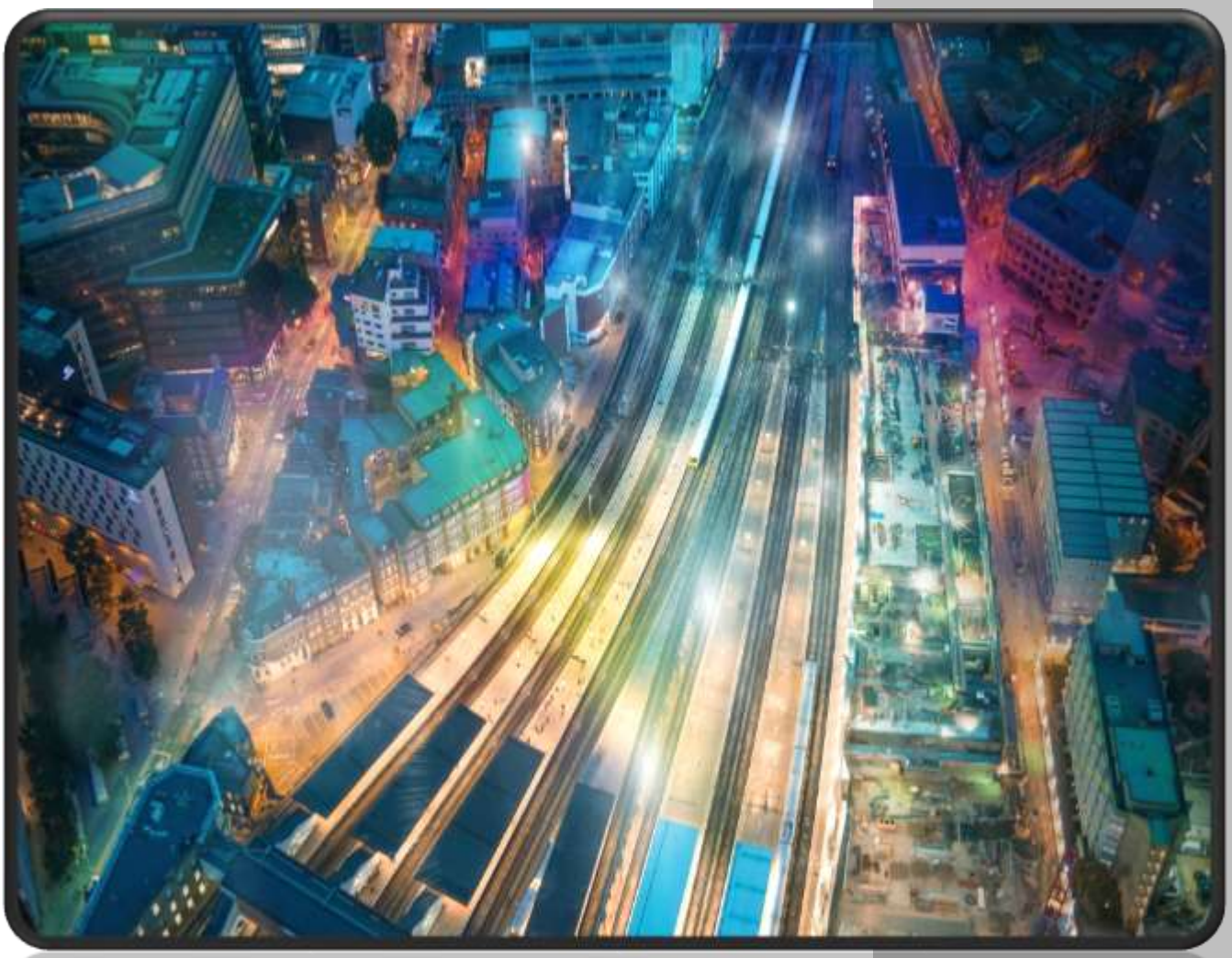
IRSE
INSTITUTION OF RAILWAY SIGNAL ENGINEERS

Making a Success of the Digital Railway



IRSE White Paper

Making a success of the Digital Railway

1. Foreword by IRSE Chief Executive

This paper has been produced by the Institution of Railway Signal Engineers (IRSE) to present our views on the Digital Railway Programme in Great Britain. The Programme has the potential to radically change this country's railways for the better. In our view it is imperative that it is successful, and we believe it can be. But the Programme is not without its problems and challenges, and in this paper we highlight some of the most pressing of those difficulties, as well as acknowledging the good work that is going on. The key messages that I believe the industry needs to heed are:

- It is absolutely essential that the industry gets on with delivering a cohesive programme of digital enhancements of the national rail network, and that it does so without further delay. The problem of how to do so is one that the industry must solve. Too much time and effort has already been wasted, whilst other transport modes are making rapid advances, and the inexcusably slow progress made by the rail industry is largely of its own making.
- A cohesive Digital Railway Programme will provide capacity improvement, greater service reliability and resilience, and reduce the whole-life costs of signalling and traffic management systems. We cannot, in the 21st century, justify perpetuating the use of fixed block lineside signalling.
- The increasing utilisation of the railway, and the general trend of increasing speeds, means that the risk of a serious accident is likely to rise, which only automatic train protection (ATP, in the form of ETCS) can address. Given this safety concern, and the industry's slow progress to date, there is an argument for mandating the fitment of ETCS within a defined period of time, just as was done for TPWS and is being done in the USA with Positive Train Control.
- To deliver a Digital Railway Programme quickly and successfully, the objectives of industry players need to be better aligned, new sources of funding and financing must be found, new contracting models need to be adopted so as to incentivise the delivery of successful outcomes, and major changes must be made to deliver projects in shorter timescales and at lower cost.

In this paper we voice constructive criticism about some elements of the Programme, and about the industry's capability to deliver it. In doing so we are endeavouring to be realistic, pointing out where change is needed. We also see opportunities, and some reasons to be hopeful. There are some good things being done, and the industry must engage and grasp them to build the capability for this transformation. Above all, the industry absolutely must make the most of this opportunity to modernise our railway.

We hope that the paper will make a positive contribution to help move the Programme forward, and to removing some of the hurdles that it faces. We stand ready to collaborate with the industry about how to continue making progress.

