62].

2.1.5 Railway level gate closing controller using Android & and GSM

In this study, gate closing and opening is controlled with the help of an android application using an android smart phone or a tablet. When the train is approaching the level crossing, an SMS is send from an android application. The SMS is sent to the GSM modem whereby it's being interpreted and further forward the command to the microcontroller. Then the microcontroller will feed the output signal to the motor and motor driver is switched on. Microcontroller receives commands to open the gates through GSM modem from an android application which will forward the signal to the motor driver. The current status of the train is displayed on LCD about the closing and opening of gates [34], [38].

Khoudor et al [62] compare different technology system used based on criteria such as Environmental condition, cost of installation, time of installation, life time, both vehicle/pedestrian detection and accuracy as shown in the table (Table 1) below.

	Technology				
Criteria	Optical beam	Sonic	Radar	Inductive loop	Video
Environmental condition	2	2	4	5	3
Installation cost	3	1	2	2	2
Life time	3	3	2	4	3
Vehicle/pedestrian detection	2	3	5	1	5
Accuracy	1	1	3	4	3
Time of installation	2	4	4	2	5
Total	13	14	20	18	21

Table 1: Comparison of different detective technologies [62]

In terms of accuracy and cost, study found out that optical beam and sonic detector optional, since they require extra sensors. Radar seems to be ideal but they only detect metals, the fact that vehicles are made from Aluminium and fibre glass nowadays. Maintenance remain the most concern because located below the road.

2.1.6 Design and Construction of an automatic Railway Gate System

Kader et al [14] wrote a paper that deals with the development of a prototype using microcontroller that integrated with other parameters such as power supply, light dependent IR sensors, force resistive sensor, and gate servo motor. The operation of the microcontroller is programmed and works based on the hardware integration. The arrival and departure of the train is detected by two IR sensors placed before and after the level crossing. Signals generated by IR sensor are sent to the Microcontroller and this will configure the operation of the servo motor and it will rotate as required requirement (clockwise or anticlockwise).

The novelty of this project is the use of Force Resistive sensor which has been integrated in this anti-collision system for the railway. The system is equipped with pressure sensors to detect any obstacle if the level crossing is not clear. Pressure sensor will take necessary action by following the developed algorithm. It system is said to be economical, reliable and less human effort required.

2.1.7 Safety Information System of Railway Level Crossings

Slovák et al [15] provided the level crossing safety by using a knowledge base and studied the level crossing existing in European countries and Japan. The accident data at level crossings were analyze and further level crossing accidents should be recorded across the Europeans countries. The new technological innovations to upgrade railway level crossings were examined. They used a web portal to create a Thematic Maps of level crossing. Road/Rail safety was enhanced by SELCAT and further helped traffic congestion avoidance. All the data regarding railway level crossing were collected, analyzed, coded, compared and matched by use of new technological innovation. This new technology require database maintenance to enhance accidents at railway level crossings reduction.

Hegyi & Mookerjee [16] collected data from an integrated system comprises of GIS, GPS, and wireless sensors. Here, data are collected with a GPS based Automatic Vehicle Location (AVL) system of the locations at different fixed time interval for road-rail network. The GIS mainly do the mapping for digital maps, high resolution satellite imagery, and digital elevation models, and they are stored in the database inventory. The wireless sensor are responsible for transmitting this data. The database inventory mapping was also done for accident site on digital maps, establishment of the post-accident responder, and cost effective measures for timely relief.

Recently, the Indian Railway further developed and launch a new technology on rail microwave radar. This type of system updates the position of train on a map whenever the train passes every station. This system doesn't provide time period for every station if they are in less than a 1 km apart unless it’s in the range of 10 to 20 kilometer apart such as in remote places [17].

Vidyasagar et al [7] proposed a sensor-based system in the past but the system was somehow not successful to a certain extent. The main reason for the failure of the sensor-based system was poor stability and less life cycle of the sensor.

Study [82] found out that there are more passive railway crossing in Australia than the active level crossings. They collected information related to passive crossing aiming to find a better solution to minimize accident at level crossings. But it’s noted that

Australia has lower population compare to other countries hence collision are relatively low. Based on the findings, they made recommendation to improve road markings, train lighting, and reflective materials and educate the public involved. Further, seeing potential in active level crossing that are relatively cheap.

Australian road and railway authorities proposed to reduce the number of level crossings with passive warnings. They improve the situation by upgrading passive level crossings to active level crossing. Level crossings with road signals provides a lot of safety benefits but not tested yet. The main reason for upgrading from passive level crossing was to test how drivers will behave towards active level crossing signs. Based on the results, the average number of vehicle's drivers reduces their speed when approaching the level crossings with response to flash lights compared traffic lights [36, 55].

2.2 Train Detection Innovation

Allotta et al [5] conducted a research about the algorithm for train detection. Since track circuit and axle counters have been the main two detectors tools implemented for train detection to ensure safety at level crossing. Knowing the train location, they could easily estimate the speed of the train, minimum closing time and also the number of axle. The above mentioned parameters were processed using cross-correlation operation to get the actual speed, minimum closing time and also the number of axle. This model was implemented in Matlab and Comsol Multiphysics environments. The algorithm was conducted through simulation to verify the performance of these operations.

Kasik &Tutsch [27] used PN300 axle counter to detect high speed train (300 km/h) to determine the occupied and free section of the rail. Digital signal generated was processed using FPGA as a controller for data transmission between the sensors and the system. Approved electromagnetic sensors were used in this research. Inductive sensors are used to detect the passage of train for digital processing. The research was successful for further security technology development. After simulation, results showed some problem regarding the development of the proposed solution.

Zhang et al [67] proposed a model using giant magnetoresistive sensors to detect a high speed train by measuring the magnetic field. They did modelling and simulation by analyzing the distribution of magnetic field on high speed rail system. The results showed the existence of train, distance, speed and number of rolling stocks.

Study [13] demonstrated a warning system that notify the train operator about the traffic load at level crossing. The system has a vehicle detector that determine whether there is a vehicle stuck at the level crossing. Information are displayed regarding the train speed and direction. It also provide warning to pedestrians and other road user about the oncoming train.

Study [25] and [60] did a research on safety at level crossing to improve safety using automation Petri Nets as a model. The modelling is done using APNs with possible failure of the system were also considered. The testing was implemented using PLC and SCADA testbed respectively in a condition were the system fail.

2.3 Level Crossing from Users Perceptive

Decision making based on human behaviors also contribute to accidents at level crossing. Kumar [24] studied that road users are intolerance to long closure duration of the gate. Further found out that almost 30% of the road users make delay decision which results in accident. Radalj at el [3] proposed a trial based on vehicle drivers on speed reduction prior the level crossing. The trial involve speed reduction from 110 km/h to 80 km/h over the distance of 600 m. demonstration of speed data analysis shows relatively mean speed differences between the set points. Ćirović & Pamučar [31] and Pattanaik & Yadav [53] found out that media and society pressure are the major factors that determine the choice of selecting the best safety system at level crossing. Hence they use fuzzy logic as an essential criteria for relevant decision making. Study [35] used fuzzy logic control for decision making during the arrival and departure of the train. Output signals are generated to warning devices. They system use three vital parameter namely; visual, acoustic, and vibration as the inputs for decision making. The model use MIMO (multiple input and multiple output) as parameters.

