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Train Crash Avoidance Strategies When Wheels on Track

Depavath Harinath

Assistant Professor, R. G. Kedia College of Commerce, Department of Computer Applications, Hyderabad, Telangana, India

Abstract: ***The railway network is one of the world's greatest transport systems. The railways are the most widely used and comfortable modes of transportation system. The causes for railway accidents are when trains are on the same track, when the rail tracks crack and sometimes due to the human errors. It is very difficult to avoid such train accidents because of the speed of train is very high and it requires some time to control it. Therefore majority of accidents occur due to improper communication among the network between drivers and control room, due to wrong signaling, worst atmospheric conditions etc, and also when the train driver doesn't get proper information in time leading to hazardous situation. This paper illustrates different train crash avoidance strategies.***

Keywords: TCAS (Train Collision Avoidance System), RFID, GSM Module, Zigbee technology

1. Introduction

The railway network is one of the world's greatest transport systems. Railway is serving millions of passengers and carrying tones of goods every day. Railways provide a better alternative to other modes of transport by being energy efficient since it can carry large number of people and goods at the same time. As a result, the railways had grown over the years and also the number of people using it. It contributes a lot in a nation's economy.

As we know that trains are one of the most widely used and comfortable modes of transportation system, but occasionally, accidents occur due to collision. It is very difficult to stop such collisions because of speed of moving trains, which needs a lead distance to stop.

There have been many train accidents all over the world. As per the report from CNN IBN India dated September 2011 85% of the train accidents are due to human errors. Surveys conducted by Indian Railway found that about 17% of total railway accidents in India are at level crossing [1].

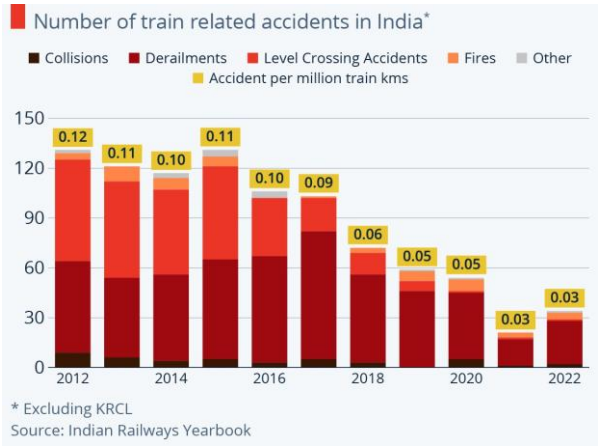

Figure 1: Illustrates number of train accidents in India from 2012-2022

A big country like India has one of the world's largest railway networks. Indian Railways (IR) is a statutory body under the ownership of the Ministry of Railways, Government of India that operates India's national railway system. It manages the fourth largest national railway system in the world by size, with a total route length of 68,043 km (42,280 mi), running track length of 102,831 km (63,896 mi) and track length of 128,305 km (79,725 mi) as of 31 March 2022. 58,812 km (36,544 mi) of all the gauge routes are electrified with 25 kV 50 Hz AC electric traction as of 1 April 2023. Safety is a big deal for such a huge railway network [2] [3].

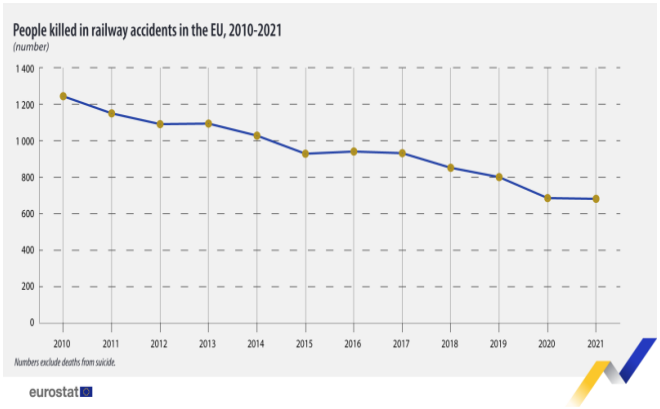

Figure 2: Illustrates people killed in railway accidents in the EU, 2010-2021

People killed in railway accidents, EU, 2010-2021 *Source*: Eurostat [4].

