ROYAL ACADEMY OF ENGINEERING

Rail technology: signalling and traffic management inquiry

House of Commons Transport Committee

April 2016

Royal Academy of Engineering Response to the consultation on rail technology

This evidence is submitted by the Royal Academy of Engineering. It is based on the views of the Academy's Fellows, including senior leaders from the rail industry.

Executive Summary

- The specifications for the European Train Control System (ETCS) are agreed on a Europe-wide basis across both operators and suppliers. As such, they take a long time to develop and to change. While the original intention was to have standards completed and released in the early 2000s, they are still not fully agreed.

- The timings for the roll out of digital technologies by Network Rail appear conservative when compared with what has been achieved on high speed projects in other countries but, in the UK environment, with multiple stakeholders, lack of alignment between costs, benefits and organisational boundaries and the issues that surround application to an in-service, mixed traffic railway there will be many challenges.

- The maximum benefits from ETCS will be realised only when implemented without conventional signals, requiring all trains to have been fitted with new technology. This causes a major 'disconnect' between expenditure being incurred and benefits being realised.

- The plan for implementation needs to have at its core a plan to grow resources, particularly human resources, within Network Rail and within its supply chain. Network Rail needs the engineering resources to specify ETCS schemes, manage their delivery and maintain the system in service. The programme for implementation of ETCS needs to be optimised to reflect the ability to grow a resource base capable of delivering it.

- Strong support will be needed from all stakeholders and it is important that governance and structure of the whole system is acknowledged as a cross industry concern and should not fall solely to Network Rail. The establishment of a single national programme with representation from all stakeholders is essential.

- There are numerous factors that will determine whether the potential benefits of ETCS will be realised and these will significantly vary from route to route. It is essential that a 'whole system' analysis is carried out for every route and its impacts on adjacent routes to find optimum solutions.

- A whole-system analysis must also apply to the assessment of digital technologies in relation to other investments both in rail and across the transport system as a whole. The Academy's recent paper on the transport congestion challenge[1] points out, there

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[1] The transport congestion challenge. Royal Academy of Engineering, November 2014.

are a number of points of potential investment that would impact on congestion across the transport system viewed as a whole.

Introduction

1. Railways have long been users of digital electronic technologies. The systems that control train routing to prevent the setting of conflicting routes have largely been computer-based since the late 1970s and early 1980s with the Solid State Interlocking (SSI), where British Rail was among the first developers. Automatic train protection to enforce signal observance and prevent speeding has also been available for 20 or 30 years, although cost considerations have affected wide-scale adoption. The consolidation of control into larger operating centres offers manpower cost savings and improvements in service delivery.

2. The railway is a large 'system of systems' and interactions are complex. The failure of a train at one end of the country can cause disruption at the other, and problems can run on for hours. Improvements in computer power, speed, cost and storage capacity mean that a range of modern digital electronic equipment is now available, providing the potential to apply digital technology further in the delivery of improved capacity and system-level reliability, in particular the ability to manage failure situations with less overall effect.

3. Centralised control, with decision support tools for optimising routing and timing decisions can significantly reduce service recovery times. Connected Driver Advisory Systems (CDAS) can pass information on route timing directly to the trains, aiding energy conservation, smooth running and recovery from perturbation. A smooth running railway is also a safer railway as predictable timing allows more complex, conflict-free timetables to be run and trains will encounter fewer red signals or their equivalent. This kind of innovation has become even more important as the traditional recovery aid of leaving spare paths in the timetable has been eroded by increased traffic.

4. The Committee's areas of interest refer to the European Railway Traffic Management System (ERTMS) and the European Train Control System (ETCS). ERTMS comprises ETCS, the Global System for Mobile Communications-Railway (GSM-Railway) and the European Traffic Management Layer (ETML). Since there has been very little work completed on ETML, and the Committee includes a specific bullet point on GSM-Railway, this response primarily concentrates first on ETCS and then on GSM-Railway. We first provide two introductory section: the first is an overview of the ETCS – including what constitutes its three 'levels' of design architecture – and the potential opportunity it provides. The second introductory section gives an overview of key challenges involved in full or partial implementation of ERTMS. We then make points specifically in relation to the topic areas specified in the inquiry scope.

Overview of ETCS: what is it and what does it offer?