Tey et al [32] found out that different types of signs at railway level crossing makes the drivers more vigilant compared to single signs. The results showed that driver's response to active crossings are higher than the passive crossings. While study [29] found out that drivers prefer flashing lights than traffic lights. Klassen [63] found out that the behaviors of road users at the LC is insufficient. Most of the road users do not adhere to the rules and regulations of the road. Standard should be applied at LC and also develop new technological innovation to increase safety at LC. Education and safety campaign awareness should be carried out regularly to inform road users about the danger of misbehaving and ignoring road rules. Study [88] conducted a research to see the most gender that violate rules at level crossings. Based on the results, they have revealed male gender are more likely to violate rules compared to female gender.

2.4 Types of level crossings

Collisions are the main cause of train accident at level crossing. Level crossings differs depending on the type of protection they offer. Study [18], [28] defined the two major types of level crossing (Table 2): *Passive crossings*: the warning are provided with road signs and marking only. It’s the road user’s responsibility to make sure whether it is safe to cross the track or not [18], [26], [30], [31], [32], [33] and [69]. *Active crossings*: where the road users or pedestrian are warned about the oncoming train by closing the mechanical barriers, activate flash lights and trigger the alarms. The active crossing operation can either be automatic (e.g. barriers raised and lowered automatically) or manual [18], [26], [30], [31], [32], [33] and [69].

Crossing type				**No**
Passive		UWC-T	User-worked crossing with telephone	1690
		UWC	User-worked crossing	475
		OC	Opening crossing	47
		FP	Footpath crossing	2099
Active	**Manual**	MCG	Manually controlled gate	149
		MCB	Manually controlled barrier	173
		MCB-OD	Manually controlled barrier with obstacle detection	81
		MCB-CCT	MCB monitored by closed-circuit television	422
	Automatic	AHB	Automatic half-barrier	437
		ABCL	Automatic barrier locally monitored	57
		AOCL-B	Automatic open crossing locally monitored with barrier	66
		AOCL/R	Automatic open crossing locally or remotely monitored	31
		UWC-MWL	User-worked crossing with miniature warning lights	97
		FT-MWL	Footpath crossing with miniature warning lights	124
Total				**5948**

Table 2: Level crossing categories by class and type [18].

Generally, automatic barrier and manual controlled crossings (including those monitored by CCTV) are mostly used on public roads with high traffic volume. Automatic half-barrier crossings with less disturbance to road traffic for each train traverse are mostly used compared to manually controlled crossings, but they have a relatively high average risk. Automatic open crossings with flash lights and no barriers have a higher average risk of train colliding with road vehicles [18].

Study [18] further said that passive crossings are mainly used in rural areas. These types of crossings either used on private roads, for instance, access to farms and fields. In general, user-worked crossings (UWCs) are comparatively high-risk compared to the volume of traffic passing over them. Level crossings that are not designed for vehicles are grouped under the category of *footpath crossings*. This category also includes bridleway and barrow crossings [18].

Classification methods of LC differs from one country to another. Other than that, there are main attributes depending on the functional of the road and railway crossing system such as Location of LC, owner of LC, volume of traffic, speed of traffic, the width of the road and equipment used at LC e.g. passive or active [61].

2.5 Level crossing in Asia

According to the statistics provided by the railways in south western division (SWR), there was 1270 Level Crossings with 750 manned and 520 unmanned. Overall, the state has 445 unmanned level crossings spread across Karnataka. In Indonesian, all level crossings are automated using sirens in place of conventional bells. Further, Hong Kong uses underground railway network or elevated overpass is the most common. This means the use of automated Level crossing are very rare. Japan also uses underground railway network system across different cities but it's estimated with 34000 Level crossings all around [45].

Pwint et al [42] wrote a paper mainly focusing on two parameters. Firstly, time reduction when the gate is closed and secondly, safety provision to road users in minimizing accidents by using automated unmanned railway gate technique. Another paper modeled the control of railway track by using an anti-collision technique, the system uses an 8952 microcontroller to avoid the railway accidents [44]. Another study proposed an intelligent railway level crossing system to prevent accidents. The level crossing image captured and warning messages are sent to the train operators through wireless communication within the level crossing zone. The warning messages are extracted using computer vision. The captured image and warning message of level crossing are recognized by train operator via message color, flickering, and warning sound. This is necessary for the train operator to take precaution and decide on action to take. At the same time, vehicle drivers are notified about the location and speed of the approaching train via LCD display [49] and [50].

Another study focuses on how to improve safety at level crossing. They discovered a new methodology for monitoring level crossing. They pin point out the main causes of accident at level crossing. Improvement of safety at level crossing is somehow costly but often known with its correlation with required cost [51] and [52].

Vinit [4] study about automated level crossing to prevent the risk factor of accident. In the system, they proposed an IR sensors to detect the when its arriving and departing the level crossing. Raspberry Pi was used as a controller to control the opening and closing of the gate with the help of servo motor.

Ramachandran and Prakash [53] developed a system based on FPGA with a System on Chip (SOC) to prevent accident at level crossing (shown in Figure 6). The system uses communication RF module (sender) and RF module (receiver) with a very large coverage of about 24 km. RF Transceiver composes of some salient features such as security and Advanced Networking, True peer-to-peer communications, Point-to-point & point-to-multipoint topologies, RF data stream up to 9600 bps, zero configuration required for out-of-the-box. The system support multiple of data formats.

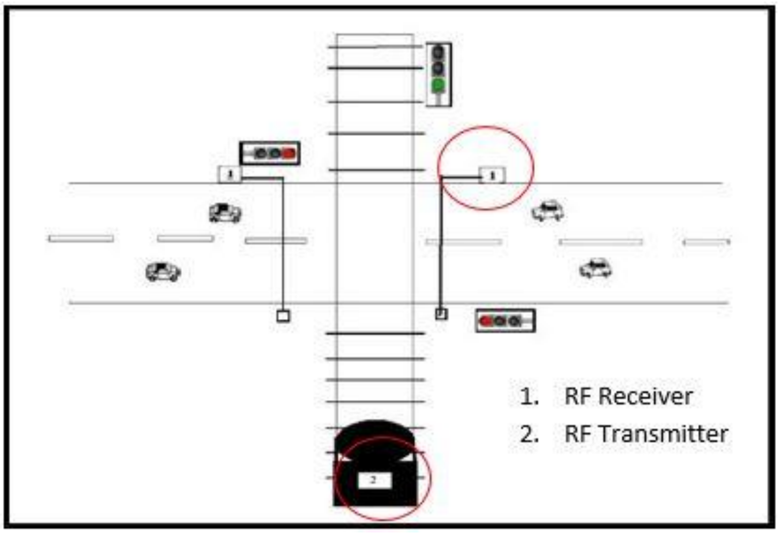

Figure 6: Proposed system for the design of SOC [53].

