INCREASING CAPACITY: PUTTING BRITAIN'S RAILWAYS BACK ON TRACK.

Institution of MECHANICAL ENGINEERS

In assosciation with

TRL

Improving the world through engineering

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CONCEPTS, SUCH AS CLOSER RUNNING, PROVIDE STEP-CHANGE INCREASES IN CAPACITY AND CONNECTIVITY BY CHALLENGING THE WAY WE USE OUR RAILWAY HARDWARE.

PHILIPPA OLDHAM MIMECHE
HEAD OF TRANSPORT
INSTITUTION OF
MECHANICAL ENGINEERS

This report has been produced in the context of the Institution’s strategic themes of Energy, Environment, Education, Healthcare, Manufacturing and Transport and its vision of ‘Improving the world through engineering’.

Cover image: The new concourse at Kings Cross station, London. Opened in 2012, this enhanced space provides greater passenger capacity, as does the new London Underground ticket hall below.

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FOREWORDS

FOREWORD FROM OUR SPONSOR

The Institution of Mechanical Engineers initiated this report, grounded in four illustrative case studies, in order to complement and build upon the Royal Academy of Engineering's Transport Congestion Challenge paper (Nov 2015), using the expertise of our Railway Division membership active throughout the UK rail industry.

Mindful of the phenomenal success of Britain's railways, doubling the passenger-km delivered over the past 20 years, our aim is to feed into the industry's Initial Industry Advice, informing committed government spending for 2019–24 and beyond. We take account of the 30-year rail traveller and freight demand forecasts and visions to transform transport.

Our target audience is wide: from the national and local politicians and civil servants who specify the railway… to the industry and its supply chain who deliver it. We want to engage innovators to generate new ideas and transfer emerging technology into rail; and to encourage exporters to sell British solutions abroad.

Above all, we want the travelling public to understand how we are solving over-crowding. We want all to share our excitement in the opportunities for railways to reduce road congestion and deliver joined-up journeys using the best sustainable transport to take them more simply, smoothly, cost-effectively, promptly and reliably door-to-door.

Our methodology included selecting four case studies to illustrate different capacity challenges and approaches, interviewing relevant experts, and reviewing an early draft at a private dinner we arranged for political and technical Transport for the North stakeholders. We started from optimising railway operation and enhancing capacity on existing lines and worked through to new routes and futuristic R&D technology concepts; we did not dwell on the mechanics of Network Rail delivery (extensively reviewed by others), nor on the skills agenda which is also already being addressed, with the National Skills Academy for Rail.

We are of course grateful to all contributors, particularly senior decision-makers in key organisations who have reviewed our recommendations as proposed for them.

We hope that this report will make a useful contribution to the political impetus for committed long-term investment, as reinforced in the 2016 Autumn Statement, including Northern Powerhouse Rail from amongst our Case Studies. We further welcome the new National Productivity Investment Fund announced for trials of digital signalling, backed by £450m from 2018–19 to 2020–21. Developing and delivering such initiatives will fundamentally shift how rail technology is deployed, increasing Britain's railway network capacity by more than 100% during the next 30–50 years. World-leading innovation deployment will facilitate GB rail supply chain growth from 124,000 jobs in Britain, already generating £3.8bn annual gross value added, with estimated turnover of £7m worldwide.

We seek to facilitate the consolidation of the future vision to deliver a railway with enough capacity to support sustainable economic and transport demand growth - and for the UK rail industry to exploit the arising export opportunities.

Rebeka Sellick
Head of Rail, TRL

FOREWORD FROM IMECHE

The UK has one of the safest railways in the world, but it operates on some of the oldest infrastructure which has lacked investment and which constrains capacity. If we are to offer businesses and passengers an attractive alternative to road, we need to invest in our rail infrastructure.

This report demonstrates that we do need investment in new projects such as HS2, and we need to go further than this. We need to enhance our existing network to make it more efficient, resolving known bottlenecks and pulling through innovation as soon as it has been proven. Currently this takes far too long. Innovations in road transport mean that it can potentially become more comfortable, timely, cost-effective and reliable. Within this report, we draw on four case studies that show how rail can also achieve these objectives.

The government should continue to make good historic under-investment in railways, recognising that UK infrastructure should move up from its current rank of 24th in the World Economic Forum's Global Competitiveness Report. The 2016 National Needs Assessment stated that in 2014–15 the UK Government financed £49bn in infrastructure development from a combination of public and private sources. While this investment is welcome, it is nearly 40% short of the Organisation for Economic Co-operation and Development (OECD) recommended target of £80bn per year by 2020–21.

Why invest so much money to improve railways? The World Economic Forum estimates that every dollar spent on capital projects generates an economic return of between 5% and 25% (PWC and Oxford Economics 2014). National and devolved governments have built rail capacity growth into their overall economic development plans. The DfT expects one of our Case Studies, High Speed 2, to return more than £2 for every £1 invested even with pessimistic cost, demand and growth scenarios, boosting annual productivity by £8–15bn.

The UK needs an integrated transport strategy that incorporates all modes seamlessly. As engineers, we are committed to sustainability and we understand the strengths of rail. We want to capitalise on the energetic, economic and safety benefits of rail over road to deliver: longer distance and inter-urban passenger and freight flows; as well as passenger movement both within and into cities.

Within this report, we consider rail capacity enhancement through real examples past, present and future. These case studies demonstrate short and long term benefits by maximising capacity, improving efficiency and providing more user and non-user benefits. Benefits must be delivered on time and on budget, whether by Network Rail, TfL, HS2 Ltd, or other third parties. Critical success factors include: consistent vision from national and devolved Government, projects that are well-developed before they are committed, sufficient investment in skills, and engagement from diverse stakeholders – train operators to freight user groups.

I would like to thank all of our contributors who gave their time to provide insight into the industry so that we could produce this report. Our desire has been to help both the policy makers and organisations within the sector to maximise the opportunities that our railways can provide.

Philippa Oldham MIMechE
Head of Transport and Manufacturing, IMechE

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It is essential that the DfT and the ORR promote the contribution of our railways in optimal national and devolved transport systems.

EXECUTIVE SUMMARY

MEETING DEMAND: TODAY AND IN THE FUTURE

Over the past 20 years, passenger and freight usage on Britain's railway network has increased significantly (by 116% and 34% respectively), exceeding Government and industry projections and expectations. As a consequence, despite recent substantial national and regional initiatives such as High Speed 2 (HS2), Northern Powerhouse Rail (NPR) and Crossrail, the network will still struggle to meet demand. The public rightly perceives an increasingly congested and capacity-constrained network, reinforced by the Department for Transport (DfT)'s own figures.

The rail industry's Market Studies (published by Network Rail) indicate that rail passenger traffic is likely to double again over the next 30 years. Deep-rooted and structural trends (eg population growth, modal shift from road) have driven growth over the last two decades and will continue. Following the UK vote to leave the European Union, analysts anticipate a slower initial pace of economic growth – and the immediate outlook for employment in large cities has softened. These factors may impact on the funding available, yet many of the planned enhancements remain essential – irrespective of further growth – because they will relieve capacity pressures which already exist today.

Importantly, the expected reduction in the rate of demand growth is small, compared with the longer-term forecast of rail passenger demand doubling. Policymakers therefore need to continue to enhance railway capacity, harnessing the best practice outlined in the four case studies contained in this report. It is equally urgent to begin addressing some of the more radical strategic and technical challenges - in order to deliver greater rail capacity in time. Fundamentally, led by the Rail Delivery Group (RDG) and the Rail Supply Group (RSG), the railway needs to ensure that the network integrates into the wider inter-modal transport picture of the future.

DEFINING CAPACITY

Capacity is often measured in trains-per-hour (tph), ie how many trains can operate on each section of a route. The greatest tph capacity is achieved with an identical fleet of trains that all accelerate and brake at the same fast rate, with matching and minimal start-stop patterns. However, in Britain, most routes have differing types of trains (freight and passenger), of varying lengths, stopping patterns, speeds and braking abilities. In addition, current fixed block signalling, which requires the train behind to be able to stop before the last known position of the train in front, inhibits capacity growth.

An alternative and more holistic measure than tph for capacity is people-per-hour (pph). Pph provides policymakers with greater scope in their decision-making by allowing more radical options to be considered for enhanced capacity on the railway network. Historically, mainline railways have been slower to embrace change than metro systems. But the pph measure promotes the transformative thinking needed. Communications advances make people less interested in how their journeys are provided or how their freight is consigned, as long as the service is convenient, smooth and timely.

Image: Britain's first high speed line, HS1, connecting St Pancras International station in London with mainland Europe via the Channel Tunnel. This line is also used by high speed domestic train services to and from Kent.

OPTIONS TO INCREASE RAILWAY CAPACITY

Conceptually simple technical changes to increase capacity such as modern longer trains are already being implemented with current funding. But the issue is that British railways fundamentally lag on investment such as in:

- High speed rail (introduced in Japan in 1964); and
- Cross-city limited-stop services (provided in the Paris region since the 1970s).

Indeed, revolutionary technologies continue to be developed across Europe, such as network-wide moving block signalling, Level 3 of the envisaged European Rail Traffic Management System (ERTMS). Moving block signalling means trains communicate with each other via a central signalling system. This transforms capacity by reducing gaps between trains. Passive provision for ERTMS is already being specified for new trains and will need retrofitting into the existing national fleet. However, moving block itself cannot be cost-effectively deployed until we have a specification that allows different suppliers' systems to work together – and it won't work until the infrastructure is modified to suit. Of course, moving block is used on metros like London Underground, as in our Victoria Line case study, but it is not interoperable. The trains from one line cannot run on another, and each line depends on specific suppliers in perpetuity.

By contrast, there are ready-to-implement options to increase capacity on mainlines, including:

- Relieving known bottlenecks on the mainline infrastructure (eg by reducing the length of fixed signalling blocks),
- Reducing the variety of train types on specific routes (so they are more akin to dedicated light rail and metro systems) and
- Creating dedicated high-speed lines (to allow slower and more frequently stopping services and freight trains to utilise the capacity freed up on the remainder of the network).