We thank all those who have participated in the development of the ideas presented here and for WSP in organising the workshops and coordinating the inputs.

2. Context

In late 2016 Mark Carne, the Chief Executive of Network Rail and David Waboso, Managing Director of the DR Programme, met with representatives of the Institution of Mechanical Engineers and the Institution of Railway Signal Engineers. Their request was that the engineering institutions engage with, support and communicate the importance of the Programme. Our response was a qualified yes. To support it in an unthinking, ill-informed manner would not be productive for anyone. Too many people have been witnesses to the problems of the Programme over the last 16 years to think that magic will suddenly happen. But the latest incarnation of the Programme does present a real opportunity to turn the corner.

This paper is part of the IRSE's contribution to supporting the Digital Railway Programme. The IRSE is the professional body for railway control systems and communications engineering. The digital railway is core to our domain of expertise. We speak not as a "club" of engineers, but because our role is all about providing public benefit. We are independent. We have no particular fixed agenda, other than the wish to see railways being successful and its customers benefitting accordingly.

The paper has been written at a time of major uncertainty and challenge for the railway industry in Great Britain. After years of unprecedented growth, there are signs of a slowdown. The industry is under greater scrutiny than ever about the justification for investment by the government, despite the pressing need for infrastructure enhancements. The nascent automation of road transport must be considered a real threat to parts of the rail market. Major investment in the railways during Control Period 5 has faltered, with programmes of electrification and signalling being curtailed and signal engineers being made redundant.

The recent announcement of the Statement of Funds Available by the Secretary of State for Transport, with expenditure focused on operations, maintenance and renewals, is to be welcomed. However, it is not yet clear how much investment will be available for the Digital Railway in CP6. What is clear is that rail plays a key role as an enabler for jobs, homes and growth in, around and between our major towns and cities, and as such it is vital to keep investing for greater capacity and travel opportunities.

It is within this context that the GB Digital Railway Programme is endeavouring to make progress in planning and implementing a range of digital applications. These changes can transform an industry that is at risk of falling irretrievably behind its competitors. The Programme is of critical importance for the railways' future, moving us from yesterday's technology to tomorrow's in order to deliver a railway that is operationally fit for the 21st century, and playing a central role in the move towards "mobility as a service" as part of an integrated national transport capability.

So we welcome the provision of £450M of government support for the Programme, which at least enables work to continue in the short-term, although more will be needed, whether from government or other sources. It is now incumbent upon the industry players to ensure it is spent efficiently and effectively, and to prove that the industry is collectively capable of transforming the railways. Delivering results that demonstrate both the benefits of digital technology and the industry's capability will be essential in order to secure further funding and investment.

We welcome too the direction of travel that the Digital Railway programme is taking. There is new thinking in evidence, and new forms of engagement between Network Rail, train operators and suppliers are starting to be explored. These are necessary (although not sufficient) ingredients for success.

But however optimistic we may be about the future, the industry's track record in this area is not something of which it can be proud. The Digital Railway (DR) Programme has been in existence in various forms for around 16 years. By any measure of progress, not much has been achieved. There has been some limited progress (Cambrian, Thameslink and Crossrail) but not nearly as much as was envisaged when the industry set off on this journey.

In the meantime, digital information technology has transformed many other areas of our lives. Around the time that the Programme began, the smartphone was making an appearance (before then there were only cell-phones). Windows XP was launched in 2001, as was Wikipedia and the original iPod. Information technology is now strengthening the competitive edge of other transport modes, including car manufacturers and relatively new players such as Google and Uber. The rail industry cannot afford to ignore these advances, and unless there is real unity and concerted action to remove barriers and seize the opportunities, these players will without doubt threaten rail's competitiveness and limit the contribution that the sector can make to an integrated transportation system and, ultimately, to the national economy.

3. About this paper

This paper represents the output from a number of discussions that have been organised by the IRSE in the UK, with the support of WSP.

The purpose of the discussions, and of this paper, is to highlight some of the key issues that must be addressed if the DR Programme is to be successful. "Success" in this context is that the Programme makes a significant and cost-effective contribution to the national rail network's capacity, reliability and connectivity, delivering benefit to both passengers and freight companies.

It was evident from the roundtable discussions that most people regard non-technological issues as the ones that must be addressed if the industry is going to deliver the Digital Railway successfully. This is not to say that all the technology issues have been resolved – but the general view is that they can be addressed. It is less evident that the non-technology issues can be overcome without new thinking and significant change.

The paper is structured into seven key themes, which are explored in Section 5. These themes emerged through the workshop discussions, and cover a range of industry issues relevant to the Digital Railway:

- Aligning industry objectives
- Targeted implementation
- Confidence, collaboration and culture
- Expertise to deliver
- Contracting
- Delivering efficiently
- Technology options and optimisation

Other topics were identified as issues to be addressed during the research for this paper, but time and resources have meant that some have had to be left untouched.

Throughout the paper we make observations, draw conclusions and offer recommendations based on what we have learned from the contributors to the discussions. We have not suggested solutions to all the challenges, but we are very willing to participate in finding ways forward.

A total of four "roundtable" discussions were held between November 2016 and October 2017, with approximately 25 people attending each one. These people were drawn from a variety of rail industry backgrounds, including the Department for Transport, Network Rail, Transport for London, suppliers, and train operators. We also separately sought the views of a number of other key individuals.

Train operator representation (passenger and freight) was not as strong as we had hoped for, but in other respects we consider that the involvement from across the industry was good. It included engineers, planners, project managers – both those with long experience of introducing technology onto Britain's railways, and some relatively new to the industry who brought insights from elsewhere.

After each session a report was produced. This paper brings together the content of those reports and adds to them to create a richer picture of the industry's readiness to deliver the Digital Railway.

4. Background

4.1. Historical development of digital technology for signalling and train control

The use of electronic digital technology for railway signalling has a long and successful history, and indeed for a while the UK was at the cutting edge of its application on railways. Solid state interlockings (SSI) were first used in the UK in 1985. Communications-based train control systems (CBTC) have been around for over 25 years, and Automatic Train Operation (ATO) was introduced onto LUL's Victoria line in the late 1960s, a world first. The UK's Integrated Electronic Control Centre (IECC) was developed in the late 1980's – and the upgraded integrated traffic management system being provided at the Thames Valley Control Centre at Didcot uses IECC Scalable, an evolution of that original product. Digital axle counters have been used for years.

