New Signalling Technology for Railways in India and South Africa based on UIC Specifications

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Summary

This paper gives an overview about the actual status of the ERTMS/ETCS pilot project of Indian Railways and the implementation of new signalling technology on the Orex line of Spoornet, South Africa.

While the European Railways and European Rail Industry are specifying and developing ERTMS/ETCS and GSM-R, railways from outside Europe are carefully monitoring these activities. Meanwhile the Indian Railways are going to implement an ERTMS/ETCS and GSM-R pilot project between Delhi and Agra and Spoornet in South Africa is going to implement new signalling/authorisation technology (based on UIC specifications) on their Ore Export (Orex) line between the towns of Sishen and Saldanha. Both projects are technically supported by UIC, especially because of the request of both railways to base their future railway signalling/authorisation systems on unified UIC specifications. With respect to timescales, the Indian Railways as well as Spoornet would like to finalise their projects during the next two years.

1 Introduction

A significant amount of development is taking place world-wide in signalling. Not only is this development in new technologies but also in the philosophies behind the execution of the safe movement of trains. Various motivating factors are behind these developments in Europe and the USA. The main motivating factor for Indian Railways and Spoornet is the need to reduce the reliance on track side equipment and thereby reduce the cost and increase the availability of train authorisation systems.

2 Communication Based Authorisation System for the SPOORNET ORE Export Line

2.1 SPOORNET Philosophy

Spoornet requires new technology train authorisation systems to reduce costs. To do this, it is first necessary to review the current approach to signalling on a philosophical level and to propose a more optimal future positioning for Spoornet with respect to train authorisation systems. It is not the intention of this document to give an in-depth study of signalling and the reasons for signalling but rather to expand the initial requirements of signalling to include the wider requirements of train authorisation and to propose more appropriate technologies to fulfil these expanded requirements.

Historically, signalling had two purposes which were:

- to facilitate the safe movement of trains by preventing derailments and collisions (primary purpose)
- to increase the capacity of the railway network by safely allowing a higher density of trains on the network

The second purpose is in fact an extension/application of the first (primary) purpose.

Prior to signalling, these functions were carried out by the operating personnel using hand signals or flags. All of the train detection and interlocking functions were vested in people. The initial development of technology-based signalling systems was therefore based on the processes which were in place just before the start of the implementation of signalling. Signalling systems (from mechanical through to full colourlight signalling) have fulfilled the primary purpose of signalling (as defined above) reasonably well over the years and where deficiencies appeared, other technologies were developed (e.g. track to train communication via track circuits for cab signalling in high speed trains) mainly as add-on's to the basic signalling system. Because of the widescale (worldwide) implementation of signalling and its reasonable success as a train authorisation system, the types of technologies used for the execution of the primary purpose of signalling were only reviewed to provide better (more cost effective, etc) conventional signalling systems (SSI, ATP, etc). It is only at this stage that a serious re-evaluation of the types of technologies to implement the primary purpose of signalling (as opposed to providing more cost effective signalling systems) has been initiated.

Before proceeding any further with the proposal of new technologies, the primary purpose of signalling was reviewed and it is now more opportune to broaden this purpose to become "the purpose of train authorisation systems". The scope of requirements of train authorisation systems is wider than that of signalling systems and the purpose of train authorisation systems has therefore now been defined as follows:

- to facilitate the safe movement of trains by ensuring that they comply with their issued authorities of movement (both speed and extent of authority)

The functions which are required to fulfil this purpose of train authorisation systems were identified and are listed in the table below. Also indicated in this table are the ways in which these functions were implemented using conventional signalling and the proposed ways of implementation in the new train authorisation systems.

REQUIRED FUNCTIONS	**FUNCTIONAL IMPLEMENTATION**	
	CONVENTIONAL SIGNALLING	**NEW AUTHORISATION SYSTEM (proposed)**
Position of train	Track circuits/axle counters identify sections of track where there is no train (or part of a train)	Provide the actual position of the train (on board determination of position)
Train complete	Track circuits/axle counters and interlockings provide information as to where there is no train (or part of a train)	Train complete detection is required
Required route section defined and clear	Interlocking, track circuits/axle counters and points	Interlocking, points and determined positions of other trains
Formulated authority	Signal aspect	Extent of movement and speed profile
Communication of authority	Lineside signals	Authority communicated directly into the locomotive
Ensure compliance with authority	Driver's responsibility	Onboard train protection system
Centralised train authorisation/management centre	CTC office (where implemented)	Integrated train authorisation, electrical control and operational management centres

Tab. 2.1-1: Functional Implementation of Required Functions of Train Authorisation Systems

The main difference between a conventional signalling system and the new “transmission based” or “communication based” train authorisation system proposed above is that the communication of authorities and the updating of train positions is conveyed via a radio network and not via ground based equipment and cables. A second significant difference is that the determination of the position of a train and its completeness is done on board the train in an acceptably safe manner.

