Journal of Rail Transport Planning & Management 2 (2012) 79–87

Contents lists available at ScienceDirect

Journal of Rail Transport Planning & Management

journal homepage: www.elsevier.com/locate/jrtpm

An overview of lessons learnt from ERTMS implementation in European railways

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ARTICLE INFO

Article history:
Received 30 November 2011
Revised 7 October 2013
Accepted 11 October 2013
Available online 7 November 2013

Keywords:
ERTMS
Interoperability
Safety
ETCS

ABSTRACT

The European Union's aspiration for railway systems that are interoperable across Europe is driven by the need to service a market that is open within and across industrial sectors and national boundaries. This in turn requires that the technologies and operational procedures that underpin the railway systems facilitate not only interoperability but also enhancement of safety, capacity and efficiency. The European Railway Traffic Management System (ERTMS) is designed to enable interoperability through use of one unique signalling system as opposed to conventional signalling systems. However, the introduction of ERTMS must be undertaken to facilitate the European wide ambition to reduce risk on the railways.

This paper addresses the issues relevant to the safe introduction of ERTMS into European railway systems, with a focus on the technical and procedural challenges of moving from conventional signalling to a new traffic management system. Existing literature, augmented with a targeted survey of subject matter experts, is used for a critical appraisal of safety considerations across Europe. Differences and variations across networks and countries are identified, and used to determine the significant issues that need to be addressed to enable the safe introduction of ERTMS. Finally, generic observations are made on the factors that impact safety and human factors as a result of the introduction of new technologies and procedures into existing railway environments.

1. Introduction

During the past decade, European railway system design and operation has become increasingly complex. This change and modernisation to railways has been driven by aims for an integrated European railway network under the terms of interoperability. Interoperability aims for unification of signalling systems, technical coherence and harmonisation. The European directive 96/48/EC (Europa Summaries of EU Legislation, 2011) details the expectations of interoperability on high speed trans-European railway lines. This directive is aimed at servicing a market that is open across national boundaries, as reflected in the current trend to markets that are more open, both within and across industrial sectors and national boundaries.

Development of railway systems such that they meet the EU's drive for interoperability has led to increased levels of automation. Automation and modernisation of railways has faced a number of constraints which include incompatibility with legacy systems and changes in operational procedures, both of which have the potential to impact safety.

The EU's aspiration for an open market makes it desirable for a common approach to safety related issues, where safety is defined as *freedom from unacceptable risk of harm* (Guidance for Engineers, 1995). Of particular interest, an aspect of safety referred to as *safety culture* is reviewed. Safety culture has been defined in a number of ways relative to its context, safety culture, has been defined as a method for assessing organisational safety at interfaces (Tessédre and UIC, 2004), alternatively, it has been described as a product of the individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine commitment to, and the style and proficiency of, an organisations health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, shared by perceptions of importance of safety and by confidence in the efficiency of preventative measures (Rail Safety and Standards Board, 2011). Thus, safety culture is a key consideration for railway system interoperability; at corporate and industrial levels organisational culture has been shown to have a direct impact on safety (Tessédre and UIC, 2004).

This paper evaluates a selection of European railway system developments, following modernisation through the introduction

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http://dx.doi.org/10.1016/j.jrtpm.2013.10.004

of the European Railway Traffic Management System (ERTMS). Emphasis is placed on the technical capability of ERTMS, which is the European Train Control System (ETCS) and the Global System for Mobile Communications–Railways (GSM-R). This is facilitated by specification of the functional and physical architecture that comprise railways as an initial step to appreciate the relationships that are crucial for an integrated railway system.

The paper is organised as follows. Section 2 describes the railway system, outlining its generic architecture and interfaces, for a conventional signalled railway. This is followed in Section 3 by the challenges faced across Europe with technically incompatible conventional signalled systems and the reasons for moving to the ERTMS. A case study is taken with respect to the status of deployment of ERTMS across four European countries and this is addressed in Section 4, highlighting areas of progression, key challenges and lessons learnt with respect to safety. The paper is concluded in Section 5 which surmises the move forward with ERTMS technology.

2. Railway systems

Railway systems from their inception in Great Britain in 1825 have been designed for transportation of passengers and goods. Railways are complex networks and consist of a number of systems which interface and integrate through technical compliance and through application of and adherence to rules, regulations and procedures (Glover, 1996). Failure in any of these systems and/or procedures has the potential to not only degrade system performance but to also cause a hazardous environment which could have a significant impact on the safety of a railway.

