22. Optimising Indian Railways Infrastructure by AI

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ABSTRACT

The pressure on the Indian railway networks has increased due to higher demand for mobility and growth in India's population over past several decades. There have been efforts to build more tracks, run more trains on the same networks, and to increase the number of coaches per train. Building more tracks or increasing the number of coaches or increasing the number of trains are coupled with high infrastructure cost. These measures have potential to solve the problem, but they come with added vulnerability in safety in running the system. Indian Railways with its investment of over 500000 Cr is presently struggling to make its Operating ratio (expenditure / earning) below 100 %. During the last 166 years of its operation many technological input has been made on its

Infrastructure, Locomotives and Rolling stock but its Train Control practices have remained Conventional – locally controlled and experience based. The developments in the area of signal processing, communication systems and artificial intelligence (AI) etc. has great potential for applications in Indian Railway right from ticketing to movement of trains, maintenance etc. The potential of AI has been felt in different applications like predicting delays, preventive maintenance of tracks and rolling stocks, forecasting algorithm for railway system. It should be possible to do more with the use of AI by intelligently using the hardware with efficient software. This includes greater information sharing, lower latency, and cleverer algorithms. Such improvements fall squarely within the ambit of AI. This paper highlights the potential contributions of AI towards improvement of India's railway system and how the application of recent technological advancement in Information Science and Artificial Intelligence can bring a change in the train operation scenario at a railway station and Control Centre and add to the profitability of Indian Railways.

Keywords: *Indian railway, Signaling, Artificial intelligence, Signal maintenance*

INTRODUCTION

The Indian Railway (IR) system is a government-owned entity, and its network is the fourth largest railway network in the world by size having route length of 115000 kilometres [1]. It runs around 11000 trains everyday having 7000 passenger trains and ferries 23 million passengers per day and transports 3 MT freight. Train operation on 7312 stations of Indian Railways is controlled from 66 control centres located all over its network. The economic impact of this transportation system is enormous. In the fiscal year 2017-18, IR carried 8.26 billion passengers and transported 1.16 billion tonnes of freight, and generated a revenue of close to 2 trillion INR [2] and two third of this revenue was generated through freight movement. Apart from the benefits delivered to its users, it employed in excess of 1.3 million people in 2017 [2]. The railway system is a giant economic machine needing constant maintenance and repair. Furthermore, it is under increasing stress to deliver even greater value as the demand for cheap, efficient transport grows year on-year.

Signal failure is one of the major cause for accidents in running of trains causing loss of lives, infrastructures etc. The signaling system is vital for safe train operations and the railways completely depend on the health of its signaling assets along with real time information. The failure of signals is one of the major reasons for train accidents and delays. Currently, remote monitoring of signaling is operational in Britain. Aiming to reduce the possibilities of signal failure, Indian Railways has undertaken remote condition monitoring of the system. This is a new approach for the national transporter to predict failures through the effective use of artificial intelligence (AI). Currently, the railways follow a manual maintenance system and adopt find-and-fix methods [3 -6].

A key reason to introduce AI is to effectively follow a predict-and-prevent approach. The system entails the collection of inputs on a pre-determined interval and sending them to a central location. As a result, any flaws or problems in the signaling system would be detected on a real time basis and rectified in order to avoid possible delays and mishaps. The system envisages data transfer through a wireless medium (3G, 4G and high-speed mobile) and data based on these inputs will be utilized, with help of Artificial Intelligence (AI), for predictive and prescriptive Big Data analytics. This will enable prediction of signaling asset failures, automated self-correction and informed decisions on intervention strategies, said the official. The railways have decided that trial be taken up in two sections of Western Railway and South Western Railway at AhmedabadVadodara and Bengaluru-Mysuru. Depending upon the feedback, the system would gradually be extended to other sections. There has been extensive studies with regard to scheduling of trains and minimizing fatalities all over world [7 – 12]. In next few paragraphs, we will discuss about present system and then give our suggestion for the signal monitoring using AI.