So digital technology is far from new in the world of signalling. Plans for using the European Traffic Control System (ETCS), Automatic Train Operation (ATO), Driver Advisory System (DAS) and more intelligent traffic management systems, with more integration between trackside and train-borne sub-systems, are the latest stage in the evolution of train control and traffic management for mainline mixed traffic railways. Metros have had this sort of technology for many years of course, and in many parts of the world driverless systems are being deployed.

Arguably, the distinguishing feature of the present DR Programme is not that it employs digital technology but that it aims to make more intelligent and integrated use of data to manage the

railway, and to do so for the benefit of the railway's customers. Signalling systems (in the widest sense of that term) are becoming data-driven control systems, using data from diverse origins to inform better decision-making that provides all sorts of customer benefits, including a highly reliable service, as well releasing latent capacity currently constrained by existing control systems.

4.2. The Digital Railway Programme on the national rail network (what is it, why, who benefits)

The GB Digital Railway Programme had its origins back in 2001, when the ERTMS[1] Programme Team was first established. Sixteen years later there is still only the Cambrian line pilot scheme as the mark of tangible progress, and to be blunt this slow progress should be a source of considerable embarrassment to the industry. Whilst lessons were learned and capability was developed as a result of Cambrian, it proved not to be the start of the revolution that the industry expected or for which it had hoped.

Both Thameslink and Crossrail (both of which will use ETCS over parts of their networks) are scheduled to be completed in 2019, and some progress is being made with Rail Operating Centres using the latest traffic management systems at Three Bridges, Romford and Didcot. However, these cannot hide the fact that over a period of more than one and a half decades the industry has delivered well below expectations in the field of next generation train control systems.

The present Digital Railway Programme offers a fresh approach and opportunity (possibly the last) to move forward. Organisationally separate from Network Rail, it is adopting a pragmatic approach by implementing a range of digital systems, rather than being a national plan for fitting ETCS in accordance with the Interoperability Directive (which characterised the original programme). It is focussed on delivering improved capacity, better connectivity and greater reliability and, above all, doing so in an affordable way. Such an approach may not meet the high ideal of being a "data driven railway", but it is pragmatic and surely better than a programme which delivers little or nothing.

The Programme is important for a whole host of reasons, but ultimately it is all about the need for the GB national rail network to remain cost-effective and competitive in the transport market-place. Intelligent traffic management, coupled with ETCS, ATO and DAS amongst other things, applied in conjunction with other railway improvements, **should** help operators to squeeze more benefit from the railway network. It **should** reduce the cost of operating the railway. It **should** create better transport for its users. Indeed, it must do these things, because without them the GB rail industry will fall further and further behind other modes of transport.

4.3. International context and relevance

Great Britain is not alone in the journey towards a digital, data-driven railway. China in particular has achieved nothing short of a miracle in less than two decades, using ETCS at the core of its train control system on the high speed network. Numerous countries outside Europe are planning ETCS implementations, in places as diverse as Malaysia, Australia, New Zealand, Saudi Arabia, India and many others. It is rapidly becoming the standard train control system produced by the world's biggest railway suppliers. Many of these suppliers are also offering advanced traffic management systems to complement ETCS.

[1] European Rail Traffic Management System

In Europe, where ERTMS began, progress has been patchy. The vast majority of ETCS implementations to date have been on new high speed lines. Countries such as Belgium, the Netherlands, Denmark and Norway are now actively planning to adopt ETCS on a network-wide basis, but others are proceeding much more cautiously. Implementation is driven, at the highest level, by the Interoperability Directive, and ETCS is the standard solution for meeting the control system elements of the Directive.

Great Britain has some of the finest minds in the field of railway engineering, and British railway engineering expertise is still sought worldwide. But without a strong home market to nurture that expertise, the industry risks a situation where the best people offer their services in other countries or move out of railway engineering entirely because there is simply not the demand in the UK. One of the sobering contexts for this paper is the current reality that signalling companies in the UK are downsizing their engineering workforces for lack of work. The industry is, as a consequence, in danger of creating a shortage of skilled engineers, and that will be as catastrophic for the future of the Digital Railway Programme as for conventional signalling work.

5. Key themes

5.1. Aligning industry objectives

The GB rail industry operates on a partially privatised model, and we believe that whilst all players in the industry may agree in principle about the overall objectives of the Digital Railway Programme, their commitment to it is in practice undermined for a variety of reasons related to their objectives as organisations, the most obvious examples of this being:

a) Network Rail as a regulated entity is concerned first and foremost with reducing operating costs, maintaining the network, and improving reliability. Enhancing the network by offering more train paths or better operational flexibility is an activity it undertakes where funded to do so (usually by the Department for Transport), not of its own volition. There is little direct incentive for Network Rail to materially improve the network for the benefit of train operators and end customers (this is an observation, not a criticism of Network Rail). We expect that this focus on maintaining the network rather than enhancing it will be a strong feature of CP6, given the current financial climate (although there may be opportunities for a private investment led approach which could unlock the delivery of the Digital Railway).

b) Passenger Train Operating Companies (TOCs) are incentivised primarily to provide services to meet timetables and to deliver against their main metric of success, the Public Performance Measure (PPM). They do so within a franchise of defined duration, which may limit their interest in a long-term DR Programme (the same is not necessarily true of the TOC owning companies of course). We think the TOCs may privately regard the risks of disruption caused by the DR Programme as being of dubious value, particularly in the case of ETCS where it involves taking rolling stock out of service for fitting with new systems, and the benefits for them of so doing are not clear. TOCs are also concerned about the impact of a programme that makes a significant part of the train control system their responsibility by virtue of it being on the train, particularly in respect of delay causation. Thus TOCs may be more receptive to technologies such as traffic management and DAS, which are in relative terms much less disruptive than the deployment of ETCS.