5. ETCS was conceived in the early 1990s by the International Union of Railways (UIC) as a new standard Automatic Train Protection (ATP) system for high speed railways. It is now mandated for all new railway and significant upgrades or renewals within the EU by a series of Directives collectively known as the Interoperability Directives. These are intended to allow the free movement of trains across borders within the EU. This

started off for high speed rail (Directive 96/48EC) but, in 2001, was extended to cover conventional railway infrastructure (Directive 2001/16EC). ETCS was conceived with three 'levels' (design architectures of increasing capability).

6. Level 1 is a basic 'intermittent' ATP system. A computer on the train reads the status of the signals via a local track-based interface using beacons or loops. Line-side signals are retained. Level 1 is purely a safety system, offering no increase in capacity. It is not being considered for the UK as it would add cost at almost no benefit over the existing Train Protection and Warning System (TPWS).

7. Level 2 uses the GSM-Railway radio[2] to communicate continuously between track and train. A Radio Block Centre (RBC) calculates safe 'Movement Authorities' for the trains and passes them to each train via GSM-Railway. Detection of train position is still track-based; the train position is known, via track circuits or axle counters only to be somewhere within a particular 'fixed block' along the track. Line-side signals may be retained but can also be removed, provided all trains are fitted with the requisite technologies. Some capacity and performance improvement is possible as the restrictions of signal sighting around curves and structures are no longer a constraint. This is the architecture used on most high speed lines for which it can be considered a mature technology. A version of ETCS level 2 known as CTCS3 is implemented on over 19000km of high-speed lines and over 1,100 trains in China where equipped trains have covered over 1.2 trillion kilometres and failure rates are now in the order of one stopping failure per million kilometres.

8. Level 3 builds on level 2 by eliminating track-based train detection. Trains track their own positions by regularly updating position data in relation to beacons of known position. Since train positions are known, the system can be 'moving block' – offering improvements in capacity particularly at lower speeds as trains can move up to a position constrained only by their braking distance and an allowance for errors and latency. This releases additional capacity in busy areas by allowing trains to run closer together. Furthermore, removal of signals and track-based train detection eliminates most line-side infrastructure (except points) leading to significant maintenance cost savings. ETCS level 3 should also end the directional dedication of tracks allowing two track lines to be used bi-directionally and multi-track layouts to run in any direction on any line. This would allow trains to pass a slower or failed service using the other line without manual procedures and even parallel running on adjacent tracks. Additional timetable flexibility may also allow improved connectivity by facilitating previously impractical stopping patterns.

ETCS: key challenges

9. To date, Level 3 has only been implemented on a few low traffic rural lines, for example, in Sweden, and on predominantly freight lines, for example, in Kazakhstan. There are significant challenges involved. For trains that are not of fixed length and composition, such as freight trains, the lack of track based train detection means that an alternative method of proving a train has completed a particular portion of track must be provided. Such 'train complete' equipment of sufficient proven safety integrity is still at trial stage.

[2] Further details on GSM-Railway are given in paragraphs 26 and 27.

10. For the systems benefits to be realised on any existing railway, ETCS level 3 requires all trains to be fitted with the requisite technology. For unfitted trains, the existing line-side signals must be retained creating a potentially complex and costly 'hybrid' system. This presents a potentially serious challenge in the UK. Depending on what railway is being fitted and the services and routes it accommodates, a large range of rolling stock types – from heritage trains such as the Flying Scotsman through to specialist services such as the Direct Rail Services (DRS), operated by the Nuclear Decommissioning Authority - would have to be equipped. The engineering required to fit complex electronic control systems to old rolling-stock, which may have been modified many times and for which there may not be a consistent fleet standard, could be significant.

11. Not only does much of the investment need to be made before the benefits are realised, in the UK context, costs and benefits do not naturally align with the organisational boundaries between Network Rail, train operators and train owners. In the contractual complexity of the UK railway, there could potentially be many financial claims that would add to the overall cost. Lease companies could claim for the engineering and development cost of fitting equipment to existing fleets and for the residual values of vehicles scrapped because they were uneconomic to modify. Operators could claim for the loss of use of assets during the modification process and for any disruption caused to timetables. Making a business case and managing the transition for any existing railway is thus a significant challenge, particularly if disruptions to existing services are to be avoided. Regulatory and government intervention is likely to be needed to ensure costs and benefits are fairly shared between stakeholders and to 'prime the pump' in terms of early funding.