CONTROL CENTRE

Indian Railways divides its operations into zones, which are further sub-divided into divisions, each having a divisional headquarters. There are a total of 18 zones and 73 divisions [13]. Every division has a Control Centre for train operations, where all the trains in the division are controlled and monitored. There are different types of control rooms such as engineering control, mechanical control etc. which coordinate with operating control and employees of the respective department. At the Signaling Control Centre, the arrival / departure information of trains from station masters of his section are plotted on the section Train Chart and the movement of trains are monitored. In recent years Train Charting is getting automated by using Data Loggers. The Controller takes into account, the train actual arrival status, arrival /departure schedules as given in the published time table and any priority order for the train movement. Based on his own experience the Controller gives instruction to Station Master for movement of the train at his station. Thus the entire process of scheduling the movement of trains is completely human experience based conventional. The Controller at the conventional Control Centre of Indian Railways has no modern technological aid / support system in his train operation decision making. He also has no radio communication with drivers running the train on his section except on some important trains.

STATION OPERATION

Train Operation on Indian Railways are conventional. A bird's eye view of the Ghaziabad railway station is shown in Figure 22-1. Ghaziabad railway station is on the Kanpur-Delhi section of HowrahDelhi main line, Howrah-Gaya-Delhi line and New Delhi-Moradabad-Lucknow line. It has 6 Platforms and handles 241 Halting Trains, 2 Originating Trains and 2 terminal Trains. Local Electric trains also run regularly from Ghaziabad for stations like Old Delhi station, Hazrat Nizamuddin station and Anand Vihar. Local trains, which run on a regular interval, are EMUs, MEMUs, and Passengers Local trains. They start in early morning hours and run until midnight.

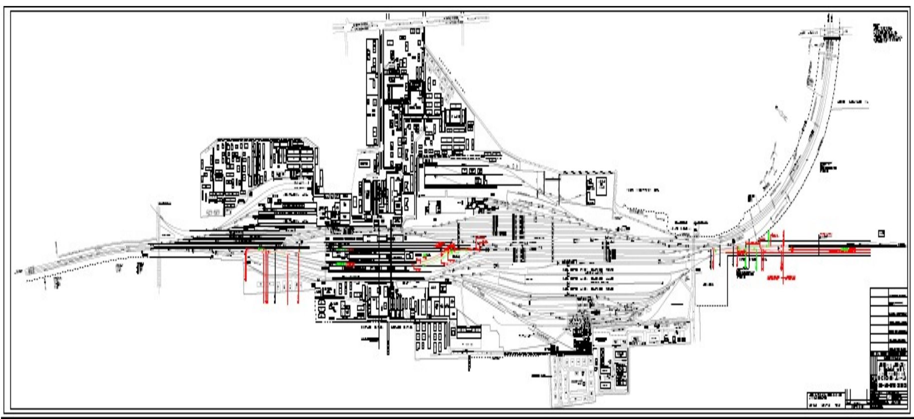

Figure 22-1 View of Ghaziabad Railway station of Indian Railways

Train operation at each station is in stand alone mode with exchange of block working with neighboring stations situated 8-10 km apart. Station Master controls the train operation within his station limits i.e. Home Signal to Advance Starter Signal in each direction based on specific instructions from Control Centre.

To control train operation by station masters, signaling panel (Figure 22-2) station panel/VDU key Board (Figure 22-2) are provided. It enables him to set the route and give Signal for reception/ dispatch of the trains, the line to which the train is to be received or dispatched, priority of train at junction station, stoppage timing at the station, waiting time etc. This is all experience based and manual, which is likely to have errors.