To reduce the accidents, loss of property and life this paper illustrates different train crash avoidance strategies and railway accident preventive measures.

2. Literature Survey

(a) M.Duraishanmugapriyan, developed the concept of "Automatic Railway Gate Controlling System", by the use of ATmega328P microcontroller with the help of two types of sensors. It has three IR sensors which are used to detect arrival and departure of the train. Even they have used RF transmitter and receiver for the transmission of sensor output to controller which is in remote location. The microcontroller forms the main unit of the system. It receives

input signal from the sensors and sends the information to the gate motor driver for opening and closing the gate. The output signal Arduino will active LCD display and alarm.

(b) Dhanashree Anant Umbarkar, Khushabu Taele, Samrudhi Salunke, Geeta Salunke developed the concept of "PLC Based Fully Automated Railway System". This system consists of self-acting PLC system which works round the clock to alert train collision and accidents at the level crosses. Thus, enhances safety in train operations by providing a non-signal additional safety overlay over the existing signaling system. The system operates without replacing any of the existing signaling and nowhere effects the vital functioning of the present safety system developed for the train operation, the proposed system gets data from the vibration sensors. The efficiency of the system is expected to the considerably increased as the proposed system takes input from sensor and also from the level crossing gates.

(c) Naga Hema Kumari.V, China Appala Naidu.R, developed a concept called "Train Collision Avoidance by Using Sensors" to provide safety to human lives and to reduce the accidents they developed a new product using UV sensor, IR sensor and LPC2184 processor. By this proposed system it can identify the both head-on and rear end collision and can be controlled. In this proposed system they are using sensor-based identification to prevent these accidents. The existing system uses traditional telecommunication systems like walkie-talkies or other communication devices. The anti-collision device uses radio modems for communication and received inputs from GPS through satellites.

(d) Dogan Ibrahim developed a new concept called as "Smart Train Collision Detection System using a Microcontroller" they introduced this system by using novel microcontroller-based system using RFID, GPS and an RF transmitter/receiver module to detect possible collisions and to inform the drivers, when the train travel on the same track. The design of novel microcontroller based system is described that which helps to detect possible train collision. Here the system uses RFID to detect the unique track ID that a train is travelling on, a GPS to know the exact positions and speeds of other nearby trains, a powerful RF transmitter/receiver module for communication between the trains and buzzer to warn the drivers of any risk of collision.

(e) Renu Dewangan, Pratibhadevi Umesh, developed the concept of "Automatic Accident Control System of Railway Tracks", This system is used to develop the presence and absence of vehicle or any object on the track within a certain range by setting the appropriate duration. Their function is when train is coming in any track and same track is damaged or any fault are present or any object are present or from other side other train is coming in speed at that time RED light which is present in engine boogie automatically GLOW or On, they inform that the driver who is driving the same train by using this system it is difficult in winter seasons to detect the light due to snow fall we cannot detect the light in the snow fall.

3. Some of the recent Train crash incidents

(a) **On 2nd June 2023** – Odisha train collision: Train 12841 Coromandel Express running at 128 km/h (80 mph) collides with a freight train (goods train) loaded with iron ore in Odisha's Balasore district. The accident happened around 19:30 IST near Bahanaga Bazar station when the train was on the way to MGR Chennai Central from Shalimar railway station near Kolkata. More than 20 coaches were derailed. 12864 SMVT Bengaluru–Howrah SF Express travelling towards Howrah passed in the opposite line just seconds before at 130 km/h (81 mph). However, the derailed coaches of the Coromandel Express smashed into the last few coaches of the SMVT Bengaluru-Howrah SF Express before it could completely pass through that section. A total of three trains were involved. More than 1,200 were injured and 296 people died [5]. [According to Hindustan Times news report says -"Odisha train accident highlights: Toll tops 290, nearly 400 still in hospitals". 2 June 2023.]

Figure 3: Illustrates Odisha train collision on 2nd June 2023

The above image is a cause of Odisha train collision.
Source of the image- Hindustan Times report [6].