Depending on the capacity and safety requirements of a particular line, the functions listed in the table above can be done entirely by people, partially by people with technological assistance, or completely by technology based systems. The levels of train authorisation systems which are foreseen for Spoornet are shown in the table 2.1-2. All of these systems rely on the train (or its driver) to identify its own position and completeness (no track circuits or axle counters) and the authority is conveyed directly into the locomotive. The control of the points at the higher levels of these systems (CBA-Token and CBA-Continuous), will be by means of radio directly to each points machine and locked by a centralised/area interlocking system. At the lower levels of these systems, the points will be operated manually, automatically (spring points) or electrically with initiation by the driver (including the option of remote control from the cab of the locomotive).

SYSTEM	COMMENT
Communication Based Authorisation-Manual (CBA-Manual)	Manual radio token system with or without non-vital assistance to the TCO and/or driver (eg Radio Train Order, Track Warrant)
Communication Based Authorisation-Manual Asst. (CBA-Manual Assisted)	Vitally interlocked radio token system with vital or non-vital assistance to the driver (eg Radio Train Token)
Communication Based Authorisation-Token (CBA-Token)	Vital radio token system with train initiation of elements (points etc) ahead of it within the token section
Communication Based Authorisation-Continuous (CBA-Continuous)	Vital radio authorisation system with continuous control of all elements and continuous detection of the train position

Tab. 2.1-2: Levels of Train Authorisation Systems foreseen for Spoornet

2.2 The SPOORNET ORE Export (OREX) Line

The Orex line is an 861 km single track line which was established in 1976 and is used primarily to convey iron-ore in 216 wagon length trains from Sishen to the port at Saldanha. Crossing loops have been established at intervals of approximately 80 km, although the original planning of this line catered for crossing loops every 40 km. This line runs through sparsely populated countryside and (apart from the existing and planned loops) there are no readily available power sources or land based communication facilities along the length of the line.