Vidyasagar et al [7] proposed a system with two vibration sensors used for gate control at level crossing. Unauthorized objects on the track are detected using ultrasonic sensor place at the crossing level. The signals generated of unauthorized objects on the track, closing, and opening of the gate is transmitted to the central control room via wireless communication protocol. Kumar and Jain [10] proposed another by detecting the rolling noise caused by the train on the rail track. The solution was safe and reliable whereby the train is detected on time and initiate warnings and barrier actuation can be done timely.

The proposed system designed using powerful magnetic x-bee sensor and microcontroller to prevent accident at railway level crossing. Two sensors (foreside and after side sensor) placed before and after the level crossing to detect the arrival and leaving of train respectively. The foreside sensor gets activated by the approaching train which initiate gate closing. The signal generated by the after side sensor initiate the gate opening via microcontroller motor turns in opposite direction automatically [54].

Punekar and Raut [56] discussed the methods of tracking the location of trains. The system involves detection and tracking integrated together. The system make use of GSM and GPS technologies which gives up-to-date information about the ongoing operation. Due to the system real time surveillance, it serves as a solution to prevent accident at level crossing by giving early warning to train operators.

2.6 Level crossing grades and Gate mechanism

Study [40] defined Level Crossing Grade (LCG) refers as a safety devices installed at the crossing. There are three crossing grades:

1. Grade 1 level crossing is equipped with a warning system and road crossing barrier. It also has a warning bell and flash lights with two barrier on both sides of the crossing. Figure 7 shows a typical schematic diagram of a typical Grade 1 crossing.
2. Grade 3 level crossing only has a warning system.
3. Grade 4 level crossing only has signs either a warning system or a barrier.

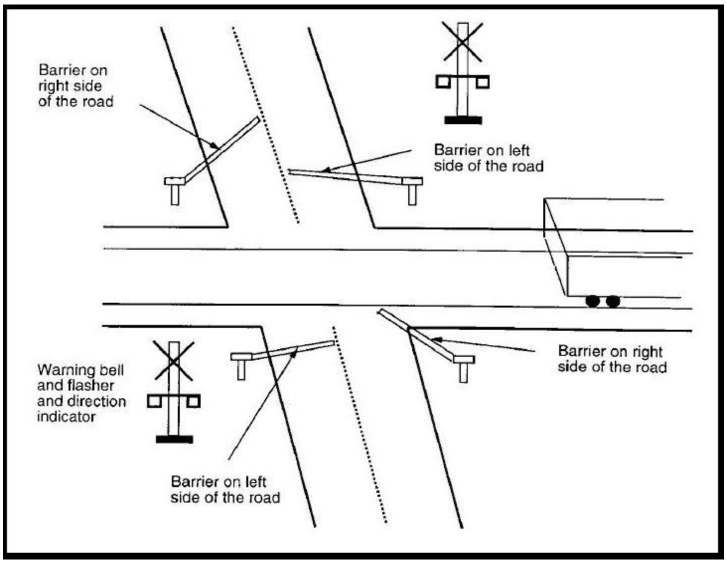

Figure 7: Schematic diagram of a typical Grade 1 level crossing [40]

Gate mechanism can either be Automatic or Semi-automatic barrier. The Automatic barrier is fully automated and is connected to the train detection system like sensors and so on. When the approaching train is detected, the barrier starts coming down; it is down well before the train reaches the crossing. Semi-automatic barriers are installed in station areas so that they can be operated manually as well as automatically. The manual operation is usually done by the maintenance staff under the supervision of the station master [40].

2.7 In-vehicle warning system

2.7.1 Minnesota In-vehicle warning

In Minnesota, they use wireless communication system between vehicle license plates and antennas built in crossbuck, ‘RXR’ sign. The signals generated from the train detection device are transmitted to the antenna. The vehicle divers are notified through the in-vehicle display by means of both visual and audio (shown in Figure 8). They used about 30 school buses to do the experiment. The buses are equipped with Head-of-Train (HOT) which help to coordinate braking between rear and front from the passive train detection system. No other infrastructure needed at the level crossing. About 80% of the vehicle driver’s behaviors were not negatively affected by the new system but rather gave on time alert. On the other hand, about 15% of driver’s driving behaviour were affected by the new system [72] and [73].

Figure 8: In-vehicle warning system [72].

2.7.2 Illinois In-vehicle warning

A project conducted in Illinois about train detection to activate level crossing warning devices using track circuit. Vehicles are equipped with in-vehicle receiver devices that receive signal from the transmitter when they come at a certain distance. The in-vehicle receiver functions in three different ways: audible, visual or both audible/visual about the presences of an approaching train. Based on the results, they found out that about 300 drivers were able to use the technology successfully [72] and [73].

According to Tokody et al [84], statistics data has proven that traffic safety can be improved by developing system that would help and support vehicle drivers. This can be system that assist vehicle drivers and train operators to avoid accident at level crossing. Collision avoidance devices could also be another optional solution that should help drivers to avoid accident at level crossing. Further, developing a system that will establish a communication between various parties (e.g. between a car and a train) is one the main element of ITS. Never the less, the development of such technology are currently in progress. The existing autonomous system only work well between Vehicle-to-Vehicle (V2V) (range up to 80m) but not suitable for high speed train. In 2010, European Directive mentioned that Intelligent Transportation System (ITS) would be one of the most important transportation technology that will improve transport safety.

2.8 Additional Devices/Systems at Passive Crossings

Most of the passive level crossings are located in countryside were traffic volumes are relatively low. Due to financial constraints, the rail industry couldn't provide more active protection systems in isolated rural areas. Track circuit are normally isolated in separate section and they are supposed to be connected to each other, as a result, such connection are relatively costly [68]. Today, there are other type sensors and communication channels used for active signaling which are relatively cheaper than track circuits [68]. According to study [70], the idea is not replace the current active device in use which are cheaper but to optimize the operation in order to improve safety at level crossing using passive signals.

According to the Victorian Parliament [71], they stressed that in places where expensive warning devices could not be justified, cheaper warning devices could be used instead. However, they narrated that chances of changing, replacing or upgrading to new technologies are very slim due to the above mentioned factor. Although, the new technologies provide a greater advantage with regards to safety at level crossing. The Committee further concluded that due to high cost of active warning devices such as bells, flashing lights, mechanical barriers, tunnel and bridges construction will impede the upgrade of passive crossing to active crossing in Australia. As a result, priorities are given to the more affordable (cheaper) solutions that would deliver same service as far as safety is concerned.

2.9 Concluding Remarks

As a summary, the best approach for "Level crossing protection system" would use single wheel detector to detect the presence of train, speed, and direction of the train. The signal transmission between sensor and the evaluation board is transferred using optic fiber cables. Further, using warning devices such as warning alarm, LED flashing lights, LCD display and automatic gate as the active warning devices to the road users.