(b) **On 24 June 2023, In United States – Yellowstone River train derailment:** A Montana Rail Link (company leasing BNSF routes) freight train derailed near Reed Point, Montana, and eight cars fell into the Yellowstone River. A few cars ruptured and leaked hazardous materials including petroleum products into the river [https://en.wikipedia.org/wiki/2023_Yellowstone_River_train_derailment].

(c) **On 6 August 2023– In Pakistan – Hazara Express derailment** – In Nawabshah, the Hazara Express derailed near Sarhari railway station, killing at least 34 passengers and injuring 100.
[https://en.wikipedia.org/wiki/2023_Hazara_Express_derailment]

(d) **On 30 August 2023 – In Italy** – A train hit workers replacing segments of the railway tracks in Brandizzo, killing five of them and injuring two others.[https://www.aljazeera.com/news/2023/8/31/speeding-train-kills-5-rail-workers-in-northern-italy-accident-reports]

(e) **On 24 September 2023– In Pakistan** – In Sheikhupura, a passenger train collided with a freight train. The cause of the accident was a track switch failure which sent the moving train crashed into the parked train on the same track. 31 people were injured. [https://indianexpress.com/article/pakistan/injured-train-collision-punjab-province-8953890/]

Figure 4: Illustrates train collision in Pakistan on 24th September 2023

(f) **On 28 September 2023 – In India** – In Mathura, a MEMU train collided with a buffer at Mathura Junction railway station while the driver was drunk and watching his phone. The driver also put his backpack on the throttle, one person was injured. [https://www.outlookindia.com/national/mathura-train-accident-probe-finds-mildly-drunk-staff-handled-train-was-watching-mobile-5-suspended-news-321215]

(g) **On 29 September 2023– In United Kingdom** – At Aviemore Station on the Strathspey Railway, the *Flying Scotsman* collided with a stationary train. Two people were hospitalized. [https://www.france24.com/en/live-news/20230929-injuries-in-scotland-rail-crash-flying-scotsman-involved]

(h) **On 4 October 2023- In Hong Kong**– Two Light rail trains collided with each other due to human error, injuring three.
[https://www.msn.com/en-xl/news/other/human-error-may-have-caused-hong-kong-light-rail-train-collision-at-yuen-long-station-that-left-3-injured-mtr-corp/ar-AA1hF4YJ]

(i) **On 23 October 2023–In Bangladesh** – In Dhaka, a freight train collided with a passenger train parked in front of it. 17 people were killed and 100 people were injured. [https://apnews.com/article/train-crash-bangladesh-dc940f11e3d0326c2bb8a4a268f8271d]

4. Railway Accident Prevention Measures

Railway accidents can have devastating consequences, resulting in loss of life, injuries, and extensive damage. As a responsible society, it is crucial to prioritize safety measures to avoid such accidents. This article aims to provide a comprehensive guide on how to prevent railway accidents, highlighting various strategies that can be implemented to enhance safety and mitigate risks. The following are the list of railway accident prevention measures-

(a) Regular Maintenance and Inspection:
One of the primary ways to prevent railway accidents is through regular maintenance and inspection of tracks, rolling stock, and signaling systems. Adequate funding should be allocated to ensure that railway infrastructure is well-maintained, reducing the risk of equipment failure and track defects that can lead to accidents.

(b) Advanced Signaling Systems:
Implementing advanced signaling systems such as Automatic Train Protection (ATP) can significantly enhance safety. These systems can detect potential collisions, overspeeding, and unauthorized access to tracks, automatically applying brakes or sending warnings to train operators.

(c) Training and Education:
Comprehensive training programs should be provided to railway staff, including train operators, maintenance personnel, and signal operators. They should be educated on safety procedures, emergency protocols, and the importance of adhering to operational rules and regulations. Regular refresher courses can help reinforce safety practices.

(d) Improved Communication:
Establishing effective communication systems between train operators, control centers, and station personnel is crucial for preventing accidents. Clear and concise communication channels should be in place to relay information about track conditions, signals, and any potential hazards.