It is a pertinent observation that non-alignment of incentives poses a serious risk to the success of a Programme that involves the integration of systems between rolling stock and infrastructure. It is hard enough to introduce such systems in a vertically integrated railway such as London Underground, let alone a railway where operators, rolling stock owners and the infrastructure manager are separate companies, and the costs and benefits may fall unevenly.

A key challenge, therefore, is how to address this problem of non-aligned objectives. One possibility would be to place passenger TOCs (and, just as importantly, their owning companies) in a position where they are much more incentivised to increase their ridership and become more profitable as a consequence, rather than being focussed on delivering a franchise-specified timetable. Operating in this more business-growth focussed manner, together with more flexibility to respond to changing circumstances during a franchise, would mean that TOCs actively drive Network Rail to deliver improvements, including those offered by digital train control technology.

This change could create much stronger "pull" for the programme, which contrasts with the current impression that this is a Network Rail "push" programme that train operators view with varying degrees of scepticism. The Department for Transport and the Office of Rail and Road have a key role to play in making this happen.

We think that TOCs need to be re-positioned as the industry players that are driving the demand for the Digital Railway, in order to deliver more capacity, better connectivity and greater operational flexibility, and so meet their aspirations for growth and improved commercial performance. The Department for Transport should therefore consider adjusting the franchise model to create much stronger commercial incentives for train operators to meet these challenges and opportunities, and to enable them to benefit in profit terms as a consequence.

Opportunities for changing the role of TOCs should be sought when franchises are re-let – ideally at the same time as digital railway programme enhancements are being contemplated on the routes covered by each franchise. We understand that this is under active consideration by the Department for Transport (DfT) and that it may well happen. We acknowledge that train operators are better placed to take the lead for some elements of the DR Programme than others, and there is a risk that putting them in a client role for major infrastructure works in the context of a new franchise could delay implementation. Nevertheless, we still believe the approach we are suggesting is worthy of consideration as a means of providing "pull" for the Programme.

As we prepared to publish this paper, the DfT launched its document "Connecting people: a strategic vision for rail". The proposals made include "new models for passenger services" and "a new generation of long-term integrated partnerships between track and train". We welcome such thinking, if that means giving TOCs greater opportunity to invest in, plan and deliver enhancements in partnership with Network Rail route organisations as a part of regional franchises. How such a

model would fit with our aspiration that TOCs should be more strongly incentivised as clients to drive digital enhancements is something that needs further consideration.

The DfT document also suggests that private investment might be a means of enabling enhancements to be made to the railway. We think that financial investment by TOC owning groups (and by rolling stock leasing companies) to help create the Digital Railway should be actively encouraged, and the approach to franchising may need to be adjusted to give more flexibility for train operators to reap the benefits of their investments, with further consideration given to related issues such as franchise durations and post-franchise remuneration of residual values. We recognise that some elements of the Digital Railway may be more attractive than others from a TOC investment perspective. TOCs will probably be most inclined to invest in elements that directly improve their operational performance and flexibility. Where multiple TOCS operate on a route, the question of who invests and who benefits is particularly challenging.

At present train operators are not structured or operated in a way that is optimal for this enhanced role. They are very much a product of the current railway business model, geared, as we have noted, to delivering performance and a timetable. TOC owning groups, however, should have a much longer term interest in the success of the railways, and with appropriate incentives in franchises they might be encouraged to invest in new technology.

Freight operators operate in a different commercial framework of course, not governed by franchises. We think that they would generally welcome use of new technology to enhance rail freight operations if it would enable shorter freight journey times, greater capacity for freight operations, more flexibility to respond to short-term needs, and higher speeds. The access requirements of Freight Train Operators (FOCs) fluctuate, necessitating short term planning and re-planning. This can be difficult to arrange alongside passenger services, but it is the sort of challenge that digital technology could help to overcome. The single greatest obstacle to these goals is the "go anywhere" nature of freight operations and the consequential need to fit the majority of freight locomotives as soon as ETCS roll out on the infrastructure commences. The concept of "targeted implementation" of ETCS, which is explored in the next section of this paper, could prove particularly problematical for freight operators.

The commencement of freight "first in class" fitment, which we understand is imminent, is to be welcomed, and we also understand that the Digital Railway Programme is working hard at consulting with freight community to ensure their voice is heard. Greater collaboration, including smaller freight operators, will undoubtedly help in building the consensus and support that is so essential if the Programme is to be a success.

More consideration needs to be given to ensuring that freight operators will want to provide "pull" for the Programme, and to how they will be assured that the Programme will improve the services they offer and provide the capability to move more freight by rail.

5.2. Targeted implementation

Until relatively recently, the approach to the ERTMS Programme has been characterised by endeavours to construct a national plan for fitting ETCS to both infrastructure and rolling stock, optimised for various objectives in different iterations of the plan. This approach has been tried many times over the past 15 years, and has always been found wanting or overtaken by events.

The approach now being proposed involves the targeted implementation of technology to meet route-specific needs, rather than making everything part of a national roll-out plan. It might also be described as "market led", since it prioritises those enhancements that deliver the best return on investment for the operational railway.

The majority of the business cases now being developed for this purpose are focused on implementation of better traffic management systems, DAS and support tools such as stock and crew rostering systems, with ETCS being a longer term objective on these and other routes.

We support a targeted approach to kick-starting implementation, as it appears to offer a more practicable way forward, and may make the funding more readily justified and affordable, particularly if it can be demonstrated that quantifiable benefits arise from individual route-based projects. However, we caution that the drive to implement ETCS must not be abandoned.