CHAPTER 3: SYSTEM METHODOLOGY

3.1 System requirement

The primarily aim of this chapter is to describe and discuss the research methodology applied in this work. In addition to that, emphasized the methods and evaluating them to increase usage, validity, and reliability in the railway industry.

The level crossing should be equipped with at least warning lights, boom gate and alarm system. When setting up a level crossing, the design should be approved by the General Manager Traffic Management to check whether it meet or does not meet the requirements as per their standards and regulation [87].

The idea is to develop a sensor-based automation system method. It contains wheel sensor attached to the track, which detect the train when it passes by. This sensor generate signals and sends information to the control unit through optic fiber cables. The control unit uses the information from the sensor module to perform required activities. The boom gate which makes up the mechanical barrier, flashing lights, and alarm warning are the required warning devices.

3.2 Train detection device

Train detection system plays a vital role when it comes safety, control, and signaling in the operation of train. However, the choice of choosing the best method depends on the specific parameters such as cost, maintenance, speed of data transfer, with regard to its application use. Nowadays, the railway industry require system the will fulfil the best functions for its operation of signalling transmission and processing. Due to ever increasing level crossing accidents, it requires advanced technology to secure safety of humankinds. Using high technological systems and equipments will guarantee smooth operation in the railway industry [2].

3.2.1 Type of train detection

Train detection are the main components of a level crossing protection system. The information from outdoor equipment in used in control logic of the level crossing protection system to initiate the warning and operational sequences. In automatic level crossing control systems, the warning and closure/opening sequence are interrelated to the signaling system and are triggered by the train movements. Nowadays the focus is on wheel detection technology for synergistic effects [20].

There is an unlimited range of availability configuration options for wheel detection. The system can be based on detection points only. But also on tract location, combinations of detection points and track location or the implementation of speed-dependent. Additional information such direction of traffic and train speed are also vital parameter for this application used to meet various different specific requirements [20].

3.2.2 Wheel detector (Frauscher’s Sensor)

The use of Wheel detection equipped with sensors plays a significant role in railway industries worldwide. They are reliable and relatively cheap based on range of signaling applications such as for level crossing protection system. However, there are many different ways in which wheel detection system can be used nowadays. Further to their detection functions, they are also used for additional signals such as direction of the traffic, wheel diameter, wheel center pulse as well as modern interfaces, opening up further new fields of applications [19] and [20].

Wheel sensor are devices installed on the rail track side to detect the existence of rail wheel (Figure 9). The installation and type of wheel sensor will determine the wheel diameter based on the signal output. Normally the devices has one or two inductive coils. Train’s speed and direction signals can be determined using the two single coil devices. Other than direction, wheel diameter etc., wheel detector also has an advantage of determining the speed of the train. To do this, the wheel detector’s evaluation board (EB) converts analogue signals from the wheel sensor coils to a digital signal. This can be output via vital dry contact relay or opt coupler [57].

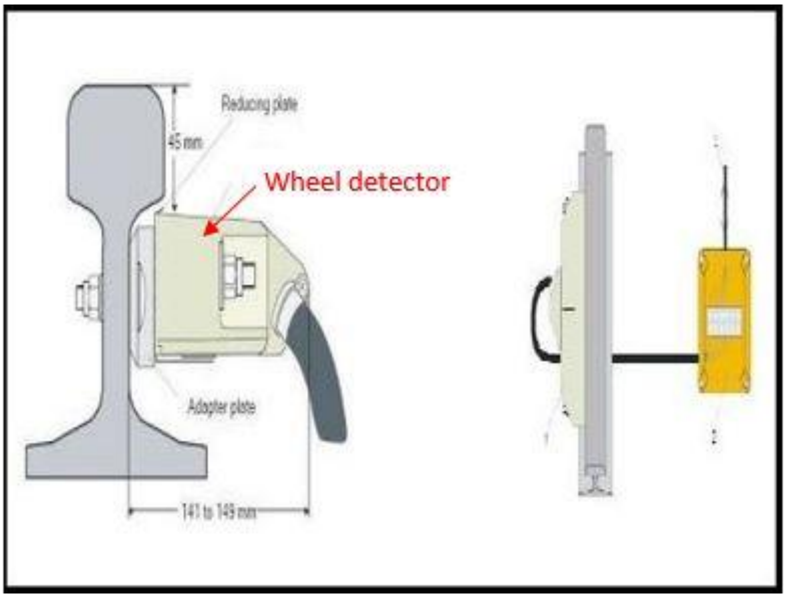

Figure 9: Wheel detector field equipment Layout [74].

Wheel detector function by detecting the travelling direction and presence of the train wheels at the strike in point. The system consist of two types of components: sensor and an evaluation board. The evaluation board is installed in a signal control box along the track line side. The evaluation board generates signal based on the sensor and generates either a vacant or occupied [77].

The advantages of wheel detector:

- Reliable and cost-effective basis for a range of signalling applications.
- Can operate with practically all widely used rail profiles.
- Open analogue interface for easy integrate - The open analogue interface of the RSR110 enables it to be integrated into the system electronics easily and directly. Evaluation can take place via a PLC or a microcontroller, for example. Since a separate evaluation board is not required, the number of hardware components also means that less space is required and less power consumption.
- Flexible evaluation - provides information in the form of load-independent current values. This enables the detection of an axle, direction, speed, axle count, and wheel centre and wheel diameter to be interpreted from the analogue signal curve.
- They have few hardware components which makes their installation simple and easy assembly of devices.
- Lower power consumption capacity range from 8 V DC to 33 V DC.
- High resistance to magnetic field interference, radio wave, and rail currents.
- Climatic condition stress: they can tolerate of temperature of -40°C to +85°C, 100% of tolerant of humidity and resistant to UV.
- Wheel sensor can detect a traversing speed range from speed of 0 km/h (static) to 450 km/h.

3.2.3 Sensor working principle

According to study [78], a detection point has two separate couple of detectors, that why the device can detect the direction in way in which the train passes the detectors. When the net count is evaluated as zero at the second sensor, then the level crossing is presumed to be clear of the train [79]. The system consists of a sensor coils, electronic unit, and the evaluator unit placed along the rail track which receives the signal from sensor when wheels entering and existence on the section.

The sensor detect the existence of the rail wheel using linkage of electromagnetic flux between two coils mounted on both rail sides. The generated flux are always in low reluctance when flowing through the coil. During the detection process, the magnetic field path is developed between the train wheel and rail track. As a result, the receiving coil will receive less flux and low induced voltage.

The induced voltage in the receiving coil is continuously monitored and its changes with some limitation threshold interpret if the wheel existence or not. Generally, the rail wheel is detected when the threshold level is more compared to the amplitude of the induced voltage in the receiving coil [78].

