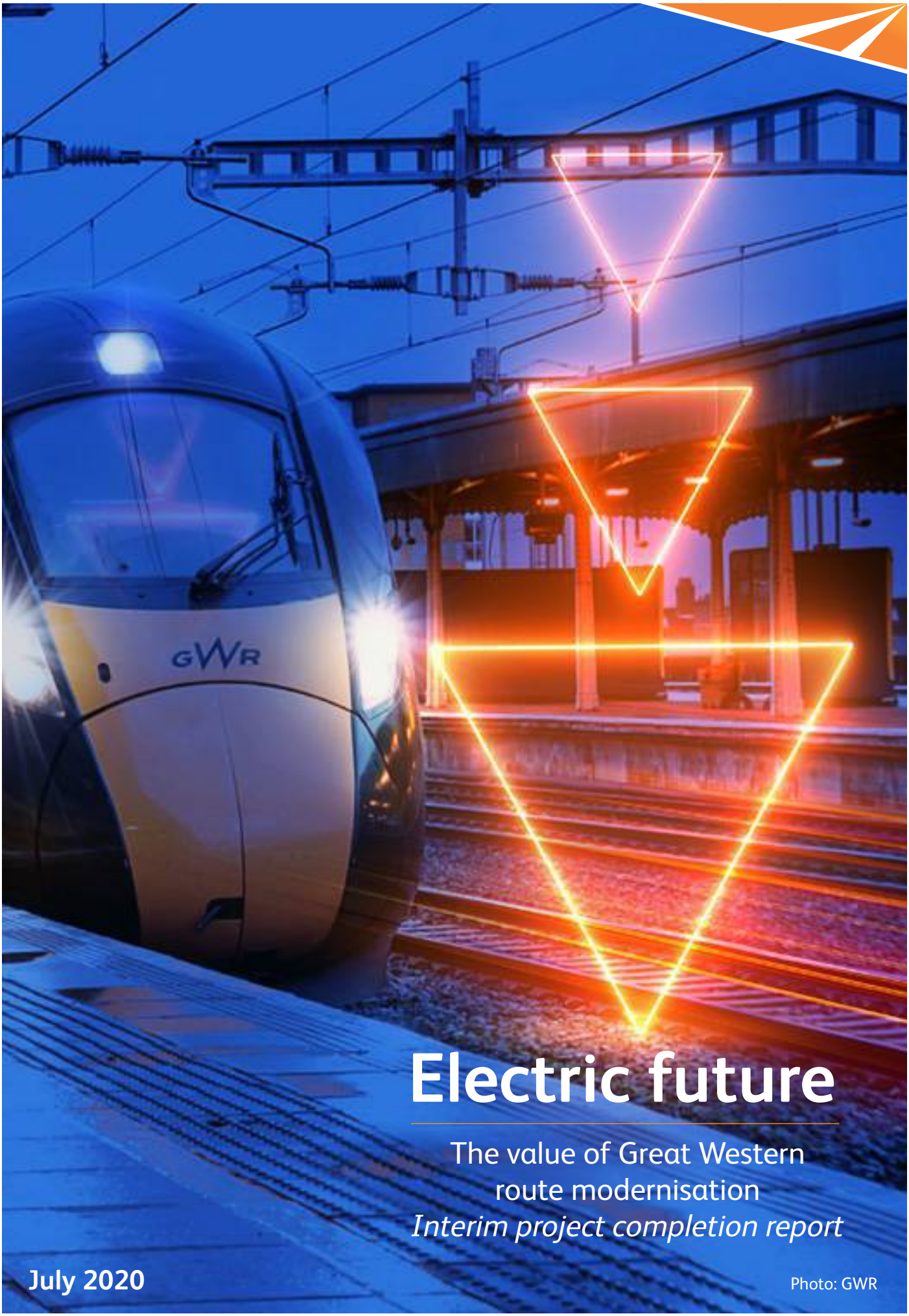


Electric future

The value of Great Western route modernisation

Interim project completion report

July 2020

Photo: GWR

Great Western Route Modernisation – Interim project completion report

Why electrify the UK's railways?

38 % of the UK rail network is electrified—much less than comparable European countries which are typically 60 % or more.

Electrified railways benefit passengers, freight customers, and the railway's neighbours. Electric trains are:

- ***better for the environment***. Typically an electric train emits between 20 % and 35 % less CO_2 per passenger mile than a diesel[1]. This is expected to improve to an 80 % reduction with the expected 2040 UK electricity generation mix[2]
- ***cleaner***. Electric trains have zero emissions at the point of use, of particular benefit for air quality in pollution hot spots like city centres and mainline stations such as London Paddington
- ***quieter***. Electric trains reduce noise pollution for those living and working near the tracks and reduce noise and vibration for passengers
- ***cheaper***. Electric trains cost less in the long term when compared to the whole–life costs of diesel trains
- ***quicker***. Electrification improves journey times due to superior braking and acceleration
- ***lighter***. Electric trains reduce wear to the track, reducing the cost of track maintenance
- ***more reliable***. Electrification reduces passenger delays, as electric trains are more reliable than diesel trains.