Looking further into the future, concepts such as Closer Running led by the Rail Safety and Standards Board (RSSB) provide step-change increases in capacity and connectivity by challenging the way we use our railway hardware. Closer Running takes moving block signalling further. It proposes direct train-to-train communication, allowing trains to operate even more closely together, and possibly even coupling with each other while still in motion.

Although this may sound far-fetched, road transport developments in autonomous vehicles (AVs) including freight vehicle 'platooning' are already being tested on automotive highways. AVs operating without human intervention, travelling at 70mph and within 2m of each other, are expected to radically increase road capacity, while providing a space where passengers can work, read or sleep, as they would on a train. Research by the Boston Consulting Group (BCG perspectives, Sep 2016) suggests that AVs could abstract 10% of rail passengers by 2025. If rail were to lose market share, this would have detrimental impacts on net transport sustainability and ultimately capacity. This "threat" of AVs should be used to stimulate railway stakeholders and policymakers to exploit rail's intrinsically more efficient and safer higher top speeds and quicker city centre penetration. Railways should invest in customer service and pph capacity for passengers and freight.

As encapsulated in their letter to The Times (21 Nov 2016), Britain's railway leaders appreciate the current programme of improvement to address the under-investment of many of the past hundred years. Feeding into the plan for Network Rail's next five-year Control Period (2019 to 2024), the Institution of Mechanical Engineers submits that research and development programmes such as Closer Running should be accelerated. This is alongside sustained investment to deliver the identified short and longer term capacity enhancement needed.

It is essential that the Department for Transport (DfT) and the Office of Rail and Road (ORR) promote the contribution of railways in optimal national and devolved transport systems. There should be a more integrated, holistic and sustainable risk-based approach to design, create and deliver the capacity essential now and for a sustainable future.

FUTURE OF RAILWAYS

Fundamentally, the Institution of Mechanical Engineers believes that society should expect interconnected sustainable transport. Railway infrastructure should embrace AV interfaces, and also deploy game-changing technologies to enable faster flexible capacity growth in rail services themselves. The government should capitalise on the potential of rail technology to deliver a key element of the sustainable and universally accessible concept of ‘Mobility as a Service’ (MaaS).

Now is the opportunity to optimise the delivery of transport capacity for customers, minimising carbon and cost. Conceptually simple but technically challenging and world-leading delivery of moving block signalling across Britain’s railways for example would improve on all the four C’s (Carbon, Capacity, Cost and Customer) of the Rail Technical Strategy. Moving block would unlock more capacity by creating more paths to run trains, enabling more efficient use of the railway. It would reduce journey times to further enhance customer benefits – and deliver more sustainably than other transport modes.

To increase overall transport capacity and optimise the value of the railway sector to the UK in the coming decades, the Institution of Mechanical Engineers recommends that the railway sector concentrates on capacity, in particular to:

1. Fast-track step-changes to unlock network capacity - pioneering world-leading development and implementation of and beyond moving block signalling. Specifically, the industry, led by RDG and RSG, and supported by RSSB, should accelerate the development of the Closer Running research workstream, including ERTMS levels 2 and 3 in the January 2017 technology input into Initial Industry Advice to Government for Control Period 6 (2019–2024), in order to ensure sufficient funding and impetus.
2. Urgently bring capacity-enhancing innovations into operational use. During 2017, RDG and RSG should identify the entry barriers to currently implementable projects in RSSB’s solutions catalogue and ensure they are surmounted eg by DfT and ORR adopting novel financing arrangements to adequately recompense individual TOCs and FOCs for implementing improvements that have a negative business case for them individually, but free up capacity on the railway.
3. Initiate the next raft of new solutions to create further capacity. As Brexit means leaving EU-funded shared R&D projects like Capacity 4 Rail, the DfT and other government agencies should ramp up British R&D investment. This should be targeted at opportunities to improve delivery of capacity through RSSB and the emerging University UK Research and Innovation Network, stimulating matching private investment.
4. Speed-up the roll-out of known solutions to relieve capacity bottlenecks. Government investment and commitment must continue for the enhancement of capacity through existing best practice, including the construction of new railway infrastructure capacity (new high speed lines, electrification, local connectivity) and other well-proven techniques as illustrated by the four case studies contained in this report.

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It is essential that policymakers address the strategic and technical challenges needed to deliver greater capacity for passengers and freight across all transport modes.

ENHANCING THE CAPACITY OF BRITAIN'S RAILWAYS

INTRODUCTION

Over the past 20 years, the UK has experienced an extraordinary increase in railway demand, with passenger-km travelled up 116% on the national network and 83% on London Underground. Over the same period, freight tonne-km has also risen by 34%. Both growth and modal shift have surpassed expectations and railway demand is forecast to continue to grow for the foreseeable future.

For the UK to support and develop its national and regional economies over the next 30 years, it is essential that policymakers address the strategic and technical challenges needed to deliver greater capacity for passengers and freight across all transport modes. To enable the optimal development, funding and delivery of Britain's railway within the overall transport mix, strategists must understand the engineering and wider railway professional challenges posed by their 30-year vision in order to optimally meet the needs of the coming generation.

The Institution of Mechanical Engineers believes that a combination of new high speed railway, enhancement of existing railway infrastructure, development of advanced signalling and control systems, expanded terminus capacity and enlarged rolling stock fleets are all needed to meet future railway capacity requirements and facilitate economic growth, nationally and regionally.

This report outlines how the industry and policymakers should increase railway capacity, and what technologies should be adopted, adapted or developed to integrate rail sustainably and seamlessly into the overall transport mix, adding overall capacity and value to the nation and its population.

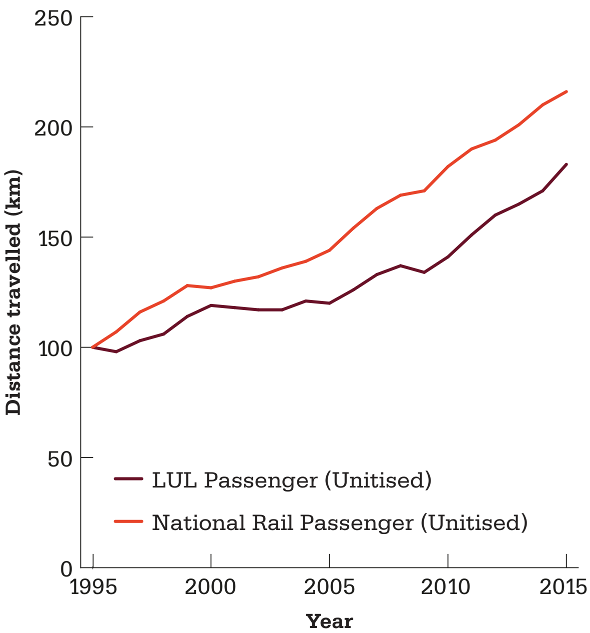

Figure 1: Passenger Km Growth Since 1995 (Source: National Rail from ORR; LUL from DfT)

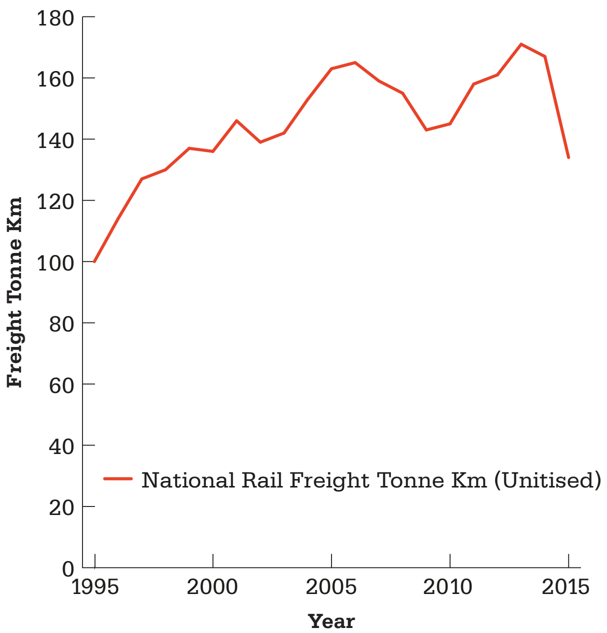

Figure 2: Freight Tonne-Km Growth Since 1995 (Source: ORR)

Image: Tunnel lining segments for the Crossrail tunnel under London.

DEFINING RAILWAY CAPACITY

A crude and often-used measure for railway capacity is the number of trains per hour (tph) that can be operated on each section of the route. For high tph capacity on a particular route, trains need to:

1. Accelerate quickly to their maximum speed. Electric power enables typically double the acceleration rate of diesel engines, which are constrained by cost, size and weight optimisations
2. Brake quickly, for any planned or unplanned stops. Slow brake rates on freight trains significantly reduce tph, especially on mixed (passenger and freight) routes
3. Be as similar as possible and go fast. A homogeneous fleet of trains, each with the same acceleration and braking characteristics (and travelling at the highest speed the infrastructure will permit), will maximise capacity, as measured in tph.

However, the tph measure fails to account for other key factors which affect capacity, such as:

1. Train length and vehicle size. The number of vehicles (freight wagons or passenger carriages) may be limited by infrastructure constraints eg platform lengths, track layout, location of points, length of overlaps, sidings, depots and freight terminals. Furthermore, the infrastructure (eg tunnels, track curvature) constrains the width, cross-section and length, and hence capacity – of individual vehicles. These constraints are conceptually simple but are sometimes difficult and expensive to surmount.
2. Railway signalling. A crucial factor is that of other trains and the signalling/control system between them. Up to a point, higher speed increases throughput and therefore capacity. However, the railway signalling principle of separation of trains holds that the train behind has to be able to stop before the last known position of the train ahead (or indeed before any potential conflict eg a junction). When braking effort is set to a maximum, faster trains travel further during braking, requiring a greater separation between trains and reducing the tph. Moreover, Network Rail currently uses fixed block signalling, based on principles established in the 1860s. Only one train can occupy a "block" (defined section of track) at any time. In practice on a mixed route, fixed block signalling reduces capacity by increasing train separation. This is because the discrete blocks must be longer than any train, wasting space around a shorter train, and because blocks must be lengthened to the braking distance required by the fastest running or slowest braking trains.