12. A further challenge will be the availability of skills. The design, installation, validation, commissioning and maintenance of digital rail technologies require skills not common in today's UK railway, for example in safety critical software. Furthermore, while it has been very effective, the existing TPWS is a 'non-vital' system, intervening by automatically applying the brakes only if the driver makes a mistake. It does not give the driver any instructions such as the speed to drive at or where to stop and, therefore, it cannot create a hazardous situation if it malfunctions. The ETCS, on the other hand, does issue such commands and malfunction could lead directly to an accident. New operational rules will be required as will a significant training programme involving thousands of staff.

13. A good contracting strategy will also be essential. The demand for such systems continues to grow and suppliers face skill shortages of their own. While recognising the need to secure value for money, too tough a stance on margins and the sharing of risk will result in suppliers servicing other markets where risks are lower and margins more secure. The UK is perceived by some as a relatively difficult contracting environment and some of the most qualified suppliers have already refrained from bidding for pre-cursor contracts.

14. There are numerous factors that will determine whether the potential benefits of ETCS will be realised and these will significantly vary from route to route. Even if control system improvements are made, additional constraints may limit capacity including flat junctions[3], station capacity and single track viaducts or tunnels. It is essential that a 'whole system' analysis is carried out for every route and its impacts on adjacent routes

[3] A flat junction (also known as a 'level junction') is a railway junction that has a track configuration in which merging or crossing tracks require trains to cross over in front of opposing traffic.

to find optimum solutions. A whole-system analysis must also apply to the assessment of digital technologies in relation to other investments both in rail and across the transport system as a whole. Some Fellows are of the view that there has been a long-standing over-emphasis on the elapsed time from ticket barrier at the point of boarding to ticket barrier at the point of arrival while investments might be better skewed towards raising the quality of experience and reducing the elapsed time for the parts of the journey outside the ticket barriers at each end. Likewise, as the Academy's recent paper on the transport congestion challenge[4] points out, there are a number of points of potential investment that would impact on congestion across the transport system viewed as a whole.

15. Overall, however, while the benefits claimed for the implementation of this suite of technologies sometimes tend towards optimism, there is no doubt that very significant potential benefits exist in terms of capacity and the cost and reliability of service delivery. Critically for some railways, the benefits of ETCS are available without the need for the cost, delays and disruption of the land acquisition needed for additional tracks.

16. Finally, it is worth noting that the resilience of the overall system should be a key consideration. On the rail network, any moves to increase efficiency while not introducing extra track capacity[5] also reduce the system's capacity to cope under abnormal conditions. Making a robust system capable of coping with abnormal events is a different challenge to maximising throughput under normal conditions and resilience of the rail network under the ETCS system requires due attention. This is all the more important given that it is not obvious who would own ERTMS assets, how the overall system safety assurance would be undertaken and whose responsibility this would be.

17. Resilience is not solely an issue of spare capacity and flexibility; there are other, often unexpected vulnerabilities that require serious attention. As an example, while electronic trackside systems are retained, they need reliable power supplies. During the power cuts in Lancaster that took place as a result of flooding caused by Storm Desmond in December 2015, Lancaster station was closed not because of a loss of signalling supply but because the station lights and auxiliary facilities were not available. A further, newer consideration with a radio-based signalling system such as ETCS is cyber security.[6]

18. While the challenges in fully realising the Digital Railway Programme are significant, we submit that the benefits are large enough to merit treating it as a project of national significance on a par with the 2012 Olympics, HS2 or Crossrail. The Digital Railway programme should remain a national one in order to retain the necessary skills at a level that can steer effective nation-wide rollout.

The efficiency of Network Rail's planned roll-out of the ERTMS and ETCS across the rail network.

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[4] The transport congestion challenge. Royal Academy of Engineering, November 2014.

[5] This includes technological innovations such as ETCS but also includes other measures such as differential pricing to spread peak loads.

[6] Infrastructure resilience will be the topic of a forthcoming report by the Academy exploring the events in Lancaster following Storm Desmond.

19. The specifications for ETCS are agreed on a Europe-wide basis across both operators and suppliers. As such, they take a long time to develop and to change. In the development of ETCS, the requirement to use it for conventional as well as high speed rail created a number of issues and significant delay to the completion of standards. While the original intention was to have standards completed and released in the early 2000s, they are still not fully agreed. Railway operators have not wanted to change their operating rules and principles because of the costly retraining exercise involved. This has meant that a 'common system' became a 'toolkit' which could work to the operating rules of the railways in each of the EU member states. Given this, the on-board system in particular is highly complex (it contains over 100,000 lines of safety critical code). This is hard to change with a lengthy reapproval process.