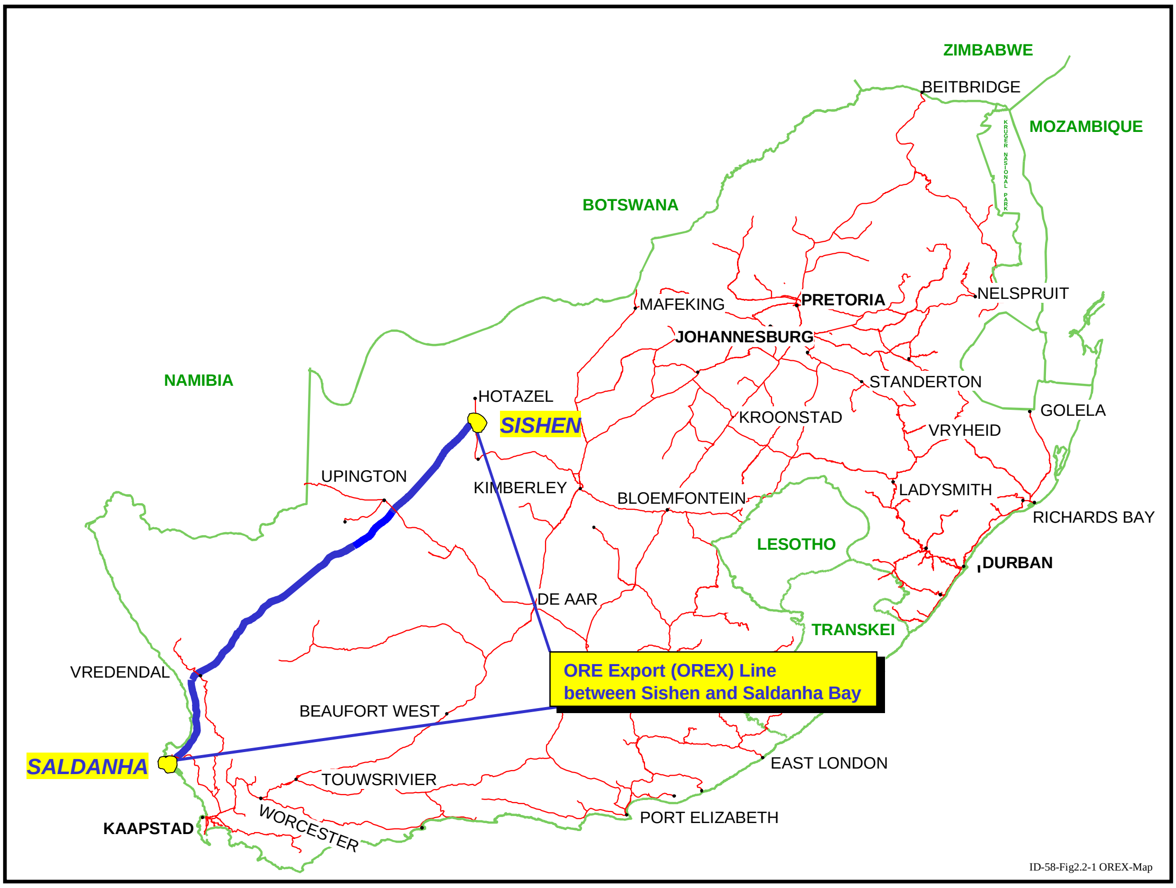

Fig. 2.2-1: The ORE Export (OREX) Line between Sishen and Saldanha Bay

The crossing loops are signalled using conventional lineside signalling with track circuits for train detection while the block sections are declared unoccupied by means of Last Vehicle Detectors. Local interlockings control the signalling at each loop and these are remotely controlled from Saldanha. The remote control communication is over a microwave backbone (recently upgraded) which has drop off points every 40 km (ie at all the existing and planned loops). Verbal communication with the locomotive drivers is by means of a radio system which also uses the microwave as a backbone.

Because of a predicted increase in capacity requirements, it is now planned to establish the intermediate loops on the entire line over the next 18 months and thereby allow for the crossing of trains every 40 km. There is a further requirement that the headway be reduced to approximately 15 km to cater for other shorter trains and inspection vehicles. If conventional lineside signalling is used to signal the new loops, all the existing block section control systems will have to be replaced with axle counters and block signals spaced at approximately 15 km. In addition to the signalling of the new loops, the existing signalling will also have to be replaced because of age and interfacing problems.

Fig. 2.2-1 and 2.2-2: Images from the ORE Export (OREX) Line

2.3 Status of the OREX CBA Project

Because of the above mentioned requirements, it was decided that a new technology train authorisation system should be introduced on this line within the next 2 years. Apart from the increased capacity, the main requirements for this system are that it is more cost effective than conventional signalling and that trackside based equipment is kept to an absolute minimum due to the long distances involved in executing maintenance and fault repair on this line. The User Requirements Specification for the Orex authorisation system has been completed and is in line with the above mentioned philosophy. The Functional Requirements Specification (FRS) is currently being produced by a Spoornet/Signalling Industry workgroup. Once this FRS is complete, it will be sent to the UIC for their comments and further input, if required. The FRS is in line with the philosophy given above and it addresses the detailed functional requirements of Spoornet in terms of Spoornet’s Principles of Safe Movement on Rail. While no technology is specified in this FRS, the seven technological areas given below are addressed:

- **Centralised Control/Management Centre:** This will enable optimal planning of traffic movements and will enable the most cost effective utilisation of assets, especially when the integration of train authorisation, electrical control and operational management is implemented.

- **Radio Based Communication System:** Radio is favoured for its ease of implementation and both data and voice communication can be provided by the same system. The radio system provided for the Orex line will make use of the existing microwave communication backbone.
- **Train/Driver Interface:** The train driver must be provided with a user friendly interface which conveys the information required to optimally control the train. The minimum information required will be the maximum safe speed, the actual speed, the next target speed and the limit of the current authority. The system must prevent the train from exceeding the maximum allowable speed and the limit of the authority.
- **New Interlocking Systems:** Interlockings will have to be provided not only to cater for the normal route locking and releasing functions but also to handle "variable position" type information where trains will request information regarding the route status at “authority reconfirmation points” and at “authority releasing points”.
- **Train Positioning System:** It is a requirement that the system provided for Orex has minimal ground based equipment and therefore the positioning system must not use track circuits or axle counters except where wagons may be staged.
- **Train Complete:** A suitable method of determining train completeness at the required level of safety must be defined and implemented. This method must not require that a wire be installed through the length of the train.
- **Trackside Signalling Equipment:** The points machines must be controlled via radio data links. Power for these points machines must be made available at each points machine (or cluster of points machines) by means of localised power generation (eg solar panels and batteries) or from the overhead electrification system.