3.3 Warning devices

3.3.1 Mechanical barrier (Automatic gates)

There functions as barrier when train is passing by the level crossing. Normally they start to lower down with minimum of 3 seconds when the light start to flash. When the crossing is clear off the train, the gate should raise back to its upright position within less than 12 seconds [89]. Level crossing mechanical barrier ensures the maximum safety both for the road user and for railway traffic. Red and white bands boom gate with 600 mm long is preferred. A retro-reflective material strip should be at least 50 mm deep that cover the whole length of every band on all the barrier sides to provide maximum visibility (Figure 10). The boom gate is automatically opened and closed with the help of a servo motor that rotate either anticlockwise or clockwise direction. A servomotor can be either rotary or linear actuator that allows for linear position, velocity, and acceleration. It’s a servomechanism with a motor coupled installed inside to sensor for feedback position. Generally, they are closed-loop system that make use of feedback position to control the final position and its motion. The control input signal can be either digital or analogue, expressing the command position of the output shaft [74]. If there is no train approaching, the active warnings should remain off and boom barriers should be raised up in the position [68].

Figure 10: Red and white stripped boom gate (gate arm) [60]

3.3.2 Flashing light signal (LED traffic light)

Flash lights at level crossing is has two red lights, a "moon-white" light as shown in figure 11 (Tokody D., personal communication, March 19, 2017). The two red light flash alternately at the rate 45 – 60 times in a minute. They are vary in design and usually pointed to the road users. They are accompanied by crossbuck mounted on the same pole on top of the lights [89]. Traffic lights (LED) are necessary to give active warning to the road users. If there is no train approaching, the active warnings should remain off, road users has a right of way [68]. LEDs signal should be of an energy-saving types. They have a long service life but yet require less maintenance. On the description of their high contrast, they shine brighter and more clearly than conventional signal transmitters and are clearly visible even in direct sunlight. Nowadays, the malfunctions of LED status can be checked and detected via current monitoring [86].

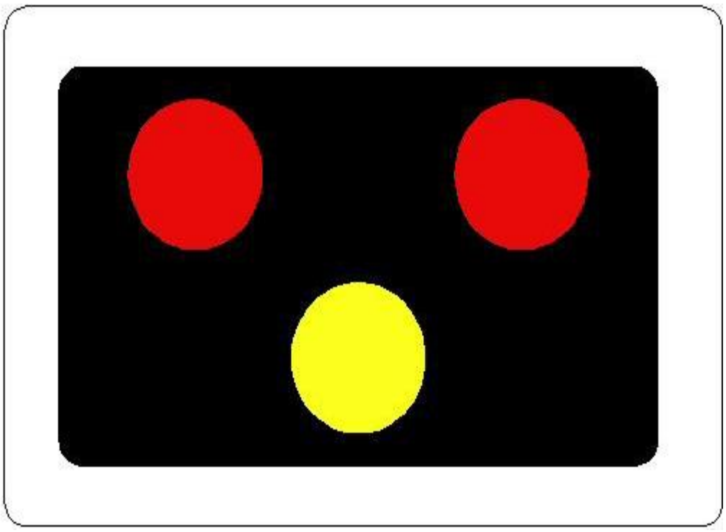

Figure 11: Typical road traffic lights signal LED [69]

3.3.3 Warning alarm

This is audible warning equipment used together with other active control devices. It necessary to warn bicyclists and pedestrians. The alarm is activated when the warning light commence to flash. The alarm should go off when the automatic gates descend down [89].

3.4 Evaluation Board

Figure 12 shows the sensor's trackside control unit, an evaluation board placed within the box on a short pillar of support. Evaluation board supply and control the sensor and sends the modified signal from the sensing systems via the optical fibre cables to the indoor equipment (MicroLok® II). The other function of the evaluation board (EB) is to converts analogue signals from the wheel sensor coils to a digital signal [85].

Figure 12: Evaluation box along the track side [85].

3.5 Level crossing controller (MicroLok® II)

3.5.1 Description of MicroLok® II

An increase in traffic volumes, use of railway worldwide requires proper management, especially at level crossing. Efficiency, safety and effective techniques with regarding to level crossing protection system would ensure operation management [81]. MicroLok® II controller is used to monitor the status of all the level crossing related devices such as flashing lights and mechanical barriers triggering, alarm activation, and also manual control of gate mechanism in case of emergency.

MicroLok II is an Ansaldo STS's manufactured control unit used at level crossing (Figure 13). It has a simple distributed architecture that require low cost user-programmable safe system. It's a highly reliable protection system controller used at railway level crossing nowadays. All the inputs are connected to MicroLok module using logic application and produces outputs to actuators, such as signal LED lights, LCD display, and boom lifts. They main key features of MicroLok include a standard PCB card file, board of CPU logic, set of vital and non-vital input/output PCBs, Power Supply/CPS PCB and a Vital Cut-Off Relay [80].

Besides its size, the design of this controller's modular is flexible collection of digital and analog I/O modules, thermocouples, temperature resistance detectors and serial modules to connect different types of interface precision devices and sensors used in the active warning system. The controller executes the program depending on the received signal from the wheel sensor. The MicroLok controller sends output signals to boom gate, alarm, traffic light LED [80].

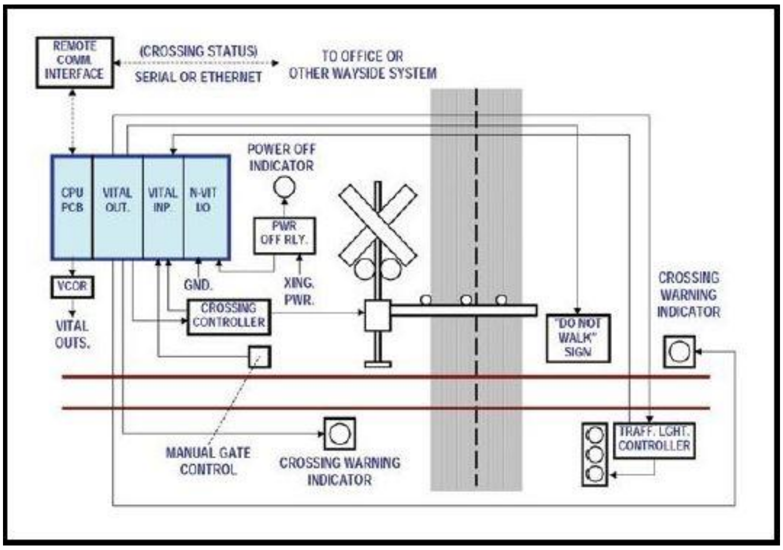

Figure 13: MicroLok® II level crossing protection system [70].

3.5.2 Advantages of MicroLok® II

MicroLok® II is a tailor-made controller for railway level crossing control applications. Based on its special design, the following features illustrate some of the unique benefits the controller offers level crossings [80].

- Handles the full range of crossing devices and functions.
- Compatible with Ansaldo STS or non-Ansaldo STS crossing equipment.
- Based on service-proven wayside signalling systems.
- Designed for fail-safe operations (gates down upon system failure).
- Ample memory, I/O channels and serial ports for any crossing application.
- Stand-alone system or integrated with larger wayside/ office control system.
- Permits remote reporting/monitoring of crossing conditions.
- Several options for receipt of crossing track occupancy indications.

3.5.3 Automated fault correction process

STS is the fully automated process of intelligent that corrects unavoidable, external interference. Once its reset, other options can be provided without affecting the system as far as safety is concerned [2].