(e) Implementing Safety Barriers:
Railway crossings should be equipped with safety barriers, such as gates and warning lights, to prevent vehicles and pedestrians from entering the tracks when a train is approaching. Public awareness campaigns can also be conducted to educate people about the dangers of trespassing on railway property.

(f) Fatigue Management:
Addressing fatigue among train operators and other railway staff is essential to prevent accidents caused by human error. Strict regulations on working hours and rest periods should be implemented to ensure that staff members are well-rested and alert during their shifts.

(g) Regular Risk Assessments:
Periodic risk assessments should be conducted to identify potential hazards and implement appropriate safety measures. This includes evaluating the impact of weather conditions, identifying areas prone to landslides, and assessing the structural integrity of bridges and tunnels.

(h) Encouraging Technological Innovations:
Railway companies should actively explore and invest in technological advancements aimed at improving safety. This can include the use of sensors, drones, and artificial intelligence-based systems to monitor tracks, identify faults, and predict maintenance needs.

(i) Collaboration with Authorities and Stakeholders:
Railway operators must collaborate closely with government authorities, local communities, and relevant stakeholders to ensure the implementation of safety measures. Engaging in dialogue, addressing concerns, and incorporating feedback from the public can help create a safer railway environment.
Preventing railway accidents requires a multi-faceted approach that combines regular maintenance, advanced signaling systems, comprehensive training, improved communication, safety barriers, fatigue management, risk assessments, technological innovations, and collaboration with stakeholders. By implementing these strategies, we can strive towards a safer railway system, saving lives and

preventing catastrophic accidents. Remember, safety should always be a top priority in railway operations.

5. Different Train Crash Avoidance Strategies

(a) Automatic railway gate controlling system:

An Automatic railway gate controlling system is shown in figure.5 at unmanned level crossing. By employing the automatic railway gate control at the level crossing the arrival of train is detected by the sensors placed on either side of the gate at about 5km from the level crossing. Once the arrival is sensed, the sensed signal is sent to the microcontroller and it checks for possible presence of vehicles between the gates, again using sensors.

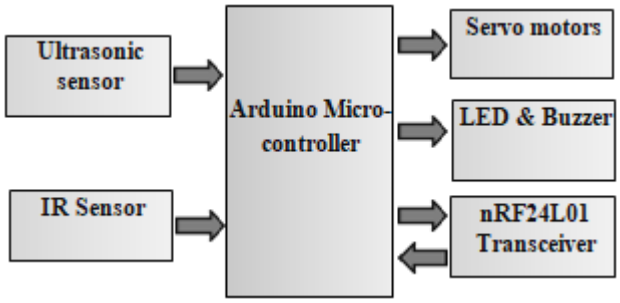

Figure 5: Illustrates railway gate controlling system

Subsequently, buzzer indication and light signals on either side of the road to alerts the road users about the train arrival. If no vehicles are sensed between the gate, the motor is activated and gates are closed. But for the worst case if any obstacle is sensed then it will inform the loco-pilot in the train using nRF24L01 transceiver before the train reaches 2km from the gate.

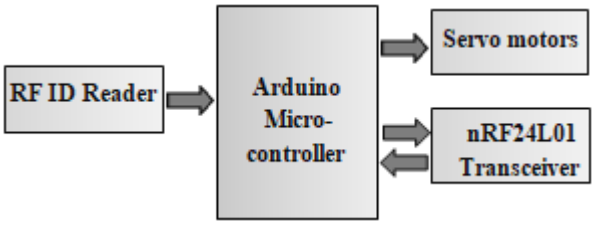

Figure 6: Illustrtes Railroad switching system

An automatic railroad switching system is shown in figure.6, it operates on Radio Frequency Identification number which is sensed by the RFID reader placed at certain distance from the track switching system and Arduino microcontroller as a controlling unit. According to the unique ID of the train, the track is switched using servo motor and it sends the acknowledgement to the loco-pilot.