As the UK moves towards de–carbonisation, and conventional diesel traction is becoming increasingly unacceptable, further railway electrification needs to be considered wherever there is a good business case to do so.

Whilst new technology has a significant role to play, only electric and diesel traction can deliver the full range of requirements including high speed, long distance passenger and freight haulage.[3] And only electric traction can do so cleanly.

1 Press release, Department for Transport (2015).
2 Electrification Cost Challenge, Railway Industry Association (2019).
3 RSSB Decarbonisation Taskforce Interim Report (2019).

Executive summary

The modernisation of Great Western commenced in 2007, with the Intercity Express Programme formed to procure new trains, and electrification was announced in 2009. Work was completed in 2020.

There was an imperative—by autumn 2013 three of the ten most overcrowded trains in England and Wales were Great Western services into Paddington. The Department for Transport forecast an 81 % growth in passenger numbers over the following five years, with Great Western the UK's last wholly diesel–operated main–line route.

The Department for Transport set four objectives for rail investment:
1. a stronger, cleaner, more productive economy
2. safe, secure, sustainable transport
3. easier, modern, reliable journeys
4. connecting people and places, balancing investment across the country.

Great Western Route Modernisation addresses these objectives via five sets of outcomes. Four reflect the operation of new trains on the upgraded railway. The fifth includes learning by the Department for Transport and Network Rail, including the costly mistakes highlighted by the National Audit Office and others.

We recognise that the Covid–19 pandemic has a challenging impact on the UK economy, operation of the route, on–going investment into rail, and ridership, as well as wider public and government impacts on transport.

Supporting our stakeholders—greater connectivity

Better rail links between cities and towns improve agglomeration[1], tending to bring people and employers closer together in time through quicker, easier journeys. This has led to a variety of rail improvement projects: Great Western Route Modernisation, Crossrail, Metrowest, and Northern Powerhouse Rail amongst them.

Improved connections give people better access to jobs and leisure, and they make it easier for business people to meet and collaborate. They help make commercial development viable. Improved rail links also make an area more attractive to live in, offering an alternative to often crowded roads. The West of England Combined Authority (WECA) rates the Bristol to London corridor as highly agglomerated, in part due to its rail connectivity.

This has encouraged greater confidence amongst businesses to invest, expand and relocate. International businesses cite good rail links as a key factor behind their decisions to relocate to Reading. Large commercial developments near to Bristol Temple Meads, Cardiff and Reading stations are complete, and more are planned.

There is an expectation of economic growth. WECA envisages improved transport connectivity improving the West of England's Gross Value Added (GVA) by £10bn or more.

Helping our passengers—more seats and shorter journey times

Great Western Route Modernisation improves connections across the region, giving modern trains that reduce journey times, run more frequently, offer more seats, and are more reliable. The fastest trains from London Paddington save 16 minutes to Bristol Temple Meads, 20 minutes to Cardiff and 24 minutes to Swansea.

Passengers on long–distance and commuter services into London Paddington all now travel on modern new trains, which offer 21 % more seats into London Paddington at peak times.

Each new nine–car Intercity Express Train provides 47 % more standard class seats than the High Speed Train that it replaced. Thames valley passengers enjoy on average 27 % more seats on each suburban train. Diesel trains previously used in the Thames valley provide more seats on busy West of England services such as Cardiff to Portsmouth, and on well–used Devon and Cornwall branch lines. Some routes show growth of 20 % or more.

Our upgraded signalling between Plymouth and Penzance enables trains to run half–hourly, double what was possible before, and was followed by an 8 % growth in rail travel in Devon and Cornwall.

1 A key feature of the distribution of economic activity is a tendency towards spatial concentration, or agglomeration. Agglomeration produces economic benefits via positive external scale economies. The UK, outside London, tends to have lower agglomeration than the more developed EU nations.

Great Western Route Modernisation – Interim project completion report

Improving our railway— lower operating costs and greater reliability

We have reduced operating costs by an estimated 44 % for long–distance trains and by 27 % for suburban trains.

New trains are more reliable—40 % better for long–distance and over 300 % better for suburban trains.

We developed a robust new electrification system for the Great Western Main Line, and this performed flawlessly during the 2019 heatwave when historic electrification systems failed.

Helping decarbonise the UK—lower emissions

Under electrification CO_2 emissions from GWR's long–distance services have been cut by 60 % under electric power, and its Thames valley services emit 34 % less CO_2.[2] Emissions will reduce further as power generation decarbonises. Overall, GWR's bi–mode Intercity Express Train fleet emits 34 % less CO_2 than it would under full diesel operation.

Industry legacy—how to electrify our railway efficiently

Great Western electrification has providing a useful insight into the challenges of modern railway electrification. This has supported the development of an efficient, affordable strategy for UK rail electrification.