Figure 22-2 Signaling Panel at IR station

Figure 22-3 VDU and Key Board based Station Control at EI station

STATION MASTER

There are Station Master at each station and he directs and control the movement of trains passing by his station. The Station Master (SM) is responsible for arranging reception and dispatch of all trains and other shunting movements in accordance with the latest issue of G&SR's, Block Working Manual and Operating Manual. He also has control for shunting in between the arrival/departure of trains or during slack period as frequently as possible to the maximum extent. He shall test the interlocking gears of the station to ensure safe operation of trains and to avoid any conflicting movements.

SM attends Section controller command promptly and furnish the controller with the arrival and departure of trains at his station well in time. The command from Section controller has to adhered. Any noncompliance would be treated as dispute provided they do not contravene any G&SR's , SWR's or otherwise leads to any kind of unsafe working.

SM will promptly attend all accidents and assist in relief measures and enquiry. He shall ensure that all failures are brought to the notice of the S&T maintainer immediately and entries made promptly in Signal failure register. He must also see that proper Disconnection / Reconnection memo is issued without loss of time.

From above paragraphs, we observe that SM is under stress all the time and there is a possibility of error in attending to above function resulting in accidents and loss of lives.

MAINTENANCE OF SIGNALLING ON INDIAN RAILWAYS

Presently based on Time schedule laid down in Indian Railways signal Engineering Manual, maintenance of Signalling systems is carried out on Time Schedule basis. Over 4000 stations Data loggers have been provided to record the status of Signalling systems and send it to Control Centre /Test Room. Where as in all developed countries, Remote Condition Monitoring and Condition Based Maintenance using artificial intelligence are being used.

NEW TECHNOLOGICAL DEVELOPMENT ON INDIAN RAILWAYS

Although Indian Railway have got new technology installed to modernize its infrastructures, but it is limited to a few sections. The trial is going on these installations and if successful, these modernization will be installed all over country. Some of the installations are described now.

A. CENTRALIZED TRAFFIC CONTROL

Centralized Traffic Control (CTC) has been recently installed in Tudla section using GSMR Train Radio Communication system. It has been installed over 2500 Kms of Indian Railways where voice communication between Controller /Station Master and Driver has been provide. A view of the CTC is shown in Figure 22-4. It has visual several displays with computer control to monitor the real life movements of trains. The operator looks at the real time movement of a train on monitor and control its future course of actions.

Figure 22-4 CTC Control Centre at Tundla

B. TRAIN MANAGEMENT SYSTEM (TMS)

Train Management System has been introduced at Mumbai Control Centre for Suburban services. It is very similar to CTC control and manages the movement of suburban trains in Mumbai. TMS is already being used in control of Metro trains. The control room is shown in Figure 22-5.

Figure 22-5 Train Management System at Mumbai

C. ETCS LEVEL 2 SYSTEM

In ETCS Level 2 system there will be visual display of train movement at Control stations as well as at Sectional control stations on a Video Display Board. This is illustrated in Figure 22-6. In this system, the Sectional Controller will also be able to control the reception & dispatch of trains at way stations. Indian railway has initiated the process for installation of ETCS Level 2 systems on 635 Kms route on Vizianagaram – Palasa, Yerraguntla - Reniguntla, Jhansi - Bina, Nagpur - Badnera sections.