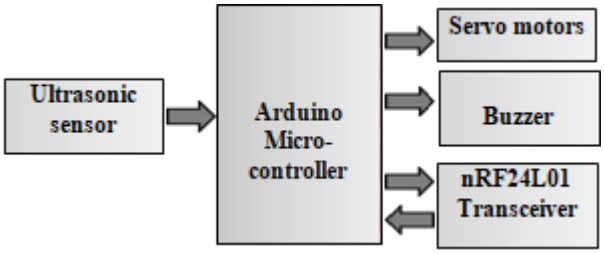

Figure 7: Illustrates Anti-collision System

An anti-collision system is shown in figure.7, which is used to sense the obstacles like animals or vehicles on the railway track for certain distance using ultrasonic sensor and servo motor to rotate the ultrasonic sensor for 0 to 180 degree. If the obstacle is present on the track it will send the information about the obstacle using nRF24L01 transceiver module, to the present train on that track.

The main object of this system is to control the railway gate at the level crossing automatically through sensors such as IR sensors or ultrasonic sensor and controlling through actuators such as buzzers, LED display, servo motors. Manual track switching errors are to be minimized by an automatic railroad switching mechanism using RFID readers and servo motors. Train accidents because of obstacles like animals on the railway track in an accidental zone can be detected by 'Anti-collision system' which has ultrasonic sensor and servo motor, which alerts the loco-pilot in the train on that track.

(b) Modern Anti-Collision Devices

Anti-Collision Trick is a combined Electronic Governor Scheme which is planned to lessen the crashes and it also increases protection on Railway Structure.

It is a non-indicating scheme and make available supplementary protection of care in train procedures to avoid hazardous train crashes which are instigated due to humanoid blunders. Ant-Collision Trick arrangement does not affect with regular performing of train actions i.e., it does not substitute any standing gesturing and joining arrangement and does not amend any actions of train processes.

System of Anti-Collision Tricks comprises of variability of strategies such as on the train (Transportable) Anti- Collision Tricks for Engines and Sentry forefronts and track-side (motionless) Anti-Collision Tricks, Level Passage Anti-Collision Tricks, Loco cabin Anti-Collision Tricks, feeler founded ACO and ACO recidivists. All these efforts are grounded on the belief of dispersed governor structure.

All Anti-Collision Tricks along the Anti-Collision Trick route join with each other through wireless announcement once they are inside a circular assortment of at least 3 kms. On panel processers practice involvements from Global Positioning System (GPS) for resolving of train position, rapidity, passage of transportable period.

Both transportable and non-transportable apparatuses of ACO arrangement argument statistics and yield choices based on train operating instructions and entrenched package to put on brakes inevitably in short of any involvement from handlers.

If two Anti Collision Objects are supposed to be at a hazard of accident, the Anti-Collision Trick scheme triggers involuntary slowing processes to avoid crashes. Loco ACO is planned to border with numerous kinds of decelerating arrangement of engines.

Arrangement offers audio-visual "Train Tactic" threatening to way handlers at level passages. At Operated LC

Gateways, when forthcoming Loco Anti-Collision Trick perceives "Entrance Exposed" ailment, the rapidity of the train/loco is abridged and saved under a pre-defined rapidity. Similarly, it can also afford cautioning and unvarying rapidity in case of travels of land grades in bottomless etchings that are "detected" through networks, inclinometer, entrenched in such slants.

(c) Collision Avoidance using ZigBee Protocol:

The main objective of this system is to prevent collision of trains by providing a channel of communication between trains. ZigBee protocol is used here.

It is a signaling system and it reduces the chances of human errors as whole system is fully automated. In this a train refer its path id to all nearby trains if another train by chance coming on same track will produce same track id and thus both trains will get same track id which would result in an alert message to both drivers to stop the train at a safe distance to avoid collision.

This uses various devices like microcontroller, switches, buzzers, LCD, Feeler (for temperature), MAX 232 sequential announcement, Explosive device finders, DC Motor, ZigBee spreader and receiver, Motor Drive. And these all devices are used in all trains which are intended to communicate.

ZigBee is a new and provides specifications for devices with low power consumption, low data rates and as well as long battery life. ZigBee is modest and inexpensive than extra end WPAN's such as Bluetooth and Wi-Fi.