The tph measure can of course help identify specific bottlenecks that can readily be relieved by, for example, shortening fixed blocks on approach to infrastructure constraints, or introducing different top speed limits for different train types. However, optimal capacity is unlikely to be derived by persisting with tph as the main measure.

A more holistic measure for capacity is people (or payload-tonnage of freight) per hour (pph). Pph provides a better measure for decision-making, enabling transformative thinking and, hence facilitating essential railway capacity growth.

HOLISTIC TRANSPORT CAPACITY

Beyond defining a more useful and realistic measure for capacity, the Institution of Mechanical Engineers believes that the 'big picture' for railways is as part of connected transport system and not as an independent, stand-alone mode. The Transport Systems Catapult (TSC)'s report "Transport Needs and UK Capability" (Oct 2015) effectively challenges the sector to integrate into the wider trans-modal transport picture. At the TSC's Mobility as a Service (MaaS) conference in September 2016, it was underlined that demand for transport will be characterised by:

1. Connectivity need. Pph flows will arise from individuals wanting connected journeys they don't even have to think about. The development of on-demand door-to-door mobility solutions could be a great opportunity for rail if the railway can provide the right data to the MaaS suppliers, and an equivalent "Uber for Parcels" offers further potential for lightweight premium freight.
2. Mode-independent. People and freight won't be interested in how their journeys are provided, so long as they are taken smoothly from door-to-door. This includes using big data to optimise door-to-door passenger and freight travel, across the best mix of modes available to meet the traveller or consignment recipient's time, cost and other needs – from coffee on tap to continuous refrigeration.

As responsible engineers, committed to sustainability, we have the opportunity to enable trunk haul to be delivered by rail, capitalising on the energetic and safety benefits rail can deliver over road. These journeys will be optimised by designing and delivering physical and human railway systems which optimally smooth people and freight flows on and off trains. For example, should car ownership fall, and be replaced by autonomous vehicles on demand, stations will need more drop-off space and less parking, and, indeed, may see further increase in capacity demand as the pain-point of parking is relieved.

But we need to act fast to be included. In a world where 2m separations between autonomous 70mph cars and lorries are already being trialled – and demonstrating a potentially huge capacity uplift for the road network – fixed block signalled railways, with theoretically high tph but mile-long gaps between trains, constraining overall pph capacity, seem anomalous.

The challenge to the railway system is not only to make incremental improvements, but also to change mind-sets. We need to develop the "fail safe" principle from "if anything breaks we stop the trains straight away just in case", to use modern technology in a more rounded risk-based way for train control systems. Fundamentally, we need to enable a step-change in the delivery of trains within connected journeys, delivering more of the UK's customer capacity and satisfaction for less cost and carbon.

OPTIONS TO INCREASE CAPACITY USING CURRENT TECHNOLOGY AND SPREADING BEST PRACTICE

Moving block signalling

The advantage of moving block signalling is that the maximum permitted speed at any one time is defined train to train, and communicated to each train by a central signalling system, rather than being fixed for all trains based on the longest, fastest, or slowest-to-brake trains operating on that route. Moving block signalling thus enables shorter distances between particular trains and therefore, allows more capacity on the same infrastructure.

Moving block is well-established on several London Underground Limited (LUL) lines (including the Victoria line in case study 1) and on Docklands Light Railway. However, different suppliers' systems are not interoperable (trains from one route cannot run on another) and they do not handle freight well. Interoperability is currently under development (see page 15, Innovations currently under development).

Implementing this fundamental step-change away from fixed block signalling on Network Rail (NR) infrastructure would radically increase route capacity, and is part of the Digital Railway vision. As a first step, European Rail Traffic Management System (ERTMS) Level 2 (cab-based signalling) is currently being planned and written into new train specifications for national rail. However, it will not deliver benefits for several years until significant sections of infrastructure are modified, and existing trains retrofitted. ERTMS Level 3 (moving block) will hopefully follow (see page 15, Innovations currently under development). In the meantime, more capacity is being achieved from the network through franchise commitments, such as to shorten identified fixed blocks where the space released can be redeployed, and to deliver new train fleets in Abellio's 10-year East Anglia franchise.

Reducing the train type mix

Capacity on a route is significantly reduced where trains with disparate characteristics operate, for example 60–75mph freight trains and 125mph passenger trains on the two-track mainline north of Preston. Reducing the variety of trains on the remaining 'classic' lines (ie by removing high speed) was a prime motivation for separate high-speed lines in Japan (Shinkansen) and France (TGV); likewise for High Speed 2 (see page 29, case study HS2) in the UK.

The UK also lags at least 20 years behind best practice in cross-city railway capacity. Although the Thameslink upgrade and the Crossrail project were both conceived for London in the 1980s, they are only now being built. In contrast Paris implemented successive Réseau Express Régional (RER) limited-stop new commuter railways from the 1970s onwards.

The Victoria Line Upgrade case study (page 18) demonstrates enhanced capacity, making the most of technical characteristics such as homogeneous passenger-only fleets, combined with operational capacity-enhancers for pph such as:

- All trains having a consistent stopping pattern, usually at all stations, to make it simple for passengers
- Managed dwell time, minimised by staff supervising rapid passenger egress and access

The other case studies give examples of optimised solutions within various key customer-driven and historic constraints.

- The intrinsic mix of 'metro' and longer distance express services on lines in and out of Waterloo (page 21)
- The Northern Powerhouse Rail (NPR) adding a more complicated network of train types and freight traffic variety to the mix (page 25)
- High Speed 2 (HS2) releasing capacity on three existing north-south main lines (page 29)

Long term planning

The capability to increase capacity on our railways has been constrained by funding, but also by the ability of Network Rail and its suppliers to deliver the complexity and scale needed, a subject repeatedly reviewed by the Office of Rail and Road (ORR) and most recently by the Hendy, Bowe and Shaw reports.

Electrification and other railway-specific skills and competencies are best nurtured in a climate of credible and consistent government policy. Investment – where required – has a virtuous circle benefit of unlocking long-term planning, nurturing people and knowledge management within individual supplier companies.

Crossrail attributes some of its on-time and to-budget construction achievements to the long parliamentary process which created the space to clarify project scope, standards and designs before starting work, and without pressure to demonstrate progress in-situ. Significantly, the creation of new infrastructure in tunnels under London has reduced interfaces with day-to-day railway operation, which have constrained new build progress and magnified costs on other projects. Ironically, when competing for labour in the aggressive London market, Crossrail benefited from the recession, in being able to provide comparatively attractive stable employment. By contrast, as Hendy notes, Network Rail committed to other capacity enhancement and electrification project plans too early, based on preliminary estimates for cost and time, with details not fully worked up or scheduled.

Bottleneck reduction

Important technical change is not always a 'major' project. Sometimes relatively small solutions need only be applied. For example, a "flat junction" (like road traffic lights, where trains potentially have to wait for each other) can be replaced by technically simple and reliable "grade separation" (analogous to a motorway junction, where we build a bridge for one route to join or cross another without conflicting movements). Grade separation is an appropriate solution for some capacity bottlenecks, enhancing resilience where flat junctions are the norm, eg. in northern England.

More widely, the negative impact on capacity of a wide variety of both train types and stopping patterns can be mitigated by creating flexibility at key nodes, such as high-speed turnouts and stations on passing loops – simple but effective infrastructural engineering, supporting professional operational analysis. Other good, proven, cost-effective and not-yet-fully-deployed local capacity restraint relievers, with potentially significant benefits, stem from reviewing speed restrictions and other bottlenecks on the network.

OPTIONS TO INCREASE CAPACITY WITH NEW TECHNOLOGY, INCLUDING RESEARCH AND DEVELOPMENT (R&D)

Railways have been seen as intrinsically reluctant to adopt new technologies, based on wise principles such as that of failing "safe" and degrading gracefully, so as to facilitate continued service delivery as far as possible, eg through carefully managed operation in degraded modes. For example, relatively long-life rail vehicles tend to change more slowly than road vehicles, off-set by the sustainability benefit of spreading first cost more thinly. However, when the national rail industry (under the Rail Safety and Standards Board, RSSB), drew up the Rail Technical Strategy (RTS), based on the four Cs (doubling Capacity and increasing Customer satisfaction, halving Costs and Carbon) in 2012, merely doubling capacity was seen by some as conservative, especially compared to rail's modest modal share in UK transport – and its green credentials.

Implementing new technologies

New capacity-enhancing technologies do exist, fostered through collective industry and academic initiatives (eg Rail Research UK Association, RRUKA), but they are not currently being implemented rapidly on UK railways.

Infrastructure innovations ripe for exploitation include REPOINT. Developed by Loughborough University, REPOINT is a deceptively simple, highly redundant line-replaceable new switching mechanism, which promises to eliminate points failing in an indeterminate position. By reducing this risk, REPOINT would increase line capacity, allowing trains to run towards junctions before the points are set in the correct position. REPOINT also promises greater reliability, as it would continue to work normally even if two out of its three motors fail, thereby enabling maintenance to be scheduled without affecting train services. Line replaceable units can be exchanged within minutes. Further benefits include a lower carbon footprint, with less energy consumption, and remote condition monitoring to exploit the benefit of the built-in redundancy by identifying and correcting partial failures or wear-outs prior to any service impact.

Ready-to-implement solutions for rolling stock include SUSTRAIL, a European Commission project aiming to help increase EU rail freight by 40% by 2030. Within SUSTRAIL, the University of Huddersfield led the creation of a new freight vehicle, improving on a widely-used design to reduce lateral track forces by 50%, while at the same time allowing a faster top speed (up to 140km per hour). This was achieved by changing the vehicle layout, optimising component parameters to allow higher speed, and adding electronic disc braking, powered by energy harvesting on the bogies. Faster vehicles with higher brake rates enable more effective train pathing for greater overall mixed railway capacity.

The prototype vehicle has been trialled successfully on a test track in Romania, but the final hurdle of gaining approval to run on mainline routes remain. At this last stage the alignment of political, planning and commercial incentives presents the greatest barrier to the production of a compelling railway systems business case. The shared benefits need to stack up well enough for freight vehicle manufacturers and operators, in their very competitive and cash-constrained market, to buy.