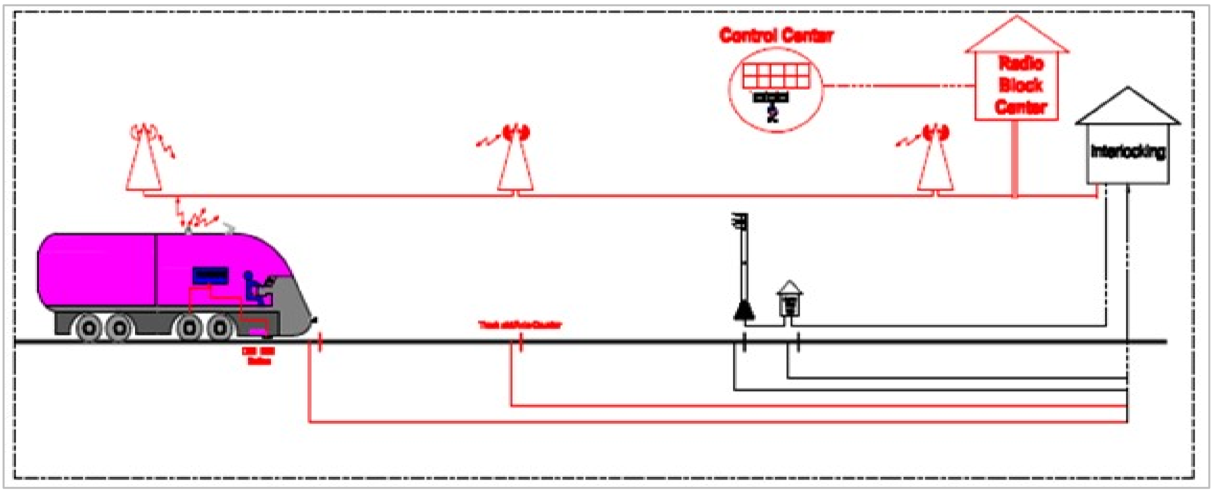

Figure 22-6 Future Control Centre after introduction of ETCS level2

APPLICATION OF DATA ANALYSIS AND AI

In order to monitor the status of Track occupancy, the data on occupancy of tracks are either collected manually or by using data logger at stations on Indian Railways by point machine operation, signal aspects etc. The status report is sent to Station and Control Centre using digital transmission and Networking. AI can be used in efficient running of trains without failure [14,15].

In future Artificial intelligence (AI) and machine learning Systems will be the buzz word in the train operation. It's going to be used widely in operation and control of train movements.

While the train is in movement, the train knows its location and the track by identifying known infrastructures and remembering it by using Machine Learning and Artificial Intelligence. Visual referencing plays an important role in identifying the known infrastructures. It checks and anticipates any registered infrastructure. AI keeps most processor power looking for abnormal infrastructure operations; e.g. obstruction or trespassing person. Thus relieving drivers looking for abnormalities in train movements.

The rail environment is different to road environments. Longer distance sensors & new algorithms are required to support rail operations. Advanced sensors are needed to gather information. AI brings operations, IoT and imaging together to completely the picture. The information are collected from GPS, inertial navigation, odometers, radars, LIDARs, cameras, and ultrasound sensors. The sensor data is integrated to create a digital virtualization of the operating environment for deeper processing. AI is used to monitor the total environment. Figure 22-7 shows a futuristic locomotives with all the accessories for AI and machine learning.