Daily diagnosis improve efficiency of the system. Regular checkup and diagnosis of the system makes maintenance work scheduling easy and also prevent the system from failing by employing other prevention measures. A widespread analytic system helps to reduce time spent in to do daily maintenance. Other important evidence, such inactive current flow in the wheel sensor, can be detected from a central service area [2].

The warning devices controller at the level crossing signals must be connected to Sydney Coordinated Adaptive Traffic System (SCATS) to make sure that the operation is monitored and alarm notified. The system has two indications mainly train demand

and crossing operation of which each comprises of two separate signals, one normally closed and one normally open (Table 3). Under normal condition, operation with free fault will change the state of the signal if the indication change. If there is any fault change of the signal detected by the controller, then the indication can either be he train demand or crossing operating circuits and the controller shall operate as if a train demand has been received. The RTA and the Railway Authority have to select a person who will responsible for each of the level crossing and establish an agreement to report all the errors/faults within the operation of system [87].

Train Demand	**Normally closed-open**	**Normally closed-closed**
Normally open-open	Train demand	NO TRAIN DEMAND
Normally closed-closed	TRAIN DEMAND	Train demand
Crossing operating	**Normally closed-open**	**Normally closed-open**
Normally open-open	Crossing operating	CROSSING NOT OPERATING
Normally open-closed	CROSSING OPERATING	Crossing operation

Table 3: Faults and malfunction diagnosis process [87]

3.6 Power Supply (Solar power)

The power supply of level crossing should consist of alternate current power source with an extra standby battery. A battery should have a sufficient capacity to ensure continuous operation of the level crossing on 24 hours/day basis including loads. Hence, it’s necessary to incorporate solar as a backup source of power when there’s no constant power supply. Power interruption during maintenance or repair should not hinder to operation at LC as such [68].

To secure the power supply to all critical systems, emergency and control systems, networks, signaling; solar system is used as a source of power to achieve “no-break” power supply condition for the system. These type of level crossing systems require simple maintenance, efficient, reliable and relatively cheaper compared to other automated system. Solar are renewable source of energy, no pollution during operation and it can be used in an isolated locations. The size of the PV solar system will depend level crossing loads such as barrier, flash light, control system, sensor devices.

Generally, level crossing protection operate as a closed system in independently from interlocking and without any central power supply, hence solar power is the only option, with a focus on a system that consume relatively low power [23].

3.7 Data transmission

3.7.1 Optic fibre cables

Fibre optic cables are known to be faster in transmitting information compared to copper cables. They are more reliable and barely affected by bad weather condition [59]. The figure (Figure 14) below show a systematic fiber optic communication with data input and output. They also have no scrap value which should deter any would-be thieves from targeting the cables and disrupting the network [57]. In remote areas with no fibre optic connections, radio network can be used instead. The primary means of transmitting signals is a fibre optic network because of high transmission rate, low cost and easy integration (Sommergruber, 2015). Single-mode fibre optic cable is preferred between locations of signals be either 12 SMOF General Installation or 24 SMOF General Installation stock standard cable as per SPM 0677 Single Mode Optical Fibre Cable [83].

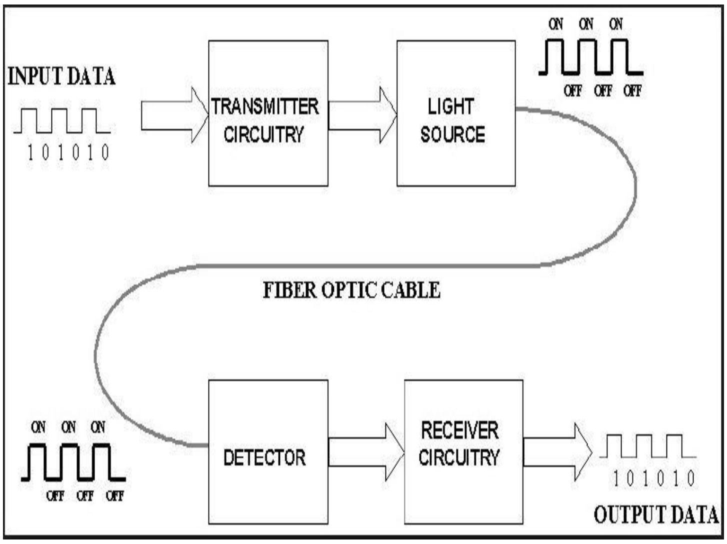

Figure 14: Basic fiber optic communication system [58]

3.7.2 Advantages of fiber optic cables

Nonetheless, nowadays fiber optics is regarded as the most highly graded and appropriate connectivity technology and experience in the railway industry now and also in the future. Looking at the system from performance point of view, fiber optic technology is regarded as one the best when it comes to data transmission compared to metal based cables [58]. According to study [57, 58], optic fiber cable is more preferred for data transmission than metal based cable due to the following characteristics:

- ***Long-distance signal transmission***

Comparing the signal transmission interval of optic fiber cable to metallic-based systems, optic fiber has low amplitude of signal and high signal integrity. But optical can't go longer than 100 km without active or passive processing.

- ***Nonconductivity***

Optic Fiber cable are not affected by electromagnetic interference such as radio frequency interference due to their non-metallic components. Further, they have dielectric nature. Another advantage of optical fibers is their dielectric nature.

- ***Security***

It's difficult to detect the signal communicated by the optic fiber cable due to their dielectric nature characteristics. As a result, it difficult access information from data cable unless one have to interfere with the connections. Security surveillance can be easily detect the illegal or shortcut connections.

- ***Designed for future applications needs***

The decreasing in the price of electronics has resulted in fiber optics being affordable and more preferred today. In most cases, fiber is relatively cheaper than copper. With rapid increase in bandwidth demands of technology, fiber optic will remain and play a significant role in success of communication in a long run.

CHAPTER 4: SYSTEM DESIGN AND IMPLEMENTATION

4.1 Introduction

Each Level crossing protection system has its own types and variants of technical design. Each country has its own specific design, standards and safety requirements as far as level crossing protection system is concerned. Each designer for level crossing protection offers different technical solution according to the standards for being either local or regional. As flexible, accessible and combined components of level crossing protection system, wheel detection technology offer many benefits that will satisfy a series of safety requirements and operational conditions [23].

4.2 Wheel detector mechanisms for LC

A single wheel sensor attached to the rail are used for train detection to activate and deactivate the level-crossing system. The train is remotely monitored when it passes the strike-in point and signal is generated. The speed, direction and state occupancy of the train are determined in the process. The status indications are evaluated and the command for activation and deactivation of the level crossing are processed by the controller.

The evaluation board take the analogue signal and converts it to digital signal. This can be output via vital dry contact relay or opt coupler (Philipp P., personal communication, April 03, 2017). The MicroLok module process the signal from the evaluation board for level control system. In main control system of level crossing systems, protection of the level crossing is initiated and monitored with the setting of the route.