Even with the benefits of this approach, determination will be required if it is to be successful, for the following reasons amongst others:

a) It is not always possible to demonstrate a convincing business case for technology upgrades, and often vision and commitment to a long term goal is required as the starting point. Transformation programmes do not always have a positive business case at the outset, and that can be true of individual early implementation projects as well, where selection of the optimal solution for any specific route may not be practicable because it is being undertaken in isolation.

b) An "early adopter" approach on selected routes may involve short-term pain for limited long-term gain, and whether there is enough appetite for that pain depends largely on the party or parties affected and whether it can be offset by the longer-term benefits. This may well be true even if a positive business case can be made for such projects.

c) An appropriate planning horizon for projects involving this type of incremental technology transformation is probably in the order of 10 - 15 years (*i.e.* covering multiple Control Periods), in order to plan and deliver a major DR enhancement project and achieve a reasonable return on investment. Generally speaking, the industry and its planning processes are not very adept at handling projects and programmes that span multiple control periods. This needs to change if the DR Programme is to succeed, and the fact that routes are to have their own regulatory settlements may not help.

d) Targeted implementations need to be considered within the context of an overall Programme and with an "end state" in mind. Most individual route-based projects will inevitably have implications for other routes or for the fleets that operate over them, and therefore will need to be planned in a wider context. Furthermore, there remains a considerable amount of development and enabling work to be done in order that route-based projects can deliver, and this needs to be done at programme level, not the individual project level. Commitment to this programme level activity will be vital.

A long term commitment by the industry (including government) to support and enable the use of digital technology across the network, in addition to individual route projects, will be important so that development activities are properly resourced and network-wide considerations are properly taken into account. This enabling work will need to be funded, and if that funding were to be associated with individual route-based projects it would very likely undermine the business cases for those projects when seen in isolation.

5.3. Confidence, collaboration and culture

The Digital Railway Programme offers a transformational change, one that both involves new technology and has a profound effect on how the railway is operated and, therefore, on the people who work in the industry and those who depend upon it. However, there is a low level of confidence in the industry that it will be delivered on anything like the scale once envisaged, largely attributable to the perpetual "start-stop" nature of the Programme and the frequent changes of plan since it originally commenced in 2001 (when it was called the ERTMS Programme). Confidence is further undermined by the parlous state of CP5 and the indicators from government and Network Rail about network enhancements in CP6.

The speed and scale of mobilisation, recruitment, skills development and organisational preparedness to deliver the programme (whatever form it may take) will inevitably be driven by the confidence that companies (specifically, suppliers) have that it will materialise. The current downsizing of signal engineering capacity in the UK because of the lack of a visible forward workload (both conventional and "digital") is not good news at a time when the industry is endeavouring to create a positive story around the digital railway.

The industry needs to build confidence by the successful delivery of a small number of DR projects that have realistic objectives and are delivered in a timely manner as part of a visible initial programme. This portfolio of projects must be selected so as to bring tangible benefits to the operational railway and its customers, and at the same time enable systematic learning and capability building amongst all involved parties.

Demonstration of tangible benefits from existing projects with a digital content, such as Thameslink (featuring ETCS, automatic train operation and traffic management), and the Great Western TMS enhancements, could act as a catalyst for culture change to create a much needed "can do" mentality in the industry. Success with these is essential if the industry is to be seen as credible for delivering an ongoing programme of digital technology.

New ways of collaboration across the industry are essential. This is a universal message which has been repeated in almost every discussion about the digital railway programme. However, "collaboration" is in danger of becoming a buzz word with little real practical meaning attached to it.

We believe that collaboration is key to the success of the Digital Railway. There is still work to be done to articulate what it would mean in practice, how the talk will translate into reality, what the tangible benefits would be and, most importantly, how to ensure that collaboration endures even through difficult times. It needs to be built on strong business relationships with a shared interest in the delivery of the outcomes.

This is not about collaboration for the sake of it. It is about collaboration where it is needed in order to enable progress to be made. Collaboration may be enabled by a variety of mechanisms such as mutual commitments, agreed common objectives, legal frameworks and commercial agreements. Collaboration may also involve agreeing sensible system boundary definitions, so that collaboration is focussed on those elements where it is both necessary and most likely to succeed.

We think there is a will amongst many industry players to develop a more collaborative approach to delivery, and there are some signs of change for the better. However, existing industry structures, planning processes and franchises tend to inhibit collaborative behaviours and the building of trusting relationships. We recognise that these structures are not easily changed (it will take time and indeed might eventually require legislation), but this cannot be an excuse for not working to improve the situation. Recent announcements, such as for East West Railway, suggest that there is a recognition within Government that alternative structures may be needed for transformational change.

Collaboration will inevitably mean compromise, and this will require strong visionary leadership as well as, in our view, changes to industry structures and processes.

Continuing to work within the current constraints will almost inevitably mean that collaboration is not as effective as it could be, with organisations continuing to focus on their own objectives and bottom line at the expense of wider economic benefit. We are not optimistic about the

success of the DR Programme unless the industry can break free of some of the existing constraints or find ways to create partnerships that circumnavigate them (this will need leadership from the DfT and ORR). The industry structure since privatisation has delivered many benefits, but it is not well suited for supporting a 'whole system' programme of this nature.

5.4. Expertise to deliver

The skills shortage in the rail industry has been a topic of discussion for several years, and even longer in relation to signal engineering in particular. But the landscape is a confusing one. There is a general sense that the industry does not have enough engineers with the right expertise to deliver the DR Programme, whilst at the same time signal engineers are being made redundant because of a shortage of work. Measuring the future workforce requirement is not easy because there is no plan for delivering the Digital Railway with which to compare available resources. This is further compounded by the question of whether the expertise required for the future will be significantly different from that which the industry has today.

Although the required resources exist to some extent within the industry already, we do not think they are yet being utilised to best effect, and are probably not deployed in sufficient numbers in those parts of the industry where it matters most for the success of the Programme. Our impression is that:

a) Network Rail seems to be heavily dependent upon a very small number of technical experts to support the Programme, and we think that this is, or is at risk of, hampering progress. This is almost certainly true at the "centre", where knowledge is needed to complete the development of a range of application requirements, most obviously in relation to ETCS (covering topics such as key management, test scenarios, national values, interfaces, cyber security, reference designs etc).

b) The lack of expertise may also exist to some extent in the Network Rail route organisations and in TOC organisations, where the current capability is probably not optimal for managing projects with a high "digital" content and which have a significant impact on how a railway operates. If train operators are to be more involved in the Digital Railway, as surely they must, they will need to acquire the capabilities to do so.

c) Suppliers are for the most part in a position of "wait and see", being reluctant to invest in people (and other resources) until a credible programme of work is produced and there is real confidence that it will proceed to contract. Given contracts with the right scope and timeframe suppliers will, we think, make the necessary long term investment in people.

d) Suppliers also face the challenge of not knowing what mix of expertise (traditional signal engineering versus expertise to support DR projects) will be required, and how rapidly this will change with time. This is particularly true in the realm of conventional lineside signalling and ETCS. For example, will a signalling system supplier need more data integrity engineers than testing and commissioning engineers in five years?

e) The migration to latest generation train control technology may in practice proceed more slowly than some of the bold predictions made in recent times, and that therefore more traditional engineering expertise will continue to be needed to deliver conventional signalling schemes for several more years, possibly longer.