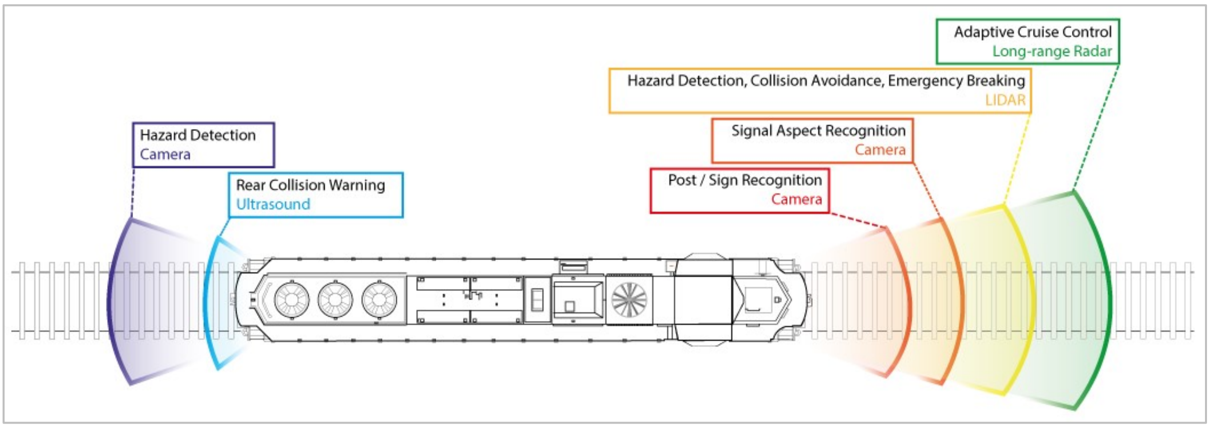

Figure 22-7 Future locomotive with all accessories

Artificial intelligence and machine learning provide the capability for a rail system to autonomous identify objects and hazards, rather than simply act to pre-set rules which are insufficient in complex systems. AI requires a deep learning processing pipeline as appropriate for rail operations. Deep learning involves detection, localization, awareness, dynamics and monitoring. Detection requires multiple sensor types applicable to rail as illustrated in Figure 22-7.

Visual, spatial and navigational data (GPS, inertial & odometer) data integration with known infrastructure are needed for localization. GPS alone may not be accurate enough in multiple track areas. Image processing allows multiple track segmentation and it can be used to generate route reference record. This allows on board decision making possible.

Signal and sign recognition, signal types, colored light are needed for train awareness. Neural networks allows continual learning of differences. The system must be aware of detected data using machine learning and how these data are interpreted. Dynamics involves managing and checking actual operations against allowed operations. It is necessary to monitor the train running parameters by checking the reports.

Track Detection consists of algorithms which identifies the tracks, provides track identification because the camera is orientated along the center line of travel, built off the existing body of work on autonomous cars. This will help in improving the GPS accuracy by localizing efficiently because we know where we are on the track.

Geographical information are obtained from pre-recorded geographic information obtained from GPS points located at some fixed distance, level crossings and aspect locations. This is helped by GPS data streaming, video streaming and display information on particular object of interest as we approach that object. OEMs of Rail Technologies in countries abroad have developed advanced sensors based remote monitoring, data analysis and prediction using latest development in Information Sciences and Artificial Intelligence in Rail sectors. Some examples are followings:

Thales (ThalesMan): A fully integrated mobile asset management product aimed at engineering and maintenance teams, back-office control staff and other key business users.

Siemens (On Track): An integrated suite of monitoring products that enables operators to access performance data about key assets such as power supplies, points operation, level crossings, track circuits and signaling.

Bombardier (Orbita): An integrated suite of monitoring products that enables operators to access performance data about key assets such as power supplies, points operation, level crossings, track circuits and signaling.

IBM (Smarter Railroad): IBM has set up a new Global Rail Innovation Center that is working on solutions to increase capacity and utilization and reduce congestion. These solutions include mobile-based condition monitoring, preventive maintenance and trainbased systems.

Via Telemetry (µWEAVE): A Web-based monitoring and middleware platform that can be configured to monitor any remote asset via the Internet and GPRS networks so that remote assets can be managed centrally and the data then used automatically by corporate business applications.

Balfour Beatty (AssetView): This performs a diagnostic process and predicts certain asset failure modes by generating statistical reports that can be used for preventive maintenance planning.

Lloyd’s Register (GOTCHA): This is a track-based asset monitoring system with postanalysis and decision support. It enables informed decision-making on asset management actions — especially in maintenance and renewal activities. Optional plug-ins to the Gotcha system are pantograph monitoring, axle bearing monitoring and sound measurements.

CDS Rail (Asset Watch): This is a fully scalable monitoring solution capable of gathering data from all railway trackside asset types and providing usable information through one central system.

Strukton Rail (POSS Online Monitoring): This tool provides comprehensive, real-time insight into the status of rail systems, based on the data from its measuring and monitoring systems. This helps spot possible defects before they occur.