Meanwhile, the industry is getting better at incremental enhancements, facilitated by the RTS research programme. Industry engagement on a project-by-project basis has resulted in RSSB outputs that deliver affordable capacity increases, such as:

- Minimising infrastructural alterations to permit larger freight containers;
- Facilitating electrification under hard-to-move road overbridges where there is insufficient electrical clearance to run normally; and
- Allowing narrower platform extensions to permit longer trains to run.

Innovations currently under development

At lower technology readiness levels (TRLs), RSSB has sponsored programmes under the RTS with the specific aim of enhancing capacity. The Predictable and Optimised Braking competition is advancing new forms of braking with linear motors and magnetic eddy currents; as well as adhesion improvement with dry ice, intelligent monitoring and even, counter-intuitively, the controlled addition of water. Better braking will enable higher capacity by unlocking closer running, with particularly significant impacts when atmospheric conditions produce a low friction rail-wheel interface: a more widespread challenge than the classic leaves on the track autumn problem.

Mainline railways are often slow to adopt new hardware (and software) compared to metro and light rail, let alone other industries. Gaining critical mass among the various individual industry stakeholders for projects, which only deliver optimally once universally adopted, is difficult, especially when, if adopted piecemeal, they constrain or complicate operations. This is particularly true where the financial or disruptive costs or risks of implementation accrue to different companies than do the downstream benefits.

Creating an interoperable moving block signalling system (ie ERTMS Level 3) is one such project. The development to interoperability would prevent dependence on, for example, a particular component manufacturer, and therefore protect against localised monopoly supply pockets. It would also ensure trains could run everywhere without creating the Eurostar-style complexity and cost of having to fit all systems on each train and switch between them across the network.

To date, however, a common, stable specification has not been developed. It is proving difficult to create a sufficiently detailed subsystem interface definition to secure the option to "plug and play" different suppliers' technologies while protecting their intellectual property, yet without constraining future innovation and development.

Innovations for the future

Looking to the longer term, other signalling concepts beyond ERTMS Level 3 would unlock further significant capacity increases. While engineers and operators declare that the railway is capacity-constrained, tracks are empty most of the time. Therefore, understanding how to fill them with more trains needs to be a priority.

Challenged by road transport initiatives such as automated cars and freight vehicle platooning, 'Closer Running' is a RSSB research workstream which considers two trains running together and, ultimately, communicating with each other instead of a signalling system. Taking closeness to the point of trains coupling up while running would enable radically longer, and variable length, trains. The potential benefits are across all 4 Cs: double Capacity, increased Customer satisfaction by providing through-journeys (without the pain point of changing trains), plus Carbon reduction through reduced stop-start, and Cost reduction through increasing load factors off peak and reducing numbers of carriages needed). The next stage will be to test the feasibility of potential options and explore implementation costs.

Concepts such as Closer Running require fundamental step changes in how we use railways. Substantial research investment must be put in place for them to be explored, developed and potentially funded through to technology demonstration. Given that costs and benefits will accrue to different companies over varying time periods, and that the whole benefit is much greater than the sum of its parts, without sufficient funding and commitment, it will be difficult for the rail industry to design and implement radical new approaches.

Further, given adequate foresight and consistent stewardship, radical changes could be delivered by incremental and relatively inexpensive changes to vehicle, signal and operational system design, together with a programme of relatively modest incremental infrastructural works, over the next 30 years to full implementation. A further doubling of railway network capacity for a relatively low outlay is a significantly attractive prize. If pursued, it may be found that selected concepts might usefully be introduced sooner, delivering not only capacity but also connectivity eg, to provide new through-train journey opportunities attractive to passengers.

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Opened in 1968, London Underground’s Victoria Line was the first in the world to incorporate Automatic Train Operation.

CASE STUDIES INTRODUCTION

The following case studies offer some comparisons and contrasts, using past, present and future projects to explore what can be done, as well as demonstrating the benefits delivered and valuable lessons learnt.

1. London Underground's Victoria line upgrade. This classic metro system upgrade represents best practice in maximising capacity, where all the trains are the same, closely matched to the signalling system and running on modern, multi-node, resilient infrastructure.
2. The Wessex Routes into and out of London's Waterloo station. This complex mainline rail system is an intensively-used, highly-constrained set of shorter and longer distance train services with different characteristics and with peak period crowding levels higher than the prescribed maximum; for which some solutions have been committed, but others are still required.
3. The Northern Powerhouse Rail. A regional transformation strategy exploring the options to meet growing demand (from Liverpool to Hull and Newcastle), across a hugely challenging set of mixed freight and passenger railways.
4. High Speed 2 (HS2). A combination of all three, ie metro attributes in national rail with regional strategic impact. The opportunity to design, mostly from scratch, a railway for maximum capacity with similar trains, but facing specific challenges around interfaces with existing transport networks (and regional strategies). Fundamentally delivering not only reduced journey times but also a step change in north-south capacity, provided both by the new infrastructure and by reducing the range of variety on several existing mixed-traffic mainlines.

Image: New trains built by Bombardier for the Victoria Line Upgrade (See Case Study 1).

CASE STUDY 1: LONDON UNDERGROUND'S VICTORIA LINE UPGRADE

The Victoria line upgrade (VLU) is an example of the impact of a capacity upgrade on the purest form of railway operation: a 'closed loop' metro system in which each train operates a near-identical journey pattern, performing similar tasks, in a high-frequency pattern for which headway management is critical, with an integrated management team operating processes under direct control. Successful deployment of high capacity comes from the integration of people, process and equipment. The Victoria Line has a particularly simple route network and pattern of services compared with other, older London Underground Limited (LUL) lines.

Opening in 1968, the Victoria Line was the first in the world to incorporate Automatic Train Operation (ATO) in which a driver is always present in the cab to operate the doors and start the trains, but only takes control of the driving in an emergency or in the event of failure of the ATO. It has 16 stations, is 21km long, and carries around 650,000 passengers daily.

Between 2006 and 2013, overall travel demand in London increased by approximately 12%, but demand for London Underground services increased by 36%. Peak period boarding on the Victoria Line increased by 21% with off-peak services increasing by about 35%. Combined with its already high mode share, this demand growth shows why the management and the performance of the system is so fundamental to the city. Demand growth is driving the need to increase the total capacity of all LUL routes.

Passenger numbers and growth in the business case for the VLU were baselined against 173m journeys in 2009/10. The projected growth was for 183m journeys in 2011/12, rising to over 200m journeys by 2015/16. Actual growth has been significantly higher than this with 213m passenger journeys achieved in 2012/13, and forecast to continue above the originally expected rate.

The key components of the upgrade have been the introduction of new rolling stock and the renewal and upgrading of the ATO and signalling system, together with work on the power and ventilation systems. Furthermore, selected infrastructure renewals were also delivered, taking advantage of the planned downtime of the VLU, with consequential benefits for safety and reliability. The work was undertaken in a series of planned packages, to minimise disruption on the line.

The principal components of the upgrade were:

- Introduction of 47 new 8-car trains to replace the existing 43 (more trains, higher performance, more capacity, bigger doors)
- Introduction of new ATO equipment and signalling system (to take advantage of the new trains)
- Construction and commissioning of a new Service Control Centre (SCC)
- Installation of 31 platform humps to assist disabled passenger access into two cars
- Supporting ventilation, track, power and depot works

Prior to the start of work, the maximum normal peak service frequency on the route was 27tph. On 20 January 2013, a 33tph peak period frequency was introduced. This was increased to 34tph in April 2014, with a final increase to 36tph to be implemented by April 2017, achieving a world-class level of frequency for metro railways. Moreover, the normal off-peak service will be 27tph: the same as the peak service prior to the upgrade. The business case for the 36tph service was overwhelmingly positive, yet the work involved to deliver it has required examination in minute detail of every single factor involved in operation, altering many details of the trains, track, power and signalling systems.

Once the 36tph service is fully introduced, there will be a peak capacity of around 36,000pph in each direction. The crush-loaded capacity allows 48,000pph, but that would be exceptionally uncomfortable. In addition to capacity enhancement, the number and extent of delays has been reduced, making a significant difference to overall system reliability. For example, the ‘Lost Customer Hours due to signals’ metric has reduced by 75% since 2006/07 while ‘Lost Customer Hours due to fleet’ has reduced by 84%.

Lessons learnt from the VLU include:

- Successful planning and implementation of a radical capacity upgrade requires attention to every aspect of operation.
- Modelling and continuous project engagement across the railway system is vital.
- Overall route capacity must take into account not only the train capacity and frequency but also station dwell times and passenger/station/train interfaces. Allowance must be made for the maintenance and overhaul of long-lived railway assets to continue to deliver capacity reliably.
- Homogeneous, automated, punctual and reliable operation of successive trains optimises total capacity. With increasing demand for capacity, these metro principles need to be applied to some parts of the national network.
- Victoria line trains are now capable of automatically speeding up a little to overcome small delays incurred during a station stop.
- By optimising performance and matching the signalling system and the trains to each other and the infrastructure, the 36tph service will be run by 41 trains in service daily (only two more than the 39 old trains needed for 27tph).

VLU was developed and implemented by a Public-Private-Partnership between LUL and its suppliers, with an integrated programme team (including the line operations team) concentrating on all aspects of system performance, incentivised by high level Key Performance Indicators. It was delivered on time and to budget, beating the original scope for a capacity of 33tph by 2013. Longer distance passengers across London have experienced a noticeable journey time reduction.

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Over 110,000 people use South West Trains services into Waterloo Station from south west London, Surrey, Hampshire and beyond.

CASE STUDY 2: THE WESSEX ROUTES IN AND OUT OF LONDON'S WATERLOO STATION (WESSEX)

The rail network in London and South East England is dominated by demand for travel into central London, within which public transport holds a 90% market share. Currently about half of the trips into central London involve the use of national rail, ie the franchised Train Operating Companies (TOCs), transporting nearly 600,000 people into the city centre in each morning peak period. Of these, over 110,000 use South West Trains (SWT) services into Waterloo station from South West London, Surrey, Hampshire and beyond.