The engineering expertise required for delivering DR will be a mix of that required for conventional signal engineering, and new capability that reflects the digital information processing and communications content of new systems such as intelligent traffic management. It will be necessary to blend existing industry experience of what enables a railway to operate effectively with experience and insights brought from other industry sectors.

The industry needs to understand if it has, or will have, a skills shortage (numbers of people) or a skills gap (lack of expertise), or both, for delivering the Programme, and we suggest that the industry should develop scenarios to understand the potential scale of the challenge, given the long lead nature of skills development and engineering training. From that it may be possible to produce and implement an industry-wide skills development programme to help the industry to plan effectively for the future.

Building on the strengths and capabilities that are developed in the early stages of the Programme is critical for sustained success. All too often, where good project leadership, effective delivery teams and sound client-supplier relationships are established, the industry does not enable these to endure beyond the specific project for which they were created, thus losing the benefits for subsequent projects. There is an opportunity to transfer and build on the expertise developed on the Thameslink and Crossrail programmes, and advantage should be taken of this.

The formation of the "Digital Railway" Centre of Excellence[2], centred on the University of Birmingham, may also provide an opportunity. It has the potential to become a powerhouse of digital technology development activity for railways, with strong industry collaboration and input, and it could also facilitate the growth of expertise to support the DR programme. There may be other ways of incubating the necessary expertise for the Digital Railway, but the possibilities associated with the Centre of Excellence should be explored first.

5.5. Contracting

Suppliers and potential funders need to know whether the programme is "on" or "off" in order to focus their offers to deliver the best overall value to the GB national railway. At present there is considerable uncertainty as to the nature of the programme, its timing and, ultimately, whether there will in reality be a cohesive programme at all rather than an adhoc series of projects. Reality is needed, rather than "hype".

Long term relationships with selected suppliers, rather than continual change, would provide stability and stimulate investment in resources. Suppliers have indicated that they would prefer to know definitely whether they have the prospect of future work or not, rather than being in a

[2] Part of the UK Railway Research and Innovation Network - UKRRIN

state of perpetual uncertainty in relation to the DR Programme, which has been the case for the past ~10 years.

Clients should establish long term stable relationships with major suppliers and system integrators for the purposes of delivering the DR Programme, with horizons of at least 7 years and preferably longer.

The observation has been made in the recent past by people entering the GB national rail industry that our approach to contracting is as much as 15 years behind best practice in other industry sectors. Collaboration between clients, suppliers, operators and maintainers is essential where a successful outcome depends on the integration of technology, people and processes. Alongside collaboration, strong leadership and clarity of roles is also vital.

There is a need to change the way clients (in particular Network Rail) engage with suppliers on projects, to encourage enduring collaborative behaviours and thereby deliver both efficiency improvements and much better operational performance of systems. There are both behavioural and contractual issues to be tackled.

A number of options for contracts have been identified as possible models:

a) Output-based contracts for suppliers with performance targets through the operational life of the systems could provide the best mechanism for successful delivery and subsequent system performance, rather than using prescriptive input-based contracts. Issues such as obsolescence management and technology refresh could be addressed through contracts of this form.

b) New (to the GB railway) approaches to funding, including private funding initiatives and shared risk-reward partnerships between clients and suppliers, need to be explored to unlock the finances necessary to deliver the programme. The Hansford Report points towards the possibility of some of these and the report itself, and Network Rail's response to it, are both most welcome in this respect.

c) The long term involvement of suppliers through "design, build, maintain" contracts would provide advantages of committed long-term support and cost-effective technology refresh. The first-hand experience by suppliers of how their systems perform in service could also be invaluable for identifying and developing product/system improvements.

d) The industry might even contemplate service contracts such as "train control as a service" rather than as a system procured and owned by the infrastructure manager. We sense an appetite amongst some suppliers to discuss these sorts of possibilities, and even if train control as a service is considered too adventurous yet, the provision of other systems in the form of a "service" could be a reality much sooner. Why not, for example, buy a rolling stock and train-crew planning system as a service, just as software is provided as a service by Microsoft and many other companies?

These sorts of approaches could, at best, be transformational, but will require a major change in culture in both client and supplier organisations. Certainly so far as infrastructure is concerned they are not the norm today (rolling stock procurement is somewhat more advanced). There are risks, including industrial relations ones, as well as advantages. Some initiatives, such as private funding, would probably require support and backing by government. Again, the Hansford report is relevant in this context.

Finally in this section, we acknowledge that the Digital Railway Programme is making efforts to change the relationships with suppliers through the Early Contractor Involvement programme, and this is to be applauded. We look forward to the possibility of "national" (multi-route) contracts being let, with durations and certainties of work that will encourage suppliers to engage and invest.

5.6. Delivering efficiently

A major obstacle to progress with the Programme as a whole and with individual projects is demonstrating that there is a positive business case. This is not helped by the widely held view that signalling projects are wasteful of resources. A number of commentators have asserted, with justification borne of experience, that 25% or more of the resources used for signalling projects are wasted on scope creep, inefficient processes, duplication of effort, re-work and the discontinuity of work that always seems to accompany the transition from one Control Period to the next.

Addressing the inefficient use of engineering resources remains one of the most significant opportunities for reducing costs, for both conventional projects and DR projects, and could make the task of producing a positive business case for Digital Railway projects somewhat easier.