A concept diagram of the proposed Orex communication based train authorisation system is given in the figure 2.3-1. The interlocking function may be done on a centralised or decentralised basis depending on the communication requirements to implement the CBA functionality.

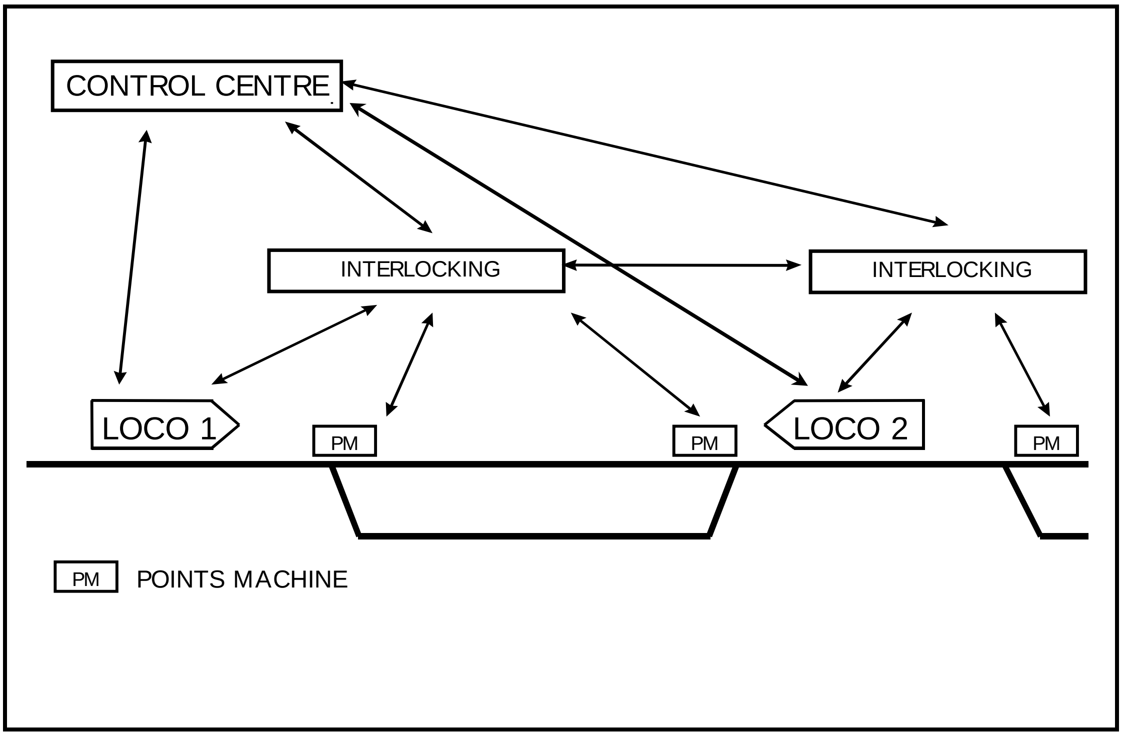

Fig.2.3-1: Proposed Orex Communication Based Train Authorisation System

3 Indian Railways ERTMS/ETCS and GSM-R pilot project between Mathura and Palwal on the Delhi – Agra section of Central Railways

3.1 Background

The historical train journey in 1853 between Bori Bunder and Thana heralded the beginning of railways in India but it also initiated the evolution of rail technology, which picked up momentum as the years rolled by.

Today Indian Railways have a multiple gauge network of about 62485 km out of which 13490 route km are electrified. Until end of the last century the rail traffic grew up to 421 million tonnes of freight traffic and up to 4594 millions of passengers a year. A fleet of 7206 locomotives, 34728 passenger coaches, 263981 freight car/wagons are owned by Indian Railways. There are 6995 stations and 40329 level crossings on its network.