Treating the mainline railway as a system, it can be defined as 'a set of objects together with relationships between the objects and between their attributes' (Hall and Fagan). Elaborating this definition, a railway system can be considered to consist of parts which are diverse in terms of their properties and variety, once linked these parts create relationships. All technical systems, including railways have emergent properties, which is defined as those properties which lead to behaviours that stem from complex system interactions resulting in beneficial or detrimental consequences (Johnson). For example, positive emergent properties can be adapted to support tasks that were never conceptualised during design, as design alone may not have produced the optimal solution. Conversely, due to the unpredictability of such properties, they can also undermine factors such as system safety. Therefore, emergent properties can have a negative output of increasing system vulnerability, either in a physical or functional context.

The safety of railway systems must be ensured through safety requirements and assessment methodologies that address different sub systems, their interfaces and how they integrate. In addition, factors including contractual, commercial and societal relationships must be accounted for. This requires, in the first instance, a detailed understanding of the architecture from both a physical and functional context of the railway system. System architecture has been developed utilising the industry experience of the author and validated through technical discussions with engineers at Network Rail in the fields of Telecoms, Signalling, Electrification and Power, and Building Services.

The approach employed in the specification of the architecture is to depict linear systems to represent track, overhead line equipment, transmission network and Ethernet/Internet protocol. The UK railway infrastructure and electrification protection sectors identify the mainline railway as a linear electrical system with multiple sources of supply (Knight, 2011). Interfacing with these linear systems are rolling stock, stations, control room and trackside equipment.

Fig. 1 captures a number of key features relevant to safety; this includes integration between key railway systems and backbone systems of power and telecommunications which are vital for operation (Dalton, 2011). Telecommunications increasingly facilitates many existing and new customer services, creating a strong relationship between the telecommunications and railway industries. Additionally, interfacing between safety critical and non-safety critical systems, such as interlocking which is a vital system for safe route locking, thus preventing manipulation of levers that could otherwise endanger a train whilst it occupies a route section and point zone telephones for communication is another example which shows a railway's complexity. The architecture highlights the level of physical integration and in general is a visual aid to identify issues that need addressing, such as the use of ageing assets and the integration of new and legacy equipment.

3. The move to interoperability

In 1989 the European Commission carried out a study on train control and signalling issues (Europa Summaries of EU Legislation, 2011). It found that the technical challenge of maintaining a safe conventional signalled railway is reflected in the incompatibility of signalling systems across Europe, and recommended a move away from conventional signalling to a signalling methodology which facilitates interoperability.

The study was required for the reason that existing railway procedures across Europe in some cases required trains to be equipped with up to seven navigation systems. This made it compulsory for trains to switch over to the operational standard applicable at a particular country's border. Furthermore, there were concerns relating to the size of the navigation system on-board the train. Other issues such as cost, differences in rail gauge, electrification systems and the variation in the number and type of train protection systems established across Europe have also been evaluated. Table 1 provides examples of these incompatibility issues, for example, the differences in track gauge, that is, the difference between the inside of the two rails. The standard gauge used in the UK and 60% of the world's railway is 1435 mm. Spain and Portugal use 1668 mm while Russia and its neighbours use 1524 mm (Siemens, 2011). Electrification is another area where there are incompatible systems. The UK mainline railways, electrified at 25 kV 50 Hz AC match the high speed lines in France (in part). However, systems in Germany and Austria use 15 kV while Holland uses 1500 V DC.

The International Union of Railways states that the goal of ERTMS is "to enhance cross border interoperability and signalling procurement by creating a single Europe wide standard for railways with the final aim of improving competitiveness of the rail sector" (Tessédre and UIC, 2004). The benefits of ERTMS include enhanced traffic management, optimised usage of energy and network resources and increased capacity, through receipt of optimal/anticipating schedules and guidelines. In order to realise the benefits, ERTMS must underpin *technical* and *operational* interoperability (Unife, 2011).

Interoperability across Europe has been prioritised according to the type of railway line. The first priority is for the interoperability of high speed train lines followed by conventional lines (Barger et al., 2010). Technical requirements for interoperability demand the application and implementation of the same interfaces between equipment. Operational requirements require application and implementation of the same interfaces between the driver machine interfaces. Therefore, a move towards interoperability requires convergence from a number of railway systems into a single system. This convergence would bring about inter-running