4.2.1 Active level crossing closing and opening time

The proposed automated level crossing system has two major detection point mainly strike-in and strike-out (shown in figure 15). The distance between striking-in point and level crossing is determined by the maximum speed of the line track. Time needed to secure the level crossing is also one of aspect that determine the distance between strike-in point and level crossing. Whereas the strike-out is located after the crossing level. The waiting time for private vehicles should be kept to a minimum. This represents a particular challenge when trains travelling at different speeds approach the level crossing [66].

Each train has its own maximum speed on the track line. Therefore it’s important to optimize the closing times of a level crossing. Wheel detection initiate and create the closing the closing time. Delay is necessary for slower moving train while immediate closing may be requested for fast moving. Conversely, necessary to determine the crossing speed at the point of closing from the wheel detection components [65] and [67].

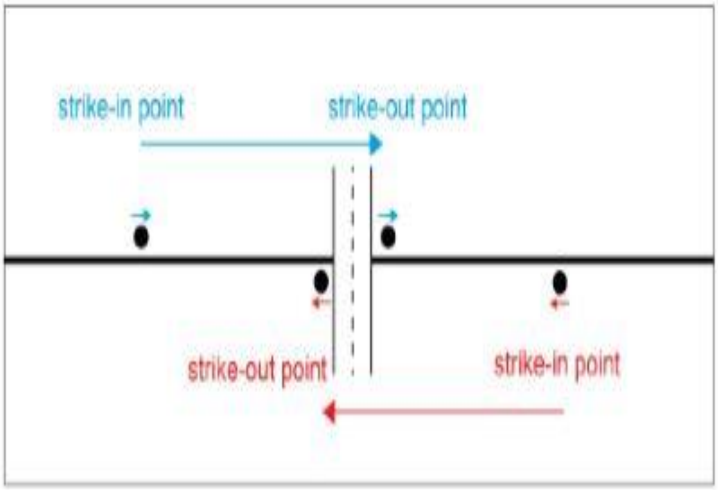

Figure 15: Active level crossing working principle [66].

4.2.2 Gate delay

Gate delay is defined as the time when flashing lights begin flashing before the boom gate start lowering down. Generally, gate delay is necessary to allow the vehicles to clear off the level crossing. Gate delay is very important in railway signalling system and its set as a range due to the mechanical tolerance variation of the boom gate.

Normally gate delay for a level crossing range between 10 to 12 seconds. In case w there are long or either slow moving vehicles at the level crossing, gates delay may be the solution to allow a vehicle which is are still under the boom gate to clear off before the boom gate start descending. The gate delay is a standard set by the Rail Authority depending on the type of vehicle use during RTA declaration. There are four main categories have been defined, with the expectation gate delay, to accommodate all vehicle based on their speed and/ or length [87].

- No long vehicles – 12 seconds
- B-doubles – 12 seconds
- Double road train – 16 seconds
- Triple road train – 21 seconds

4.2.3 Speed Relation of different trains

Nowadays, wheel sensors are used for train detection at the level crossing protection systems control [64]. In most cases, the strike in distance is determined by the speed and the time train will take to reach the level crossing. Hence, waiting time for road users should be set to minimum. But it's somehow challenging because different trains approaching the level crossing runs at different speed. Figure 16 shows the relationship between speed and time difference or level crossing waiting time to the road users.

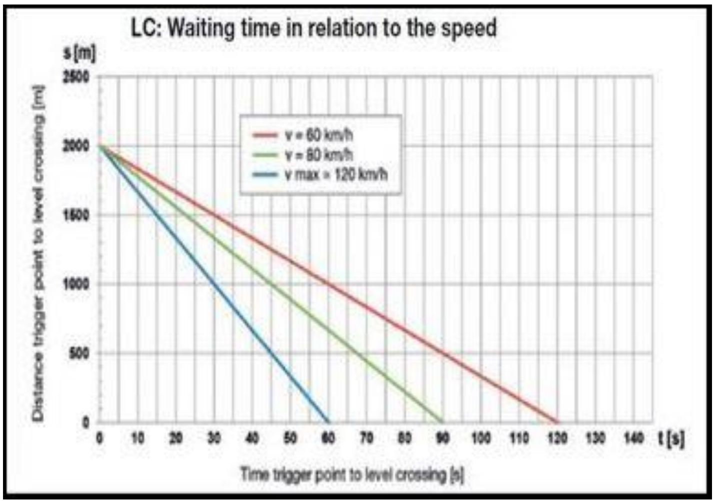

*Figure 16: Speed-dependent control of level crossing protectio*n systems [65]

For instance, Assume two trains running at the maximum speed of 120 km/h (passenger train) and 60 km/h (freight train) respectively, the striking-in point is situated at the distance of 2 km from the level crossing protection system. Therefore, the road users have to wait for about 60 seconds at the level crossing or sometime slightly longer than that if necessary. The level crossing activation for slow running train can be delayed by reducing the waiting time provided the train's speed is measured at the striking-in point [65] and [66].

4.3 Barrier crossing time

4.3.1 Warning time

Regardless of what speeding the train is operating on the track, the circuits controlling the automatic warning devices should provide a minimum operation of 30 seconds before the train arrive at the level crossing. This 30 second is a minimum warning time. The warning time should be enough at least to make sure that all the vehicle that are operating at the crossing are cleared off. Factors that determine the minimum closing time are such as; the type of road grade, the crossing width, the speed and length of the vehicle using the level crossing, and the state of crossing surface. Warning time should not be excessive, as road users may enter the crossing if they cannot see the oncoming train especially if the site is obstructed or curved track line [89].

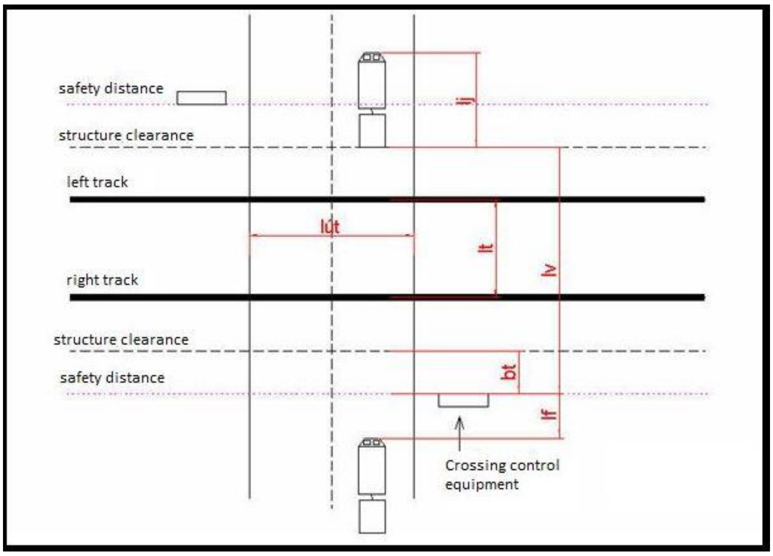

Figure 17: Level crossing min closing time calculation graph

4.3.2 Mathematical calculations: minimum closing time

Parameters:

$-t_{\min} - \min$: Closing time (minimum 30 sec)