Relevant to capacity, key features of these routes and the associated train services include:

- Almost all of the routes are electrified.
- The long four-track section of main line between Basingstoke and Wimbledon is configured so as to minimise conflicting moves between the faster and slower pairs of tracks, with grade-separated junctions at many of the key locations where converging routes join the main line.
- The rolling stock fleets achieve industry-leading levels of reliability.
- The large fleet of shorter-distance, 30-year-old trains has been modified with metro-style interiors, with fewer seats and more space for standing, in order to increase total pph capacity and shorten station dwell times through quicker boarding and alighting.

Current levels of overall punctuality for SWT (achieving a moving annual average of 88.4% Public Perfomance Measure (PPM)) and customer satisfaction (82% 'Satisfied or Good') are higher than for the other large TOCs in the South of England, but lower than has been achieved by SWT in the past.

A key challenge affecting both punctuality and customer satisfaction is the growing level of peak period crowding. In the most recent survey published by the Department for Transport (DfT) relating to autumn 2015, these routes had a 5.6% 'Passengers in Excess of Capacity' (PIXC) over a three-hour morning peak period, compared with the long-standing benchmark of 4.5%. From the same data, peak period demand on SWT into Waterloo rose by 15.1% over the last six years, whereas the national rail routes into London overall saw an average peak period increase of 11.5% over the same period.

Network Rail (NR) and SWT have jointly been planning how peak period capacity can be increased, and have received DfT support for a package of measures that focuses on the shorter distance routes into Waterloo from as far out as Dorking (22 miles), Guildford (30 miles) and Reading (43 miles). On these routes, trains have previously been constrained to a maximum length of eight 20m coaches. Changes now being introduced include:

- The former Eurostar platforms at Waterloo are being brought back into use.
- Other platforms and associated signalling and track on these routes are being modified to permit 10-car operation.
- 10-car trains are being formed by a combination of:
  - — transferring in some 2-car units from another TOC to add to existing 8-car trains
  - — converting 4-car units to 5-cars to run in multiple
  - — and procuring 150 new vehicles configured as 5-car units, also to run in multiple.
- The new 5-car units will have full-width interior gangways as well as other metro-style capacity-maximising internal features.
- The older units are being fitted with new traction motors and control equipment, in order to create greater performance homogeneity (maximising tph) and to reduce the total maintenance workload. This will enable the enlarged fleet (with 258 additional vehicles, almost 20% more) to be accommodated within the existing maintenance depot.

Image: Alstom-built trains operating on the shorter distance routes into London's Waterloo station, recently reconfigured to provide 10-coach trains in place of the previous 8-coach trains on these routes.

These projects and procurements demonstrate the benefits of integrated planning by NR and the relevant TOC, supported by DfT.

Further capacity increases for the shorter distance services will be achieved in the long term, if the ‘Crossrail 2’ project comes to fruition as proposed by TfL and supported by the National Infrastructure Commission. Under this proposal, many shorter distance Wessex services will be diverted into a new underground route inwards from Wimbledon, with an underground station below Clapham Junction station and then in-tunnel under central London to join up with the Lea Valley route from Liverpool Street. The Government has provided £80 million of initial funding for development of this project, which aims to submit a hybrid bill to Parliament by 2019 and open the line by 2033.

However, these enhancements, including Crossrail 2, will not be sufficient to provide additional capacity for the longer distance services into Waterloo (eg from Alton, Portsmouth, Bournemouth, Salisbury). On such routes, DfT policy requires seats to be provided for most passengers who are travelling for 20 minutes or more. Providing space for additional standing passengers is not therefore an acceptable solution. Moreover, most peak period trains on these routes already operate at a maximum length of twelve 20m vehicles or ten 23m vehicles, with some passengers standing throughout their journeys for an hour or longer (eg from Basingstoke and Winchester).

The Network Rail Wessex Route Study published in August 2015 sets out a range of possible solutions to help meet the future peak period passenger demand contained in Network Rail’s London & South East Market Study.

Shorter-term options suggested by NR comprise:

- Procure additional rolling stock to lengthen the peak period longer distance services that do not at present have 230/240m train length, with the further possible option of operating two more trains during the busiest peak hour; and
- Reconfigure some or all of the internal accommodation of the rolling stock that has standard class seating in a ‘2+2’ configuration in order to provide additional seats in a ‘3+2’ configuration.

Medium-term and longer-term options suggested by NR include:

- Divert some of the middle-distance trains using the fast pair of tracks in the peak periods, onto the slow pair of tracks, in order to provide more capacity for longer distance services.
- Grade-separate the principal remaining ‘flat’ junctions, specifically at Woking and Basingstoke.
- Provide rolling stock with a greater commonality of acceleration and braking characteristics.
- Develop and introduce train control and signalling systems that would enable trains to run more closely together and make best use of the infrastructure at junctions.
- Consider whether double-deck trains might offer a viable solution for some of the longer distance Wessex routes, if this could be done without requiring disproportionate capital investment or having a detrimental impact on station dwell times.
- A costly option would be to create a fifth track between Wimbledon and Clapham Junction.

Other studies have suggested that some congestion relief on the two-track sections of route between Basingstoke and Southampton might be achieved if intermodal freight trains between Southampton and the West Midlands could be electrically hauled, assuming new 25kV electrification via Winchester and/or Salisbury.

The next SWT franchise is scheduled to commence in June 2017, with a term of seven to eight years. DfT's Stakeholder Briefing Document for this franchise, issued in February 2016 following extensive consultation with stakeholders, states that "Our plans for 150 brand new carriages, and new and longer platforms at Waterloo mean we're looking for the next franchisee to make the best use of this additional capacity for passengers. But we're challenging bidders to go even further. We've asked for innovative proposals for delivering even more trains, more space and faster journey times". This document refers to an overall increase in peak time capacity of 20% by December 2020, and that "passengers will see quicker journey times on at least 70% of all services". It also emphasises the need for improved levels of punctuality and reliability, and higher overall levels of customer satisfaction.

Instructions to bidders for the new franchise, including explanation of how these improvements will be specified, measured and incentivised, are included in the Invitation to Tender (ITT) and the draft Franchise Agreement that were issued in June 2016. One detail included in the ITT gives new emphasis to the need to achieve maximum stop-to-start dwell times at stations of 45 seconds or fewer where the current requirement is one minute or more, and 30 seconds at all other stations, by December 2020 – even with a full passenger load (seated and standing). This is linked to a stated DfT expectation that the present shorter-distance rolling stock, and the new 150 coaches already on order, cannot in practice be loaded to the presently assumed maximum of $0.25m^2$ per standing passenger, and that $0.35m^2$ will be more appropriate to achieve the required dwell times at stations with very high interchange numbers at peak times, such as at Clapham Junction.

In summary, this Wessex Routes case study finds that while many excellent commitments already exist to increase capacity on the shorter distance passenger services to and from Waterloo, and many options exist to increase capacity in the future on the longer distance Wessex services, much ingenuity and skill will be required to achieve these combined objectives to improve peak period capacity, punctuality and reliability, and also to reduce journey times. Furthermore none of the options for the longer distance services would individually achieve compliant levels of present and future peak crowding. It will be essential for the new franchisee, NR and DfT to commit to work together to prioritise projects to be implemented, within a longer-term strategic framework for the Wessex routes.

> It is hoped that the Northern Hub Network will provide a step-change in rail capacity and quality of service, and help rebalance economic power from south to north.

CASE STUDY 3: THE NORTHERN POWERHOUSE RAIL (NPR)

"A rail strategy for the north, delivered by the north" proclaimed the then Secretary of State for Transport, Patrick McLoughlin MP, heralding the 1 April 2016 launch of the new Northern and TransPennine Express (TPE) franchises. These TOCs, alongside Rail North Limited (which represents 25 local transport authorities) will deliver the Northern Hub Network, including fleets of new electric, diesel and bi-mode trains. Northern Powerhouse Rail (NPR) aims to increase east-west rail capacity, supported by the National Infrastructure Commission, and to integrate with HS2 Phase 2. It is hoped that this step-change in rail capacity and quality will help rebalance economic power from south to north and attract investment.

The two new franchises connect the five largest cities in northern England – Liverpool, Manchester, Sheffield, Leeds and Newcastle. The new Northern franchise, let to Arriva Rail North, will provide a new network, dubbed 'Northern Connect' and consisting of 100mph trains on 12 long distance routes, linking many other cities and towns as far east as Hull.

TPE, let to First Group, will provide 125mph trains across an enhanced network including new links to Glasgow and Edinburgh. By 2019, both TOCs will deliver additional and improved links to Manchester Airport, which will be developed as a key HS2 hub station.

NPR proposes to create transformational opportunities beyond the extra rail capacity required, acknowledging the start point of suppressed rail passenger demand and seeking to facilitate modal shift away from cars, reducing carbon and promoting healthier lifestyles (because public transport users generally spend at least part of their journey in self-powered walking or cycling, compared to door-to-door car-users). In addition to better connectivity, there will be significant pph capacity increases, delivered by service frequency increases (National Infrastructure Commission supporting the vision for up to 6tph between the key city pairs, for which some new infrastructure will be required), new longer trains with more seats and material journey time reductions.

Image: A–Z 'next train' destination indicators at Manchester Piccadilly station.

Public transport research has found that having a train every 10–15 minutes (ie tph of 4 to 6) itself drives a step-change up in utilisation of park and ride, engendering a 'turn up and go, don't worry about the timetable' mentality. The higher quality rolling stock will encourage modal shift from road vehicles, by attracting customers onto the network, recognising their emerging needs eg that the provision of free on-board WiFi is a baseline requirement, not an optional extra.

Greater regional capacity for passenger and freight services will deliver better transport, which, combined with enhanced digital connectivity, will enable economic growth. Hence the preferred term Northern Powerhouse Rail rather than HS3 – and the integration with HS2. HS2 is not just a fast route to London. Its construction will free up existing railways, helping to deliver higher passenger and freight capacity on three existing north-south main lines and within the regions. Further, it will bring city regions closer together, with shorter journey times promoting economic integration (and hence more people travelling, in a virtuous circle). As identified in its Northern Transport Strategy (Spring 2016), Transport for the North (TfN) is working with DfT and Network Rail to establish the extent and phasing of possible new infrastructure requirements alongside upgrades to existing line. The aim is to deliver the best long term overall regional value.