Various improvements could be made, some of which were also referred to in a previous IRSE report on signalling projects in 2015, titled "What does good look like?" Most of these were originally conceived in the context of conventional signalling, but they undoubtedly have relevance to DR projects as well, and therefore we re-state them in this paper:

a) Work harder at achieving a stable specification (preferably output-based) before detailed design commences, and avoid the temptation to change it unless there are compelling

reasons for doing so which are supported by all parties. This also means that other elements of a project on which the signalling specification depends have to be stable – such as the track layout and the capacity requirements. Although specifications can never be frozen entirely, this probably offers one of the two greatest opportunity to reduce costs (the other being the inefficiency caused by the fluctuating workload that accompanies Control Period transitions).

b) Considerably more could and should be done with modelling and simulation during the conceptual development stages of a project, to understand and demonstrate the operational performance of the system. This would help to minimise the need or temptation to alter the specification once detailed design has commenced, and is particularly appropriate for modern digital (software-based) control systems.

c) More progress is needed with the introduction of automated methods of design and testing. The supply industry must be allowed to lead on this as they seek to improve their cost-effectiveness, although the involvement of client organisations (and Network Rail in particular) as regards the further standardisation of data formats is probably necessary.

d) Even greater use of off-site assembly and testing should be made, building on the early successes of "modular signalling".

e) Some of the excesses associated with the design and construction of lineside infrastructure need to be rolled back. Overly large and expensive signal gantries have been cited as a prime example in the context of conventional lineside signalling.

f) Standards need to evolve (or be removed) in harmony with the introduction of new and automated processes to enable efficient design, testing and approval for entry into service. There is a view that whilst standards are changing faster than industry's ability to apply them, they are not necessarily enabling more efficient delivery.

Without these improvements, and probably others as well, the industry will simply import into DR projects the inefficiencies that have been accumulated over the years in conventional signalling projects.

5.7. Technology options and optimisation

Despite numerous communication events by the DR Programme team, we were surprised to find that people remain unclear as to what the Programme comprises in terms of technological scope. This is probably attributable to the fact that it had, until relatively recently, been proclaimed as a digital revolution that affects almost every aspect of how a railway operates – train control and traffic management, electronic ticketing, train-crew rostering, voice and data services on trains, real-time journey planning, modal interchange, and more.

Within the last two years, reality has set in and the DR Programme team has re-defined the scope of the work to focus on train control and traffic management, directed at capacity and reliability improvements and better connectivity.

This constrains the scope to:

- European Train Control System (ETCS) in its various forms.
- GSM-R (most of which is already in place, although thought will need to be given to its successor).
- Intelligent Traffic Management Systems (and the greater centralisation of operational control).
- Driver Advisory Systems (DAS) in various forms, including "connected" DAS which dynamically informs drivers of the optimum speed profile dependent on current and even projected state of the railway and other trains.
- Automatic Train Operation (ATO).

This re-focused scope is, however, not as widely understood by the industry as the DR Programme might believe it to be. We also see potential for further confusion because we sense that the prioritisation of investment may now favour Intelligent Traffic Management Systems and DAS, rather than ETCS and ATO (although some ETCS cab fitment may continue). It has also been suggested that data driven tools for stock and crew rostering may feature in the mix.

From this we are tempted to conclude that perhaps there is neither the funding, nor the business case, nor perhaps even sufficient collective will to make rapid progress with ETCS in Britain, and that with a few exceptions the railway will have to continue to make use of conventional lineside signalling for the foreseeable future. We hope we are wrong with this interpretation, because our view is that removing lineside signalling equipment and using in-cab signalling is the single most effective way of delivering train control with high reliability and capacity, and at lower whole-life cost. There is a glimmer of hope in the DfT strategy document to which we referred earlier, suggested that ETCS will be used to replace lineside signalling as it becomes life-expired. It remains to be seen whether this will be the reality; at present schemes are still being developed which use lineside signalling to replace life-expired systems.

If the industry does not embrace the next generation of digital train control (including ETCS), it will have to replace today's lineside signalling by more of the same. Either way, a programme of ongoing train control system renewal/enhancement is a necessity. The "stop/go" approach and trickle funding that so often characterises railway modernisation tends to lead to partial replacement and "patch and mend" of signalling systems, which is not conducive to a programme involving a step-change in technology.

Intelligent Traffic Management Systems and DAS undoubtedly can deliver improvements, including a more resilient railway service, energy savings, better time-keeping and, to some extent, greater capacity through optimisation of traffic flows. They may offer the best opportunities for some "quick wins" to improve performance and boost industry confidence. However, they are ultimately constrained by the principles and practices associated with

conventional lineside signalling, particularly evident in terms of capacity and operational flexibility at stations and junctions.

By contrast, cab signalling enables the placement of "virtual signals" almost anywhere they are needed (particularly if moving block is used), thus enabling the safe optimisation (reduction) of the distances between successive trains at junctions, stations and on plain line, all of which can help to improve capacity[3]. It also improves operational flexibility to meet changing needs, as the signalling system is less "hard-wired" to deliver a particular service pattern. It is interesting to note that in the days of mechanical signalling there was much more flexibility about where to place signals, which particularly helped to minimise constraints on capacity in station areas. When multiple aspect colour light signalling was introduced, this advantage was lost, with all signals being spaced at braking distance apart (or half braking distance in the case of 4 aspect signalling). We are not, incidentally, advocating a return to mechanical signalling (!), but this example should stimulate the industry to think whether we could do more with existing lineside technology pending the widespread adoption of ETCS.

ETCS is also important because it brings with it automatic train protection (ATP) – in other words, full and continuous supervision of the speed profile of each train. The Train Protection and Warning System (TPWS) has served Britain's railways well, but it is not the same as ATP, nor as effective. It copes tolerably well with misjudgements in braking, but it does not provide the same level of protection as ATP. A train that fails to slow down as it approaches a red signal may be brought to a stop by TPWS, but not before it has gone a considerable distance beyond the signal. ATP does not permit that to happen. As we put more trains on to the network, and as speeds are raised, the likelihood and severity of an accident caused by a train over speeding also increase.

Aside from the question of funding, the single biggest problem associated with ETCS is that it involves major changes to both infrastructure and rolling stock. Tying these together to form a viable ETCS project, whilst keeping the railway running during the migration phases, and avoiding undue constraints on which trains can use the upgraded infrastructure, all pose real challenges. Moreover, to get the greatest benefits it is necessary to use the higher "levels" of ETCS (either level 2 or level 3, with lineside signals removed), and the challenges of implementing these are generally greater than the lower levels (level 1 or level 2 with lineside signals, where ETCS is overlaid on the existing signalling). Much of the tangled web of history of Britain's ERTMS Programme has been associated with optimising the migration process from lineside to cab signalling, also not helped by regular changes in the objectives of the programme.