$t_{\min} \geq 30s$

L_v = the length of the route at risk

L_j = long vehicle length (22m)

L_f = evacuation speed of stopping distances (3m)

V_j = evacuation speed (1.6 m/sec = 5.7 km/h)

t_0 = extra security time (10 sec)

L_{ut} = Road width, minimum traffic lane width 3m (Road with min. 2 x 3m = 6m)

b_t = Distance between structure clearance and safety distance = 2m

α = Crossing angle, can be any parameter from $0^\circ - 90^\circ$

L_t = Distance between track centres = Min. 4m (straight track) new construction min. 5m, reconstruction min. 4,75m

$$\text{Formula: } L_v = (4 + \mathrm{L}_t + \mathrm{b}_t) / \sin\alpha + (\mathrm{L}_{ut} / 2)\,\mathrm{tg}\,\alpha$$

$$= (4 + 5 + 2) / \sin 45^\circ + (\frac{6}{2})\,\mathrm{tg}\,45^\circ$$

= 18.56 m

$$\text{Formula: } t_{\min} = \frac{L_v + L_j + L_f}{V_j + L_0}$$

$$= \frac{18.56m + 22m + 3m}{1.6m/s + 10s}$$

= 52.44 s

4.3.3 Design of system block diagram

This block diagram (Figure 18) represents the working principle of unmanned and advanced automated level crossing, in which when the coming train is detected by the first wheel sensor, it sends signal to controller which will command the driver to start and control the servo motor to let the boom gate to close automatically, it will automatically warn the commuters about the train arrival with the help of alarm and LED traffic lights and LCD which will show the countdown time related to the distance. The train deactivates the level-crossing protection system and resets it after its passes the strike-out point. After this, the stepper motor starts operating using driver circuit based on the instruction from the controller. The gate arm which is connected to the shaft of the stepper motor open very slowly step by step. The train wheel bridges the one set of two Transmitter/Receiver coils of different frequencies while passing over them and creates an overlapping pulse for Phase detector 1 and phase detector 2 which results in state occupancy. When phase detector 2 signal is zero “0”, and no disruption, errors or faults are detected, the system will send out signals that the level crossing is cleared for deactivation. In other cases, the level crossing remain active if the track is occupied.

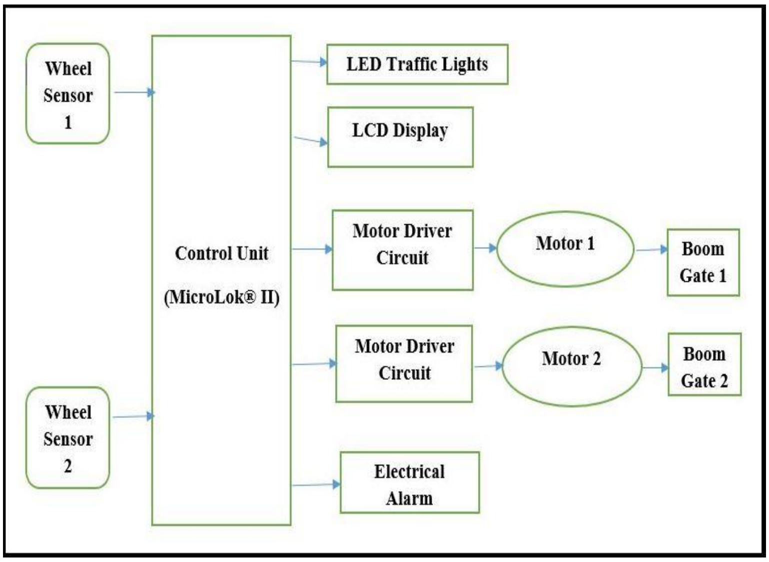

Figure 18: Block diagram of the system design

4.4 Sequence of Operation

Basically, this automatic railway level crossing system consists of 4 main parts. Sensing, transmitting, processing and controlling. Considering the train coming from either side when it reach near the check-in point, signal will send the signal to the control unit via optical fiber transmission medium. Then the gate will be closed. When the train reach check-out point it gets activated and send the information to the controller. The controller will open the gate.

When there is no train approaching the level crossing, the warning signals should be extinguished, the mechanical barriers should be raised up in a position, right of way to road users and warning alarm should be silent. When the train is approaching the level crossing, the warning signals should start and continue to flash alternately and the warning alarm should start and continue to make sound. After 10 seconds of the interval time, the boom barriers shall commence to lower with an additional time of 10 to 13 seconds they should be fully lowered position completely.

In the case of level crossings with extended warning time due to slower train, the delay before the mechanical barrier starts to lower should be increased between 5 seconds to 16 seconds further. If the minimum closing time has expired the front of the approaching train will reach the level crossing. After the train has cleared the level crossing (check-out point), the booms will start to upswing to the upright position and the bell will be silenced. The mechanical barriers will reach its upright position within 10 seconds and the warning signals should be extinguished.

CONCLUSIONS

The automatic railway level crossing system is developed on the idea of reducing accidents at level crossing around the world. Level crossing without active warning devices such as mechanical barriers, flashing lights, and alarms present dangers to both rail and road traffic. Automation of the closing and opening of the barrier gates using wheel detector sensors would reduce accidents to a greater extend. At the same time, it may not always be practical or necessary to remove a railroad crossing through costly grade separation in order to improve safety for rail and road travelers.

By utilizing the hardware and software components and linking them up into an entry access system, this system would serve as the best, cost-effective, convenient, efficient, and secured and best suited to be implemented in the railway industry.

This system is very efficient and convenient at the same time could save time. However, when there is no reliable source of power the system just becomes a white elephant and is of no use unless if a solar power supply is installed on site. Education and safety campaign awareness should be carried out regularly to inform road users about the danger of misbehaving and ignoring road rules. The proposed system is cost-effective, convenient, efficient, secure and tailor-made level crossing protection system that is best suited to be implemented in the future of railway industry.

RECOMMENDATIONS

This work is developed in order to help the railways in making its present working system a better one, by eliminating some of the loopholes existing in it. Based on the responses and reports obtained as a result of the significant development in the working system of Railways. This research can be further extended to meet the demands according to the situation. This can be further implemented to have control room to regulate the working of the system. Thus, becomes the user friendly. The automation of the railways is such that it saves energy, provide full safety from the loss of human and materials. So, this type of system can be applied in any railways. This will be very helpful in the development of any country both financially and technically.

This circuit can be expanded and used in a station with any number of platforms as per the usage. Additional modules can be added without affecting the remaining modules. This allows the flexibility and easy maintenance of the developed system.

DEDICATION

We dedicate this research work to everyone close to me. A special feeling of gratitude goes to our loving parents, brothers, and Sisters whose words of encouragement pushed for tenacity ring in my ears. We also dedicate this dissertation to my friends and church family who have supported me throughout the process. We will always appreciate all they have done, especially Mr. Daniel Tokody for helping me develop our technology skills, Rituraj for the many hours of proofreading, and Sam Shaanika for helping me to master the leader dots.

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