While this system can avoid collision of trains on same track whether it is from front end or rear end but it only works when both the trains on the same track have this system embedded in them.

(d) Train crash avoidance strategy by using RFID and GSM technology:

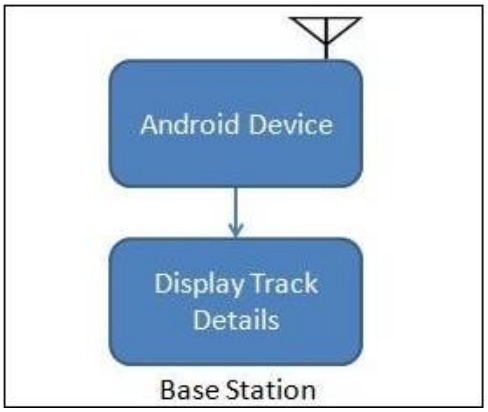

Figure 8: Illustrates base station unit

The train tracks are divided into segments with individual track segment number. Whenever a train enters a segment of the track, the track number of that segment of track is read from the Radio Frequency Identification (RFID) tags present at the beginning of each segment of track. This track number read by the RFID reader is stored and then given to Radio Frequency (RF) Transceivers. The RF communication is established among the adjacent trains, which are in the range through an algorithm (which is explained later), so that the track numbers are shared. Now the track number of its own from RFID reader is compared with the track numbers of other trains from RF Receiver. Upon detection of same track number the system will alert the motorman. With no further action (detected with the help of speed sensor) taken by the motorman after an interval of human response time, the system will override the motorman by braking the train, with the help of actuators.

In Indian railway system the train tracks are divided into different frames and each segment there is separate track id number. In the proposed system the Radio Frequency Identification (RFID) tags are attached at the beginning of each segment of track at 10 km distance. When the train enters in the specific segment, the track number of that segment of track is read by the RFID reader in the RF receiver. Then this number is stored in the memory of microcontroller then given to Radio Frequency (RF) Transceivers. The RF transmitter sends this track id to the base station. And the GSM module sends the SMS to the authorized person to take appropriate action. In this way the RF communication is established among the train and the base station. At the base station there is LED is present which is the indication of two trains at the same track.

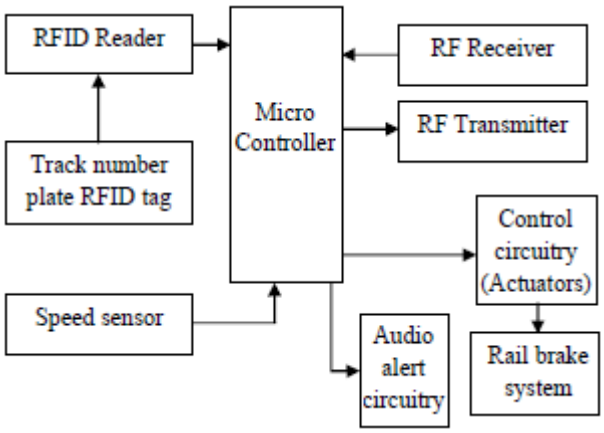

Figure 9: Illustrates block diagram of the proposed system

Figure 9 shows the android device which is present at the base station which is used as a receiver. On the android device the different track ids are displayed. If two trains are travelling on the same track then system sends the same track id to the base station at the base station there is sensor is present as shown in figure 10.

The two track ids which are same are senses by the sensor and given to the microcontroller. The microcontroller sends the signal to the LED and GSM module. The LED is blinked which is the indication of the two trains in the same track. Simultaneously the GSM module sends the SMS through GSM network to the authorized person to take appropriate action. In this way it avoids the collision.