Between 1950 and the end of the 20th century passenger traffic on Indian Railways has increased by about 360% and freight traffic has increased by about 455%, whereas the route length has increased by only 17%. This has been achieved by steady increase in productivity of assets, wherein signalling and telecom has played an important role.

Starting in early 1880s, from the mere job of signalling a train to next station, today rail/transit signalling is entrusted with major responsibility of train control, safety enhancement, line capacity optimisation and real time train information to users and railway personnel.

With increasing competition from road and dwindling transportation share, the need for Indian Railways to be safer, more cost effective and customer friendly is now crucial. Adoption of modern technology in signalling and telecommunication is the key to success. Successful introduction of radio based ETCS level 2 on Mathura – Palwal pilot section will provide the touchstone technology for improving safety, capacity and IT on Indian Railways in the years ahead.

3.2 Quest for a New Signalling Technology

Indian Railways made their first attempt to provide an Automatic Warning System (AWS) on the main line between Calcutta and Delhi in the 1970s. But in spite of best efforts made the project could not succeed due to theft of track magnets. Since then the search has been on for a suitable pilfer free Automatic Train Protection system for Indian Railways.

Aftermath of a major accident at Ferozabad in 1995 Indian Railway Board appointed a committee to study the various AWS systems in use and recommended a suitable AWS system for Indian Railways. After a comprehensive study of the various ATC systems in use world-wide, the committee recommended adoption of a radio based ATC system i.e. ETCS Level 2 for Indian Railways.

3.3 The Pilot Project

In 1999 Indian Railways sanctioned a pilot project of ETCS Level 2 on Palwal -Mathura section on Central Railways. This 82 km long double track section is on Delhi – Mumbai 25kV AC electrified trunk route of Indian Railways. It is provided with Multiple Aspect Colour Light Automatic Signalling (MACLS) covering 180 main signals and is controlled from the control centre at Agra. The design speed on the section is 160 km/h maximum. It covers 10 stations and 37 level crossings. Thirty five locomotives are planned to be equipped with ETCS cab equipment. Radio coverage will be in GSM-R frequency band.