20. This reluctance of the industrial partners involved in developing the ETCS to lose their technical heritage and to undertake significant levels of retraining has introduced limitations to the extent to which equipment is standardised and interchangeable across suppliers. If a train is equipped with an on-board system from a given supplier, then in broad terms spare parts can only come from that supplier. While there has been work to address compatibility between different suppliers, the specifications are extremely complex and any change risks further differences in interpretation and new issues.

21. Some are also of the view that the supply industry is 'dragging its feet' in the development of Level 3 ETCS technologies because it wants to recover significant investments made in Level 2 technology and therefore has little incentive to implement a technical solution that will significantly reduce sales of low risk, high volume, high margin trackside components.

22. The key specification document for ETCS is the System Requirement Specification (SRS) which is formalised as a Technical Specification for Interoperability (TSI) under the Directive. All TSIs are now managed by the European Rail Agency (ERA). Most ETCS systems currently in service are built to SRS version 2.3.0.d which is suitable for high-speed passenger railways but does not define many of the features needed for a high density, mixed traffic railway. The latest version of the SRS is version 3.5.0. This contains most of the features Network Rail will need - including the use of GPRS – but is so new that none of the ETCS suppliers are yet able to provide it and issues may still arise in implementation. For a system that is mandated for use across Europe, maintaining backward compatibility with previous versions is a key issue that has been proving challenging, for example, the first release of the latest version is now being deemed a 'technical release' only, as it is not backward compatible. This shows that, even after more than 20 years in development, there remain risks around the mandatory standards in terms of completeness, backward compatibility and compatibility between suppliers.

23. Caution is needed where Network Rail proposes the use of ETCS Level 3, given that specifications are yet to be finalised. ETCS Level 2 without signals would appear to be a more practicable option for implementation for the foreseeable future and to grow the industry capability until such time as the conceptual systems become realisable.

24. The implementation of the Rail Operating Centres (ROCs) is not dependent upon the new ETCS signalling technologies and can be considered as an independent initiative on its own merits.

25. Finally, there are issues to be resolved at the interface of different signalling systems as they are currently being rolled out on major rail investments. Interface issues can and do arise such that, where introduced, the future transition to ERTMS is inhibited. Overcoming interface issues will add costs to the roll out of ERTMS. There is therefore a need to avoid a mismatch of technologies on new and current rail investment schemes that will need migrating to ETCS level 3 at a later date.

How the state of current GSM-Railway technology impacts rail infrastructure.

26. Global System for Mobile Communications – Railway (GSM-Railway) is the radio system mandated as part of ETCS. This is the dedicated railway version of the Global System for Mobile Communications (GSM) developed for commercial mobile phones. It has a number of additional features needed for a railway radio such as 'priority and pre-emption' for emergency calls, voice broadcast, location based connections and 'group calling'. GSM-Railway originated from a UIC project and was later converted to a European standard solution. GSM-Railway has its own SRS which, having been released in 2010, can be considered reasonably mature. The radio is a non-safety critical information bearer with encryption provided to a standard protocol, called EURORADIO. GSM-Railway has radio frequencies allocated to it.

27. Network Rail has implemented GSM-Railway for voice radio to replace the earlier National Radio Network (NRN) (now obsolete) and Cab Secure Radio (CSR). However, the voice radio implementation will not be sufficient in most areas to support the data requirements for ETCS Levels 2 and 3 and further investment will be needed in this area. To date, apart from in some limited trials, ETCS has used GSM-Railway in 'circuit switched' mode; where the train maintains a circuit switched digital modem connection to the train control centre at all times. Since studies conducted in 1996[7], it has been known that the frequency band allocated to GSM-Railway does not allow sufficient connections to be established and maintained in dense traffic areas, such as close to terminal stations. Since radio spectrum is a scarce and high value commodity, the chance of obtaining additional GSM-Railway spectrum is remote – indeed, interference from adjacent channels already allocated for commercial operations has been an issue in some places and the GSM-Railway equipment manufacturers are having to adopt additional filtering. The UK has therefore long promoted the inclusion and use of the General Packet Radio Service (GPRS) of GSM within GSM-Railway and the ERTMS standards to provide additional ETCS data transmission capacity.

28. GPRS uses data packets with inbuilt destination addresses, passed via a single transmit/receive frequency pair. Recently released, it has taken nearly 20 years to get it agreed. Almost all of the work to develop, test and assure GPRS against security, latency and data quality criteria had to be funded and executed by Network Rail since most other European railways have, at least to date, stopped using this type of system on the approach to termini, instead relying on conventional signalling. For a terminal at or close to full capacity that immediately negates any capacity benefits.