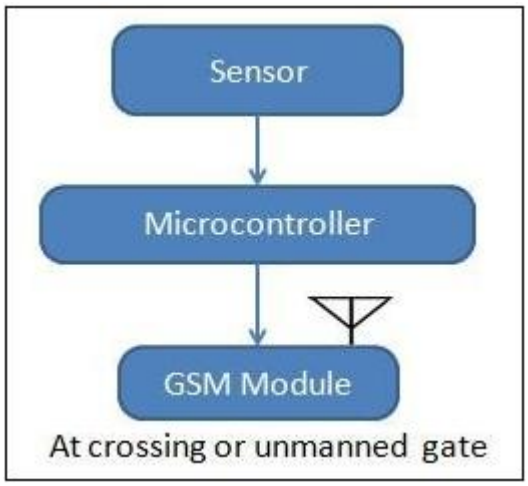

Figure 10: Illustrates crossing unit

(e) Kavach (train protection system):

Kavach (lit. 'Armour') is an automatic train protection (ATP) system indigenously developed by Indian Railways through Research Designs & Standards Organization (RDSO). Initial development of Kavach started in 2012 under the name Train Collision Avoidance System (TCAS) and completed development in 2022.

Kavach has been certified for compliance with safety integrity level 4 (SIL-4) operations. Kavach has been promoted as being the cheapest ATP system available in the world, costing roughly 50 lakh (five million) rupees per kilometre to operate compared to about two crore (20 million) rupees worldwide. The Union budget of India for the FY 2022-23 allocated funds for the rapid implementation of Kavach across 2,000 km of track, as well as sanctioning its implementation along 34,000 km track of the Golden Quadrilateral rail route, which is to be implemented by 2027-2028.

- Kavach is a technology designed to bring a train to a halt automatically when it notices another train on the same line within a prescribed distance.
- It is India's very own automatic protection system in development since 2012, under the name **Train Collision Avoidance System (TCAS),** which got rechristened to Kavach or "armour".
- Kavach is developed by **Research Design and Standards Organization (RDSO)** in collaboration with Indian industry.
- Simply put, it is a set of **electronic devices and Radio Frequency Identification devices** installed in locomotives, in the signaling system as well the tracks, that talk to each other using ultra high radio frequencies to control the brakes of trains and also alert drivers, all based on the logic programmed into them.
- **One of its features is that by continuously refreshing the movement information of a train,** it is able to send out triggers when a loco pilot jumps signal, called Signal Passed at Danger (SPAD), a grave offence in railway operations with respect to safety, and the key to accidents like collision. The devices also continuously relay the signals ahead to the locomotive, making it useful for loco pilots in low visibility, especially during dense fog.
- Trains will also stop on their own when digital system notices any manual error like **"jumping"** of the red signal or any other malfunction.
- **TCAS or Kavach includes** the key elements from already existing, and tried and tested systems like the European Train Protection and Warning System, and the indigenous Anti Collision Device. It will also carry features of the high-tech European Train Control System Level-2 in future. The current form of Kavach adheres to the highest level of safety and reliability standard called Safety Integrity Level 4.
- The **'On-Board Display of Signal Aspect' (OBDSA)** is to help loco pilots check signals on board consoles. RFID tags are provided on the tracks and at station yard for each track and signals for track identification, location of trains and identification of train direction.
- **Once the system is activated,** all trains within a 5-km range will halt to provide protection for trains on adjacent tracks. Currently, loco-pilots or assistant loco-pilots usually crane their necks out of the window to look out for caution signs and signals.
- It also includes **stationary equipment to gather signaling and loco inputs and relay them** to a central system for seamless communication with the train crew and stations.

6. Conclusion

The railway network is one of the world's great transport systems. Railway is serving millions of passengers and carrying tones of goods every day. The railways had grown over the years and also the number of people using it. It contributes a lot in a nation's economy. But occasionally, accidents occur either due to collision or by other means. In order to avoid such accidents this paper illustrates railway accident prevention measures and different train crash avoidance strategies.

Therefore, this paper concludes that how to prevent railway accidents and what are strategies to be followed to avoid train accidents.

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Author Profile

Depavath Harinath, Assistant Professor, received Master of Computer Applications degree from Sreenidhi Institute of Science and Technology, an autonomous institution approved by UGC, Accredited by NAAC with 'A+' grade and accredited by NBA, AICTE, New Delhi – permanently affiliated to JNTU, Hyderabad, Telangana, India. Having more than eleven years of experience in teaching and already published 18 manuscripts in different international journals. Research field includes Computer Networks, Network Security and Artificial Intelligence.