The impetus for NPR has been partly top-down, as a result of national strategies recognising the imperative to shift growth from the constrained south of England to areas of unfulfilled potential in the north, to derive national economic benefits. In addition, there has been a strongly bottom-up drive too, embracing devolution and manifest through bodies such as Transport for Greater Manchester (TfGM), which published 'Transport Strategy 2040, Our Vision' (August 2015). Building on their "model for sustainable economic growth based on a more connected, talented and greener city region", this vision specifically includes more targeted transport investment:

- To improve access to economic opportunity for more deprived groups.
- To reduce road congestion eg by increasing the capacity of railways as part of improving the reliability, frequency and attractiveness of public transport.
- To encourage more sustainable individual decision-making eg with education on private cars' pollution contribution, and by offering joined-up mode-independent travel choices with big data collection and deployment through digital media.

Following consultation on this Vision, TfGM will publish their full Strategy (in December 2016) including critical transport measures to drive its implementation with 5-year local transport and delivery plans.

To meet forecast increases in volume, measured by pph, TfGM is significant within NPR because flows into Manchester and Leeds dominate the nearly 90,000 passengers travelling by rail into the biggest five cities during the morning peak (DfT, autumn 2015). While general levels of peak crowding are lower than in London and the South East, with 4% passengers in excess of capacity (PIXC) into Manchester and 2% into Leeds, the current problem is severe overcrowding on a relatively small number of trains. Overall, rail has a smaller market share in the north, so improved tph and train service quality is expected to lead to a rapid increase in demand, encouraging modal shift away from private cars to relieve heavily congested roads.

Some capacity enhancements are conceptually simple. For example increasing the number of trains per hour or increasing train lengths from the present typical two to three coaches per train. This can be attained by the new longer trains or by working Diesel Multiple Units (DMU) or Electric Multiple Units (EMU) in multiple, subject to classic constraints such as platform lengths (or selective door operation), signalling (eg space for longer trains not to obstruct or foul other routes when held at a red light), and length of sidings and depots.

One concern, post-franchise award, is the 10-year horizon, and whether the new rolling stock and other commitments will be sufficient to satisfy demand post-2024, and yet prior to HS2 Phase 2, and possible new NPR infrastructure arriving nine or so years later.

Compared with the South East (Case Study 2), the current NPR railways are characterised by a series of networks linked by routes, quite different from the radial pipelines into and out of London. Thus, NPR represents a more open railway system, hard to divide into bounded areas, within which to optimise solutions. There are more complex city-centric, sub-regional, and inter-city trade-offs to analyse, and a bigger variety of challenges to resolve. For example, how should we value TPE passengers' need for quick inter-city journeys, compared with local commuters' need for stopping services into and around their nearest hub, especially when many routes have only two tracks and few grade-separated junctions?

Reflection on the different customer needs when the railways were built, as well as more recent history, explains the gulf in service provision compared to Case Study 2, and, conversely, the future NPR opportunities. A single company's passenger services predominated from the outset on the Wessex routes, where the requirement has always been for a mix of longer distance express services among commuter traffic. In contrast, the Northern network took on the shape it has because several railway companies built competing lines. Further, until the railway renaissance of the last 20–30 years, the predominant east-west market was freight, so passenger train frequencies were low and journey times relatively slow. This explains the NPR opportunity to reap significant capacity benefits from well-established 'simple' infrastructure enhancements to track layouts, possibly including some grade-separated junctions.

Terminal station capacity constraints to passenger throughput are common to all but the VLU case study, requiring, for example, a significant investment programme to Manchester Piccadilly for both NPR and HS2. It is worth noting that, for example, Manchester's rail links have been improving incrementally since the 1980s, eg successively providing conventional and light rail connectivity between Manchester's two principal national rail stations, otherwise separated by a 25-minute walk.

There remain some intrinsic constraints and some myths to dispel. For example, lack of system complexity is a more significant determinant of train service reliability than age of rolling stock. Currently, the self-contained, closed, electrified Merseyrail network demonstrates that old trains do not necessarily equate to an unreliable railway, scoring 93% for customer satisfaction in the National Rail Passenger Survey of autumn 2015, compared with Northern Rail and TPE at 84% and 83% respectively. High reliability is a necessary condition to deliver high capacity, understanding that route complexity and reasonable cost optimisation intrinsically prevent Northern Rail and TPE from meeting or closely mimicking the Association of Train Operating Companies (ATOC)'s golden rules for rolling stock reliability (eg all vehicles coming home to a single depot every night to ensure both psychological "ownership" and the physical potential for 'tender loving care').

However, there remains plenty of scope for joined-up infrastructure management to resolve service-impacting issues and to increase operational resilience and recovery from any delay incident. Although we cannot realistically simplify or close the overlapping networks and routes of TfN, targeted investment in railways can deliver significant increases in railway capacity in terms of pph. These investments range from electrification in general to specific capacity improvement schemes such as the crucial Ordsall Chord between Manchester's Victoria and Piccadilly stations.

Over the next 30 years, growth of peak period rail passenger demand is forecast to increase up to 115% for the Northern cities. The NIC's High Speed North report (March 2016) proposes some new infrastructure, eg to reduce the Manchester-Leeds journey time (49 minutes for the 40 miles today to reduce to 40 minutes by 2022, and thereafter just 30 minutes with up to 6tph). Whereas, on more lightly used routes with lower pph needs, tram-train and light rail approaches can enhance flexibility to service local and emerging markets at lower operating costs.

Overall, an optimal mix of different technologies and costs should be deployed to deliver different capacities between different nodes of TfN. Arguably, the best mix might be 4tph for passengers, in order to free up freight paths for a better overall route capacity and greater net economic, environmental and societal impact.

In summary, we need to fix our gaze on the 30-year horizon, with a holistic approach, knowing the whole railway sector is more than the sum of its parts. To enhance rail capacity most effectively, we need top-down and bottom-up visions to meet and to drive strategies and programmes that best augment physical railway track and train assets for people and goods. While maintaining our focus on the 30-year picture, we must be mindful of a key gap – with planning for CP6 underway and an emerging strategy for post-2033, we risk another capacity crisis on the North of England network around 2024. Transport bodies must therefore be clear about ownership of the strategy for this period. The design and development of "soft" digital infrastructure must be integrated to provide more sustainable joined-up mode-independent journeys today, and to capture information to enable anticipation and capacity-building to meet future demand, in a positive long term feedback loop. The government has provided £60million of initial funding to develop proposals for capacity and journey time improvements between the cities, prioritising Manchester to Leeds flows. We understand the aspiration to set up a direct funding agreement to give TfN more financial autonomy, analogous to that enjoyed by Transport for London. The Institution is clear that sufficient additional funds must be transferred to enable effective delivery.

> Construction of HS2 should create 25,000 jobs directly, and support over 100,000 more.

CASE STUDY 4: HIGH SPEED 2 (HS2)

Despite the name, the rationale for HS2 is:

- Increased capacity (to relieve congestion on other north-south rail routes for mixed traffic),
- Creation of a high speed line with infrastructure future-proofed for 400km/h, although trains will not run at this speed initially, and
- Enhanced service quality.

All three improvements will promote modal shift from air and car, unlocking carbon benefits. High speed is needed to maximise efficient rolling stock utilisation, minimising the total number of trains, and for journey time reductions, aspiring to three hours for London-Scotland, in order to achieve maximum modal shift from air – as Eurostar has achieved for London-Paris.

In system terms, compared to our other three case studies, HS2 has the great advantage of being designed from scratch for tomorrow's needs, but with Phase 2 not due to open until 2033. HS2 will go beyond responding to needs, creating new demand with the explicit aim of helping to rebalance the economy to Birmingham, Manchester and Leeds from London and the South East, on the same principles set out in Case Study 3.

Consonant with our definition of capacity, the aim is to provide a throughput of not so much 18tph, but of 20,000pph. This aim drives whole-system design. For example, flows through stations are critical to enable efficient boarding onto and alighting from trains, aiming to achieve station dwell times of a maximum of 120 seconds and enable tight headways between trains. To keep dwell times within the threshold, HS2 plans wide platforms and step-free platform-train interfaces (providing accessibility for all), plus even distribution of passengers along the train. This will be facilitated by:

- Lifts and escalators spaced every 100m along the train
- Passenger information to optimise their use
- Gate numbers rather than a single platform number
- Seat reservations spread along the train
- Vehicles that welcome passengers carrying luggage

Engineering and operational thinking has sought to optimise key design parameters. For the train design, the need to operate many services onto the existing 'classic' infrastructure – beyond the new HS2 Phase 1 and 2 lines – precludes the purchase exclusively of vehicles built to the larger European body size. Rather than mix the initial fleet, HS2 will procure only 'classic-compatible' trains for Phase 1. For Phase 2, a mix of standard GB size classic-compatible and larger Euro-size trains will be procured. HS2 aims to make the two train types as similar as possible (top speed 360km/hr, same acceleration and braking characteristics) to maximise capacity on the tph measure. HS2 may depart from their initial plan for all trains to be 200m long and able to run with two trains coupled together – as is TGV practice. Cost and capacity optimisation suggests some trains will be built 275m long for Phase 1, in order to provide greater flexibility. Platform heights may be difficult to optimise as will platform screen doors, which might enhance safe and prompt passenger flow onto large vehicles, but might not fit the standard classic-compatible fleet.

Generally, though, in contrast with projects such as West Coast Route Modernisation, but more in common with Crossrail, HS2 can largely be built without disturbing existing infrastructure except at key interconnecting nodes and stations. So HS2 is not as self-contained as case studies 1 (VLU) and 2 (Wessex), nor yet as complex as case study 3 (NPR). It will be a semi-open system, designed to provide additional capacity and intentionally having a transformational impact on future travel patterns. The idea is to think out to the 30-year future aspiration, then think back to where we are, in order to stage our progress towards it.

Image: The proposed route for HS2, Phase One and Phase Two.