29. The GSM-Railway network will need additional base-stations, the movement of some existing base-stations and the addition of GPRS capability to support the data capacity and quality needed for the Digital Railway programme.

[7] For example on Railtrack's upgrade of the West Coast Mainline.

How realistic the timings proposed in Network Rail's 'Digital Railway' programme are and how these will be achieved.

30. The timings proposed by Network Rail appear conservative when compared with what has been achieved on high speed projects in other countries but, in the UK environment, with multiple stakeholders, lack of alignment between costs, benefits and organisational boundaries and the issues that surround application to an in-service, mixed traffic railway there will be many challenges. There will also be a need for supporting civil works in some places such as junction remodelling, including the construction of flyovers for grade separation and short additional sections of track. These are likely to entail delays associated with, for example, consultation and land acquisition.

31. The most significant long term challenges will be client and supplier capability and resources, including the new engineering skills for the design, implementation and maintenance of the new systems required. Resource shortages are already being felt in this regard which additional initiatives will only exacerbate if not considered as part of the implementation programme.

32. As already noted, the maximum benefits from ETCS will be realised only when implemented without conventional signals, requiring all trains to have been fitted with new technology. This causes a major 'disconnect' between expenditure being incurred and benefits being realised and will result in pressure to provide an infrastructure roll-out that cannot be realistically resourced. The plan for implementation therefore needs to have at its core a plan to grow resources within Network Rail and within its supply chain. Network Rail will need an engineering capability to specify ETCS schemes, manage their delivery and maintain the system in service. This will require a combination of theoretical learning and practical experience. A steady flow of projects is the most effective means by which to develop the resource and skills bases that are currently lacking.

33. Academy Fellows suggested that, a strategy for growing the necessary resource capability in Network Rail might include employing 'trainees', through a combination of apprentices and graduates/sponsored students, to work on the initial projects alongside experienced staff on the early projects. Staff will likely require a combination of formal training courses on individual aspects of ETCS and practical experience of scheme design and delivery. Staff who gain such experience in delivering ETCS will become key assets and intelligent knowledge management will be key.

34. Most of the detailed engineering design of ETCS will, however, be undertaken in the supply chain. Resources to design and test signalling systems are already in short supply and act as a major constraint on the ability to deliver renewal and enhancement schemes. Long term contracts for the delivery of ETCS, explicit requirements that the supply chain recruit and train new, locally based, resources and reciprocal arrangements such that the supply chain can make use of training courses in Network Rail, and vice versa, would all be useful measures for growing the capability within the supply chain.

35. The incorporation of contractual requirements to engage apprentices has been used successfully on Crossrail, with all of the initial targets being exceeded and this success should be replicated as far as possible. In general, the programme for implementation

of ETCS needs to be optimised to reflect the ability to grow a resource base capable of delivering it. Strong support will be needed from all stakeholders including government and the establishment of a single national programme with representation from all stakeholders is essential.

What legislative and other action the Government could take to support the rate of change in signalling and traffic management technology.

36. The roll-out of several key safety improvements such as TPWS, the Driver's Reminder Appliance, train data recorders and train sanders have all been facilitated by compulsion, with enforceable implementation dates, either through regulations or through standards change, made mandatory by licence condition. Given that the UK railway's safety performance is already amongst the best in the world, ERTMS systems will not result in any significant improvements in safety. They will, however, be replacing existing safety assets with significant benefits in terms of reduced costs and enhanced performance. As such, compulsory adoption in some form might seem justified. Provision for the new equipment must be built into all franchise renewals and the necessary funding be made available to Network Rail to support the significant up-front costs. For reasons already outlined in previous sections, suitable regulatory mechanisms will be needed to ensure costs and benefits are shared equitably and to validate this in practice.

Whether timetable planning is suitably optimised to meet demand for both passenger and freight rail, and how traffic management technology can be used to improve this.

37. Network Rail currently timetables in three-minute increments. To maximise utilisation of the infrastructure, this needs to be dramatically reduced, potentially to as low as five seconds. The tools are available for this but their full capability is not being used. The selection, roll out and training for a suitable standard timetabling tool suite should form part of the overall programme. The additional resilience, recovery management capability and improved predictability of the times at which trains run that come from digital technologies like Connected Driver Advisory Systems (CDAS), should allow this more detailed timetable planning to consistently and reliably release additional capacity and connectivity.