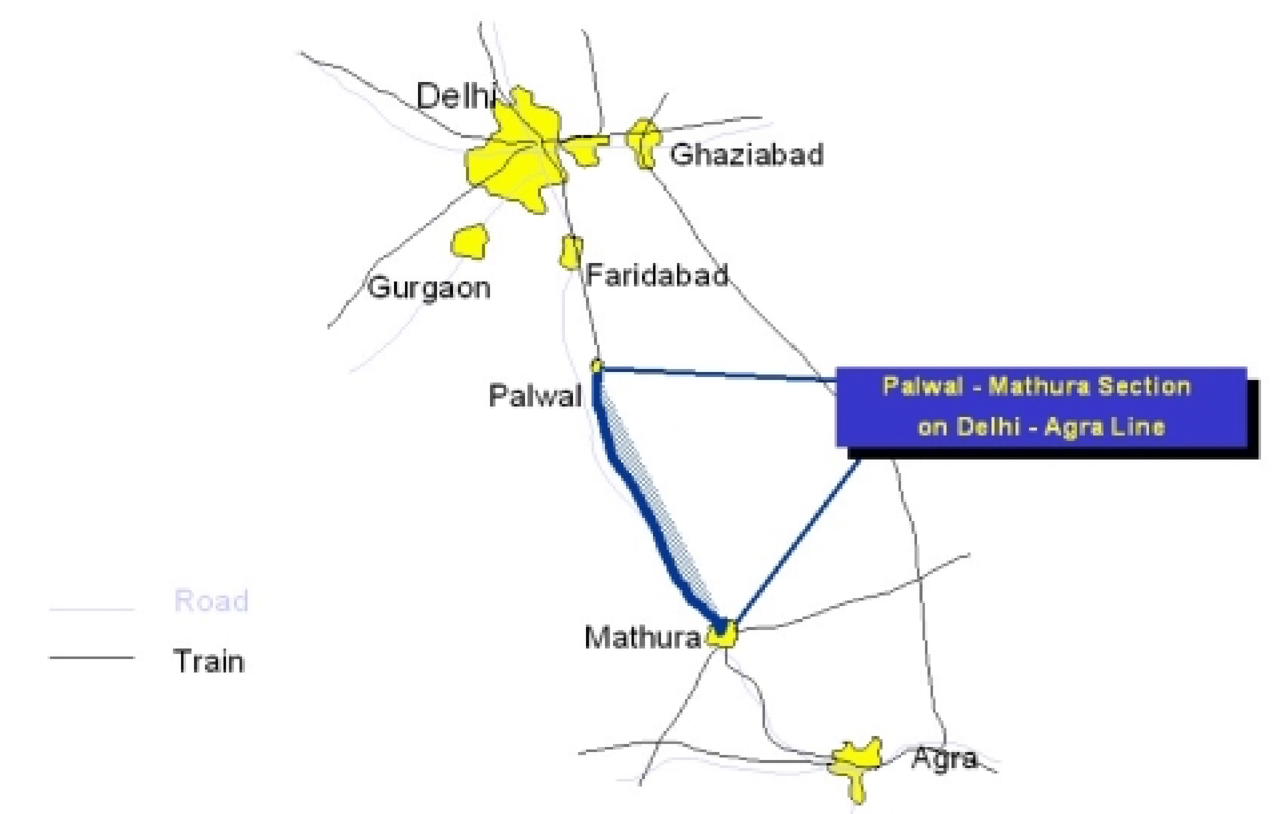

Fig. 3.3-1 Palwal-Mathura Section on Delhi-Agra Line

The IR-ETCS pilot project is expected to be generally conform to the Functional Requirement Specification (FRS) of ETCS and EIRENE and shall basically, as a minimum, follow the Class 1 requirements of UNISIG.

While in Europe, ETCS is being introduced primarily to meet interoperability and high speed requirements, for Indian Railways it offers one window solution for improvement of safety, capacity and real time train information for public / rail personnel. The safety features planned to be validated and achieved on Mathura – Palwal pilot section are:

- Automatic train protection and speed control.
- Train approach warning to level crossing and staff working at site.
- Temporary and permanent speed restriction enforcement.
- Train radio communication between driver and control centre.

The radio based ETCS can also increase the sectional capacity with suitable modification in signalling practises for ETCS equipped trains. The on line train information data available at Agra control centre can be interfaced with audio/visual/IT based train information system for use by public. The GSM-R radio network will enable shunting radio, maintenance radio and value added services for passengers.

Fig. 3.3-1 and 3.3-2: Images from the IR-ETCS Trial Site between Palwal and Mathura of Central Railways

3.4 Present Status of the IR ETCS Level 2 Project

The Ministry of Railways (Railway Board) of India called for pre-qualification for design, manufacture, installation, testing and commissioning of IR-ETCS in 2000. The pre-qualification phase was supported by pre-qualification meetings in Delhi, where possible tenderers could clarify open items and visit the proposed trial site. Amongst the offers received, five consortia were pre-qualified. Out of this pre-qualified companies two consortia have sent an offer for the IR-ETCS project to the Ministry of Railways in Delhi. At the moment (July 2001) some additional discussions with tenderers/evaluation of the offers are in progress by the Ministry of Railways in India.

3.5 Future Aspects

Depending on the results of the technical validation and performance of the IR-ETCS pilot project on Delhi - Agra section its application on 14864 km of main Indian Railways routes and on 4000 locomotives of Indian may be envisaged in the future years.

4 Conclusion

The rapid development of communications technology has made it possible to investigate alternative technologies to implement new train authorisation systems. In North America, the main motivation is safety and optimisation of operations while in Europe, the main motivation is interoperability. In India the main objective is safety enhancement and future utilisation of increase in section capacity and use of on line train information. In South Africa the main motivation will be cost saving and, to some extent, the implementation of pilfer free signalling technology. These savings should be achieved by lower capital costs and the reduced maintenance requirements (due to the reduction of track side equipment). The migration path to communication based train authorisation systems will be complex on certain parts of Spoornet’s and Indian Railway’s network and may require an overlapping period of usage of both conventional and new train authorisation systems. These complexities and other technological difficulties should, however, not prevent Spoornet and Indian Railways from moving towards the adoption of new technology as it will prove to be more cost effective and efficient ways of authorising trains. The Orex line will be the first line on Spoornet to use a fully technology based Communication Based Authorisation System as its primary method of train authorisation while in India the IR-ETCS trial site will be the first line on Indian Railways to use such a new technology. Both projects show that communication based train authorisation technology more and more steps into the railways and that ETCS technology is moving out of the boundaries of Europe to railways world-wide.