Indra (DaVinci System): This package integrates all control, supervision and communications systems required to manage and monitor the operation of a high-speed railway network.

Alstom (Iconis): This orchestrates operational functions and traffic management through Iconis ATS for urban automated train supervision, Iconis CTC for main lines and Iconis SCADA for infrastructure monitoring, in conjunction with interlocking and automated train control (ATC) subsystems.

Invensys (Avantis): Working in partnership with Invensys Operations Management (IOM), Invensys Rail provides the highest levels of monitoring and predictive maintenance incorporating techniques that enable moving from “find and fix” to “prevent and predict” maintenance. The software enables real-time decision support and analysis of trends in the operation of signalling and other railway equipment.

Modern sensor based data monitoring, Data Analysis and application of AI for Signaling, Track, OHE and rolling stock systems will enable us to predict the system deterioration in advance and introduction of predictive maintenance. The application of modern sensor based data monitoring, data analysis and application of AI will greatly improve punctuality of train services, sectional capacity and reduce equipment failures. With these application the shape of future Train Control and infrastructure maintenance will take a new shape as visualized in Figure 22-8.

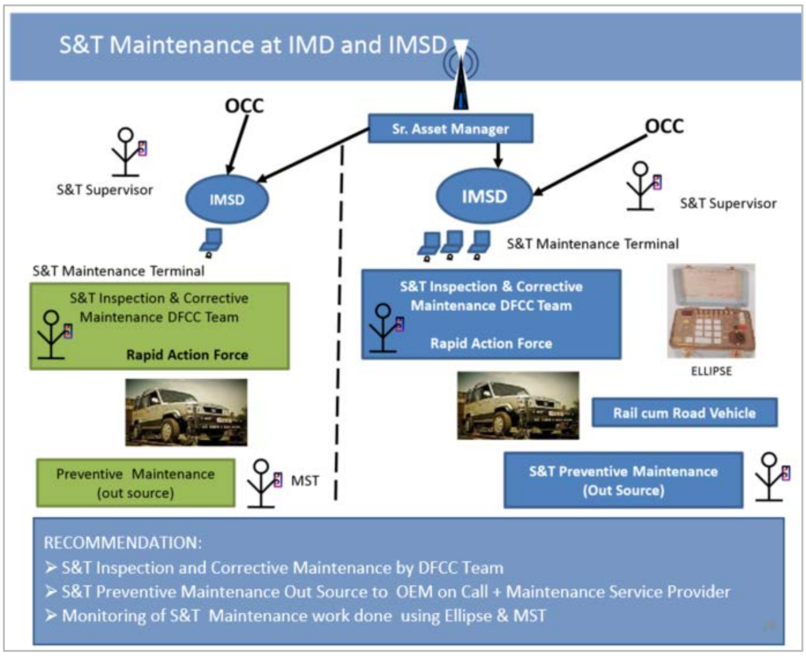

Figure 22-8Block diagram of train control and infrastructure maintenance

CONCLUSION

Artificial Intelligence is already a reality for several applications. It has proven its value by doing high complex tasks that humans could never comply or doing simple tasks very efficiently. Programming and teaching an AI can be a lot cheaper and faster than classical logical programming. AI should never be allowed to have full authority in critical functions because it's likely to fail as well. An alternate algorithm must be provided in the critical function operation. Use of AI in Indian Railway is likely to reduce infrastructures because with a train location and performance are being easily managed on board. This in turn will not distract the driver's attention. The system will incorporate continuous machine learning because with each run master data sequence used for track reference by a locomotive's computer systems are getting improved. The data on hazards & changes in real-time from all locomotives operating on a route can be easily shared with other rail users, which is completely absent in present scenario. The train control can be separated from infrastructure systems by use of AI resulting in ultimate interoperability that a locomotive is able to independently operate over any line. Finally with a never distracted drivers's assistant and technology based operation of autonomous trains in future is going to have improved safety.

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