It is not impossible to find a way forward with ETCS however, and there are precedents that should give the industry reason to be cautiously hopeful. The implementation of GSM-R on the GB network was much less complex, but the programme did involve both rolling stock and infrastructure, and roll-out was completed in ~7 years. Countries such as the Netherlands, Sweden, Denmark and Norway have started major ETCS programmes for their networks (albeit those networks are much smaller than in Britain, and have their own challenges), and others such as Australia, South Korea and India are also actively pursuing the adoption of ETCS. TPWS was implemented in Great Britain by legislation, and given the safety concerns and the industry's slow

[3] In the past claims have been made for the extent of capacity improvement achievable which we think are overly optimistic. In practice the improvement depends heavily upon the extent to which the existing signalling is optimised for the train services and patterns that are operating on the route.

progress to date, there may be an argument for similarly mandating the fitment of ETCS within a defined period of time – on higher speed routes at least.

The challenge of migrating to more modern train control systems is one manifestation of a more general feature of railway engineering, namely that asset life-cycles are generally measured in decades. In a world where digital technology evolves quickly (typically in periods of five years or less), railways are placed at a significant disadvantage. The industry needs to find ways of taking advantage of the leaps in digital and software capability, and unless the industry can become more agile in doing so, it will fall progressively further behind other transport modes and run serious risks of losing market share. Ways need to be found of enabling asset replacement on the basis of business benefit rather than life-expiry. How can rapid and frequent technology replacement be made affordable? Performance-based or "design, build, maintain" contracts may help here. But there are also opportunities to adopt different architectures for our systems, adopting technology platforms that can be configured and upgraded to meet changing operational requirements, rather than having to be thrown away when they are no longer fit for purpose. This sort of approach could facilitate software upgrades in response to the changing needs of the consumer with far less disruption to the railway.

Finally, a brief comment about "closer running", a subject that has featured recently in research work and papers (including some produced by the IRSE), and with which topics such as "virtual coupling" of trains have also been associated. These concepts are aimed at increasing capacity by enabling trains to run with smaller distances between them. Opinion is divided about the practicalities, safety and benefits of such ideas, but debate on these matters should be welcomed, and further work conducted to develop the concepts should be encouraged. Even if some of the ideas are radical to the extent that the industry feels unable to embrace them in the foreseeable future, it is quite possible that more modest and practicable proposals would emerge in the process that would still improve rail's competitiveness. As many commentators have noted, with rapid advances being made in automotive and aerospace technology that will challenge railways, we cannot afford to stand still, either technologically or operationally.

6. Concluding remarks

In this paper we have endeavoured to offer honest opinions about the challenges facing the industry in taking forward a programme of new digital technology. It is a subject area that has been much discussed in the past, and doubtless there is much more that could be said. Our view of the key issues that need to be addressed can be summarised as follows:

a) **Aligning industry objectives:** Getting stronger commitment in practice to the DR Programme by the industry players is critical. We think that the best way to achieve this may be to re-position and incentivise TOCs as the industry players that are actively driving the demand for improved capacity, connectivity and operational flexibility to meet their plans for growth and improved commercial performance.

b) **Target implementation:** We support a targeted initial approach to implementation, as it appears to offer a more practicable way forward, and may make the funding more readily justified and affordable, particularly if it can be demonstrated that quantifiable benefits arise from individual route-based projects. However, we caution that the drive to implement ETCS must not be abandoned, and that "network wide" factors must be taken into consideration, rather than allowing an uncoordinated patchwork of projects to emerge.

c) **Confidence, collaboration and culture:** Collaboration is key to the success of the Digital Railway. It will inevitably mean compromise, and will require strong visionary leadership[4] as well as, in our view, changes to industry structures and processes which inhibit collaborative behaviours and the building of trusting relationships. Cultural changes are needed, perhaps supported in some cases by frameworks, legal and commercial agreements that engender collaborative behaviours and promote win-win outcomes.

d) **Resourcing:** Successful delivery of the programme will depend on having the right expertise, particularly in client organisations. Although such resources exist within the industry, we do not think they are yet being utilised to best effect, and are probably not deployed in sufficient numbers in those parts of the industry where it matters most for the success of the programme. Future expertise and resource requirements should be assessed, and mechanisms found for acquiring them.

e) **Contracting:** The industry's approach to contracting for digital systems must change radically, involving suppliers on a long-term basis, giving them both assurance of workload (to encourage them to invest in people and other resources) and incentivisation through performance-based contracts. New sources of funding and financing must be explored.

f) **Delivering efficiently:** A major obstacle to progress with the Programme as a whole and with individual projects is demonstrating that there is a positive business case, which is not helped by the widely held view that signalling projects are wasteful of resources. Addressing these inefficiencies is one of the most significant opportunities for reducing costs, for both conventional projects and the DR Programme.

g) **Technology options and optimisation:** If the industry does not embrace the next generation of digital train control (including ETCS), it will have to continue replacing today's lineside signalling

[4] Some people have spoken of the need for a "directing mind" for the Programme.

by more of the same. We think this is not the right way forward, and that the continued use of fixed block lineside signalling in the 21st century cannot be justified. Either way, a programme of ongoing train control system renewal/ enhancement is a necessity, and it may be that a programme of ETCS fitment should be mandated through legislation.

The imperative now is for action, to make tangible some of the benefits of the technology that is available. The opportunity is considerable, and the downsides of stagnating for even longer than has already happened are serious. The industry needs to come together as never before to create a new world-class railway, one that can compete effectively with other players in the transport sector who are undoubtedly at present outstripping the railways in terms of technology innovation and revolution. This is the “burning platform” that the industry needs to tackle.

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The Institution of Railway Signal Engineers
1 Birdcage Walk
Westminster
London
SW1H 9JJ

Web: www.irse.org
Email: hq@irse.org
Tel: 0044 (0)20 7808 1180