The relative number of Euro-size versus classic-compatible trains, the latter inevitably having more design compromises for core HS2 operation, and the degree of compromise/consistency across the total fleet selected, will directly impact joined up service delivery. However, the existence of sub-fleets inevitably introduces a more difficult and costly maintenance, operations and reliability proposition of itself, as well as the risk of importing delays from the classic network into HS2 – and vice versa. Additional system reliability pressure arises from the fact that HS2 is two-tracked, whereas the other existing mainlines have significant stretches of 3 and 4-tracked route. The biggest single risk is of a loss to the electrical traction infrastructure, eg dewirement, with its associated service impact multiplied by a long time to repair. Anticipation and hence prevention of pantograph/catenary failures are a key focus for the HS2 Innovations team.

Unreliability not only reduces effective capacity but is also the principal determinant of passenger dissatisfaction. Considering more widely, how will we attract most passengers onto public transport, making productive journeys sustainably? How passengers are best served with easy door-to-door travel not only by physical connection, but also with effective integrated ticketing or smarter user-friendly payment systems? How will we bridge the information (and perception) gap to shift individuals to select transport options, which deliver the national imperative? It is salutary to note in passing that each private car in Europe spends on average 92% of its time parked (and often roadside, contributing to congestion). Not a good sustainable utilisation, given the high environmental first cost.

Public transport options to the new Birmingham Curzon Street station, for example from Walsall, will include bus, light rail or train competing with taxis and private cars. Installing facilities such as car parks might abstract from local public transport, encouraging driving to a park and ride at Birmingham Interchange. Perhaps the Italian model of a ‘navette’ fleet of shuttle buses, branded like their high-speed trains and offering through tickets is worth pursuing for HS2. Perhaps on-demand autonomous vehicles will have superseded our 20th century thinking. The Royal Academy of Engineering report reviews technologies and their applications and asks what problems Government wants to solve – in order to steer which technologies should be applied. Technologies offer different capabilities and the rail industry is in need of some political steer on their relative values to society. HS2 will have the opportunity of several years before Phase 1 goes live, during which the selected options for linking in and out of key nodes could be ‘sold’ to the travelling public, eg as providing the simplest journey interfaces, eliminating the pain points most feared, or whatever other criteria are prioritised. To facilitate optimisation, the flow of people needs to be better-understood, not merely capturing data from station to station usage patterns, but identifying origin to destination ie where passengers are actually coming from, and why they select particular modes.

Public engagement comes to the fore as a prime risk in terms of planning consents, each of which were capable of introducing project delays, especially if backed by determined (and not necessarily representative) individuals, who may or may not have a valid argument. Impacts can be mitigated, eg aesthetically appealing electrification can be envisioned, but new routes are ultimately matters of political decision-making, albeit informed and supported by engineering optioneering.

An important balance to project cost discussion is value. Traditionally, the value created to passengers and society by the delivery of the project has been understated. It is harder to proclaim the benefits that will accrue to people not yet born as loudly as today's protesters can shout. The key value of HS2 is both to provide additional capacity (the 20,000pph) of itself, and to free up capacity for passengers and freight on the West Coast, East Coast and Midland mainlines, and also on routes between Birmingham and the NPR and those between the NPR and Scotland.

And there is economic value in the process. Construction of HS2 should create 25,000 jobs directly, support over 100,000 more (70% of which will be outside London), and is set to include 2000 apprenticeships. All this contributes to the potential for exporting UK railway technology and services, as identified in the Rail Supply Group (RSG)'s Fast Track to the Future (Feb 2016).

The Institution supports the progress of HS2 through parliament, and looks forward to contributing to the joining up of HS2 with NPR and Midlands Connect, some new regional infrastructure for better connectivity, and potentially the extension of Britain's high speed network to (and between) Glasgow and Edinburgh.

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There has been a sustained level of growth in freight and passenger demand over the last 20 years.

DISCUSSION

Capacity challenge is significant

We should embrace and celebrate the unparalleled renaissance of rail transport in the UK. There has been a sustained level of growth in freight and passenger demand throughout national rail, light rail and metro networks over the last 20 years. The national networks are struggling to meet this demand, becoming congested and capacity-constrained. Therefore the significant on-going and proposed investment in railway infrastructure, rolling stock and control systems is paramount. The interconnected nature of railways means, for example, that dedicated high speed passenger routes, joined up freight corridors and 'local' improvements will release capacity for other freight and passenger traffic, with impacts penetrating far across the network.

Simplification of the mix of trains on any route enhances its capacity. Therefore identifying and drawing out the highest speed, least frequently stopping services (eg through alternative intercity provision with HS2), or the slower running, most frequently stopping services (eg by regional/city authorities applying 'metro' principles) increases the capacity of the existing railway to deliver other train services.

Forecasts indicate that transport demand will continue to increase over the coming decades. The railway must engage with mode-independent Mobility-as-a-Service (MaaS) integrators where rail can best serve society with more pph capacity and shorter journey times for less energy cost and more safely:

- Railway operators must rethink through-ticketing with Smart technologies that provide the right data for MaaS providers to integrate rail (trunk routes, constrained corridors, etc) to optimally meet capacity demand with seamless connectivity across modes, conceivably using technologies such as the Lift Gaming platform/ knowledge base for customers and suppliers.
- Network Rail should enable future flexible timetables, developing concepts so operators can respond to emergent journey demand with more services eg when MaaS providers signal rising prices for the 1600 from Paddington to Plymouth, operators can consider inserting an additional train at 1602 – assuming they have also engineered some clever rolling stock provision.
- Station developers should consider likely reduction in carparking needs as autonomous vehicles are redeployed or park themselves elsewhere – in addition to increasing drop off and collection facilities for providers.
- Amenities at stations also promote their use by pedestrians and cyclists, enhancing the uptake of health-promoting self-powered first and last mile connectivity.

Image: Intermodal freight – the fastest growing sector of rail freight in Britain.

Spread best practices to maximise value for money

In parallel with new build, there is scope to make better use of existing infrastructure. By using smart data capture technologies, it is possible to adjust the mix of parameters that determine capacity to match the current and emerging demand. We should not underestimate the impact of conceptually simple changes to timetables, nor the journey-smoothing impact of information and human support. Nor should we underestimate the need to keep re-engineering our long-lived assets to maintain and strengthen reliability and performance, taking advantage of advances in remote sensing and big data.

Best practice includes recruiting policymakers and funders with railway engineering competency, linked to an appreciation of the different railway business realities. There is a need for an effective selection and implementation of worthwhile projects, eg the relative prioritisation for funding of projects arising from regional and national government, such as reconciling the North of England Electrification Task Force's list of Tier One requirements with "national" electrification and other schemes.

Adopt and foster innovation; build the resources and skills base for more

Our best current technologies should be adopted to achieve value for money from existing capacity and from future investments, for example through use of enhanced signalling and train control systems. ERTMS Level 3 interoperable moving block signalling is some years from being sufficiently specified and developed, and it will present significant logistics challenges and costs to deploy. However, despite providing a potential step-change in available network capacity, it will not be a panacea. Indeed, none of the currently envisaged enhancements will be enough. This Institution concludes that the capacity challenge is significant and the overall funding requirement is substantial.

The Rail Delivery Group (RDG) and Rail Supply Group (RSG) should engage the railway and other industries, to define our "problem" and opportunities. We should articulate and implement the RTS through the emerging RSSB Capability Plan process, together with academia, in the quest to scope effective research and development work-packages across the range of TRLs.

Governments and their agencies need to systematically seek further innovation:

- Supporting the UK railway for the innovation needed, including Network Rail's Digital Railway.
- Seeding it with Engineering and Physical Sciences Research Council (EPSRC), InnovateUK, DfT, RRUKA and RSSB research calls and technology development competitions.
- Nurturing the University Centres of Excellence and creating test environments to enable fast-tracking to de-risk innovation adoption.
- Facilitating delivery collaboration and technology transfer into railways with the Railway Industry Association (RIA)'s Unlocking Innovation events.

Their priorities should be to stimulate projects with potential to enable the 30-year vision by sponsoring both near market and more speculative relevant long-term innovation activity aligned with the RTS. Such projects need to promote UK exports, aligning with other RIA and RSG support initiatives to facilitate international sales penetration and grow volumes of trade.

Create an environment to nurture delivery of the vision; use informed clients

Railways that best deliver capacity around the world tend to have evolved:

- Where government railway policy has been strong and stable, eg MTRC in Hong Kong, high speed traditionally in Japan, and more recently in mainland China (enabling or driving long term planning and development in the supply chain).
- Where close and integrated long term planning and delivery have characterised investment projects. Examples include:
  — the successive Evergreen projects on Chiltern Railways, unlocked by a (to-date) unique 20-year franchise
  — the current Wessex franchise where effective relationships between SWT, Network Rail and DfT were forged
  — Crossrail, with its thorough definition and planning facilitated by having a realistic development timeframe, coincidentally imposed by a slow parliamentary approval process.
- Where engineers and other railway professionals are respected and supported, nurturing the critical skills base and attracting new entrants throughout the industry. UK governments can set an example in their own recruitment of more informed policymakers and funders with railway engineering competency as part of taking a societal lead in valuing engineers as a key component of sustainable economic growth.

CONCLUSIONS

BUILDING ON THE PAST

National and devolved Government, DfT, Network Rail, the train operating companies, TfL and their supply chains are massively focussed on expanding railway capacity, as illustrated by the four case studies in this report. The problem is that 'GB Rail' is in heavy catch-up mode. For decades, successive Governments (Conservative and Labour) declined to invest in High Speed Rail, Crossrail, the Thameslink upgrade and mainline electrification. Now the rail sector is delivering all of these major projects simultaneously, while also challenged by 20 years of the fastest rate of passenger demand growth of any railway in Western Europe. The Institution unambiguously supports these committed investments. The Institution further believes the as yet uncommitted investment needed must continue through the current economic uncertainty following the Brexit referendum, in order to enhance future capacity for nationwide freight and passengers (with High Speed, East West and other mainline rail), and for regional and city services (with light rail/rapid urban transit and metro).

Some perceive railways as being resistant to change, citing the painful impact on customers of trade union resistance to the introduction of Driver Only Operation on Southern Railway, an initiative which is widely and successfully in use elsewhere, and which includes some customer and capacity benefits by reducing station dwell times. This should not be confused with the need to expand sorely needed capacity on the constrained Brighton Main Line, itself expected to be acknowledged as a high priority for investment the next Control Period (2019 to 2024).

Fundamentally, the overall UK rail position today includes many initiatives to improve both capacity and wider customer satisfaction, as illustrated by the case studies and by the modal shift achieved from road to rail. Recent franchise award announcements such as for the Northern, TransPennine Express, and East Anglia TOCs, all of which commit to a big expansion of total train capacity with many other contracted commitments to improved quality and passenger service. They have built-in mechanisms to drive and deliver value-adding innovation throughout the franchise, including the research and development of both local and potentially nationally beneficial (and internationally exportable) yet to be conceived projects.

Network Rail's strong wish to accelerate the adoption of digital technology including the ERTMS Level 2 and 3 train control systems is held back not by ideology or dogma but rather by the fact that ERTMS is, for good engineering and commercial reasons, a Europe-wide project (and will remain so, even after Brexit). Further, to maximise the benefit, we will need to apply ERTMS to some of Britain's busiest, most congested main lines, something not to be undertaken lightly or with unproven systems. Hence the need for conventional forms of capacity enhancements – supported by the congestion relief of High Speed Rail – to proceed in parallel with the development of ERTMS and Closer Running (as outlined in the case studies and elsewhere in the report).

COMMITMENT INTO THE FUTURE

The way in which people and freight move, is entering a revolution, signified by the concept of Mobility-as-a-Service. This defining technological step-change in how we see and use all transport modes will have fundamental consequences and opportunities for the railway sector, challenging it anew to help deliver Britain's future demands. As engineers, we are continually challenged to balance and manage risks, and the railway sector needs to demonstrate that it has the willingness and capability to increase future capacity, and become more interconnected with other modes of transport.

In addition to the investment in hand, we outline in this report further solutions, developing technologies, and new concepts that can address the issues of capacity and interconnectivity with other transport types. Some radical developments will need to be adopted by the railway to optimise the sustainable delivery of national transport needs across the range of technological modes. However, for this to happen, engineers, operators and the whole of the railway industry must effectively engage current and potential customers, politicians, policymakers, regulators and trades unions.

RECOMMENDATIONS

Fundamentally, the Institution of Mechanical Engineers believes that tomorrow's society will expect interconnected sustainable transport. People and freight will be mode-independent, so the railway should embrace autonomous vehicle technology, both to facilitate smooth transfers between modes and to take on board the competitive challenge to a potentially significant slice of rail market share. The government should capitalise on the potential of rail technology to deliver a key element of sustainable and universally accessible concept of 'Mobility-as-a-Service'.

The opportunity for railways (and for the wider economy) created by the emergence of a committed longer term strategic vision for transport infrastructure, over 30 years (beyond seven to ten year DfT franchising cycles, and NR investment five year Control Periods), should be fully exploited. The Institution strongly supports the devolution of power to competent regional and intra-regional transport authorities to prioritise, plan and fund their own committed projects.

Now is the opportunity to optimise the delivery of transport capacity for customers, minimising carbon and cost. To increase overall transport capacity and optimise the value of the railway sector to the UK in the coming decades, the Institution of Mechanical Engineers recommends that the railway sector concentrates on capacity, in particular to:

1. **Fast-track step-changes to unlock latent network capacity by pioneering world-leading development and implementation of (and beyond) moving block signalling.** Specifically, the industry, led by RDG and RSG, and supported by RSSB, should accelerate the development of the Closer Running research workstream and ERTMS levels 2 and 3 within its January 2017 technology input into Initial Industry Advice to Government to ensure sufficient funding and impetus.

   Fundamentally, during 2017–8, the rail industry needs to work out how to think in a more holistic risk-based way, decoupling railway operation from the "if it fails we stop the trains" signalling principle. ORR and the DfT should engage with Network Rail's Digital Railway, so that delivery progress can be planned from CP6 (Network Rail's next Control Period, from 2019–2024) onwards. This will enable the railway to keep pace with road vehicles as they become more rail-like, enabling customers to "put their pods on the train", finding themselves travelling on a railway where it makes environmental and economic sense.

2. **Urgently bring capacity-enhancing innovations into operational use.** During 2017, RDG and RSG should identify the entry barriers to currently implementable projects in RSSB's solutions catalogue and ensure they are surmounted eg. by DfT and ORR adopting novel financing arrangements to adequately recompense individual TOCs and FOCs for implementing improvements that have a negative business case for them individually, but free up capacity on the railway.

   To deliver benefit for UK rail and unlock export potential, industry sponsors (including members of RDG and RSG, HS2, the Transport Systems Catapult) must bring worthwhile innovations forward from high Technology Readiness Levels (TRLs) into service. Key projects should be selected and committed to (and, where appropriate, accelerated) across a timeframe longer that the current five to ten years, providing confidence for the supply chain to match investment in people, plant and facilities.

3. **Initiate the next raft of new solutions to create capacity.** As Brexit means the UK has to leave EU-funded shared R&D projects like Capacity 4 Rail, the DfT and other government agencies should ramp up investment in British R&D targeted at opportunities to improve capacity through RSSB and the newly emerging University Centres of Excellence for railways. To enable railways to continue to deliver a transformative economic impact, innovators and their enablers (eg OEMs, start-ups, universities, RSSB, RIA, RRUKA, EPSRC) must engage with the industry-wide and governmental vision and initiatives to conceive and realise new technologies and techniques. They must facilitate the ongoing delivery of the Rail Technical Strategy eg building on the Capability Delivery Plan detailing the actions beneath the RTS.

   Government investment in and for researchers and innovators should be increased, particularly for technology demonstration and prototyping in order to maintain momentum for sustainable and useful railways, creating and delivering improved transport across the UK for decades to come. Devolved and national government funders should facilitate the delivery of the 30-year vision (eg by stimulating with seed capital, offering funding competitions, identifying innovation priorities to target, providing relevant technical and commercial information) to draw in new technologies, processes and professionals to relieve congestion, unlock suppressed demand and grow rail capacity.

4. **Speed-up the roll-out of known solutions to relieve capacity bottlenecks.** Government investment and commitment must continue for the enhancement of capacity through existing best practice, including the construction of new railway infrastructure capacity (new high speed lines, grade-separated junctions, electrification, local connectivity) and other well-proven techniques as illustrated by the four case studies contained in this report. Informed governmental and devolved buyers (eg NPR, DfT, NIC, NR, TfL, TfN) must enhance railway capacity through demand-driven, cost-effective national, regional and distributed investments complemented by the intelligent deployment of best operational practice.

Railway technology has the capability to move vast amounts of people and goods in a safe, cost-effective, sustainable and reliable way. The Institution believes we should make the most of it, within an intelligent and holistic transport system. We should find new ways to enhance railway capacity not only to unlock suppressed demand for UK rail, but also to facilitate Britain's exports of novel technologies, continuing to adapt the railway that was invented here – and sell it abroad.

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BIBLIOGRAPHY

Publications within the past year

Dame Colette Bowe: Review of the Planning of Network Rail's Enhancements Programme for Control Period 5, from 2014 to 2019 (Nov 2015)

Rail Supply Group (RSG): Fast Track to the Future (Feb 2016)

Rail Delivery Group (RDG): Long term Passenger Rolling Stock Strategy for the Rail Industry (4th Edition, Mar 2016)

Transport Systems Catapult: Traveller Needs & UK Capability Study (Oct 2015)

Transport for Greater Manchester: Transport Strategy 2040, Our Vision (Aug 2015)

Royal Academy of Engineering: Transport Congestion Challenge – Getting the most out of the UK's road and rail networks (November 2015)

Sir Peter Hendy: Report on Network Rail's investment programme (Nov 2015)

DfT: Shaw report into the shape and financing of Network Rail (March 2016).

IMechE: Leading the Change, Inspiring the Next Generation through Education and Policy (2016)

North of England Electrification Task Force: Final Report to DfT (2015)

'Smarter railways to meet expectations' letter to the Editor, The Times (21 Nov 2016)

Will Autonomous Vehicles Derail Trains? Bcg.perspectives (Sep 2016)

Published earlier, but with pertinent developments on-going

The RSSB-led cross-industry Rail Technical Strategy (RTS, 2012) which defined the 4 Cs and offers a vision of the railway 30 years on from then. Supporting the RTS, a Capability Delivery Plan is currently being developed to bring together the technology contribution to Government decision-making beyond CP5. The Capability Plan aims to improve the path from idea to deployment and is led by RSSB, currently engaging with stakeholders.

The Network Rail Technical Strategy (2013) and the four Market Studies (2013): which will result in 12 Route Studies currently undergoing development and publication.

GLOSSARY

ATO: Automatic Train Operation

ATOC: The Association of Train Operating Companies

The 4 Cs: Carbon, Cost, Capacity and Customer parameters to drive railway improvement as defined in the RTS

CP: a successive 5-year regulatory Control Period, eg CP5 runs from 1/4/2014 to 31/3/2019

DfT: the Department for Transport

DMU: Diesel Multiple Unit

EMU: Electric Multiple Unit

ERTMS: European Rail Traffic Management System

EPSRC: Engineering and Physical Sciences Research Council

ITT: Invitation to Tender

LUL: London Underground Limited

Lost Customer Hours: is a measure of the delay minutes to the train service multiplied by the assumed number of customers affected at the time of the incident.

NIC: National Infrastructure Commission

NR: Network Rail

NPR: Northern Powerhouse Rail

OEM: Original Equipment Manufacturer

ORR: Office of Rail and Road

PIXC: Passengers in Excess of Capacity. DfT's measure of overcrowding for Franchised TOCs in defined peak periods

PPM: Public Performance Measure. Shows the % of trains arriving within a defined margin of right time. It is the industry standard measure of performance in terms of reliability and punctuality.

pph: people per hour. high level, holistic measure of the capacity of a route, starting from tph but taking a wider system view of customer volumes

RIA: the Railway Industry Association

RRUKA: a group of universities with particular expertise in railway research in the UK

RSSB: the Rail Safety and Standards Board

ROSCO: a company that owns and leases rolling stock

TfL: Transport for London

TfN: Transport for the North

TOC: a Train Operating Company

TPE: the First TransPennine Express TOC

tph: trains per hour: a high level capacity measure irrespective of the size, length and speed of trains

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