Well–publicised failings led to the reviews by Dame Colette Bowe and Sir Peter Hendy, two National Audit Office reports, and an appearance before the Public Accounts Committee. As a result from this, the Department for Transport and Network Rail have changed how they work together.

Improvements have been embodied in the two organisations' Memorandum of Understanding, the Investment Decision Framework (which includes the Programme Delivery Lifecycle), and the Enhancement Framework. Changes include an 'industry programme' approach which covers timetable, rolling stock, infrastructure, franchise and operation, clear mandatory decision points, and clear definition of roles and responsibilities.

Network Rail is changing to be more responsive to the needs of passengers and freight users. The Putting Passengers First (PPF) programme is supporting Network Rail's ambition to have the skills, culture and focus to put passengers and freight users at the core of everything it does.

Experience nationally has shown that a 'rolling programme' approach can be more cost–effective, allowing people to gain and apply experience, and incorporate technical improvements that emerge from earlier phases.

The Great Western team developed a world–class system approach to electrification, including power supply that incorporates substantial redundancy, highly reliable components, and safe isolation for maintenance.[3]

We developed expertise in construction methodology—how best to build OLE based upon experience and innovation—and the Rail Method of Measurement cost planning tool has been updated.[4]

Great Western's engineers pioneered progressive assurance in accordance with the ORR guidance on authorisations, saving time and money by removing the need to authorise each entry into service.[5]

Our engineers developed a risk–based approach which is helping to prioritise which bridges to need to be replaced. We learned to design the overhead line equipment first so that less work would be needed to reconstruct bridges.

The December 2019 timetable change, which rolled out capacity increases and journey time reductions, was a great success. Working closely with GWR and other train operators, we showed that lessons from Thameslink and Northern Rail in May 2018 have been embedded.

2 These figures reflect the lighter weight of the trains, the greater energy efficiency of centralised power generation, and the UK's grid mix (which includes a proportion of renewable and nuclear generation).

3 The Rationalised Autotransformer System scheme significantly lowers fault clearance times, reducing damage to equipment caused by faults. RATS has been incorporated into European standards on modern traction substations as a pioneer example of wide–area fault protection.

4 For example, the RMM now includes three levels of OLE complication—low normal, nigh normal, and abnormal—which cover the range of conditions found on UK railways.

5 There was one system authorisation at the end of the project.

Contents

GWR and Paul Stanford kindly supplied photos. Other photos were sourced from the Network Rail Media Hub.
Maps and charts were produced by the author unless otherwise credited.

This report was prepared by:
Julian Ross CEng FIMechE
Senior programme manager,
Wales & Western

Assistance was provided by:
Andy Powis
Alex Nathanson
Ben Sturgess
Ben Whitlock
Charles Varey
Dr. David Hewings
David Tunley
Francis McGarry
Graeme Tandy
Howard Elliott
Jane Jones
Joanne Griffiths
John Spencer
Matt Barnes
Nick Gray
Paul Stanford
Russell Gange
Simon Gardner
Tom Lydon

Glossary of terms

Class 16x	…	Diesel Multiple Unit train of Class 165 or 166
Class 387	…	Electrical Multiple Unit train of Class 387
Department	…	The Department for Transport
DECA	… …	Delivery Environment Complexity Assessment
DMU	… …	Diesel Multiple Unit train
EMU	… …	Electrical Multiple Unit train
GRIP	… …	Governance of Railway Investment Programmes
GVA	… …	Gross Value Added
GWEP	… …	Great Western Electrification Programme (a component of GWRM)
GWR	… …	Great Western Railway (a train operating company)
GWRM	… …	Great Western Route Modernisation
HLOS	… …	High Level Output Specification
HST	… …	High Speed Train
IDF	… …	Investment Decision Framework
IET	… …	Intercity Express Train
IPA	… …	Infrastructure and Projects Authority
LEP	… …	Local Enterprise Partnership
OLE	… …	Overhead Line Equipment
PRTF	… …	Peninsular Rail Task Force
South West	…	Devon and Cornwall
WECA	… …	West of England Combined Authority (Bristol, South Gloucestershire, Bath and North East Somerset)
West of England	…	Bristol, South Gloucestershire, Bath and Somerset (i.e. WECA plus the remainder of Somerset)

1. Background

Photo: GWR

1.1 About this report

This report reviews the value provided by Great Western Route Modernisation (GWRM), including the wider socioeconomic impact of the new and improved train services. It responds to a request made by the Network Rail Board in February 2020.

1.2 Why modernise?

Millions of people depend upon the UK's railways. Passengers who travel on our trains. Organisations whose workers commute by train, and businesses whose goods are carried by train. Business people who travel by train. People who don't travel by train, but whose livelihoods depend upon a well–functioning local economy. City dwellers who would suffer more congested roads if trains didn't share the burden of transport.

By autumn 2013 three of the ten most overcrowded trains in England and Wales were Great Western services into Paddington. The Department for Transport (the Department) forecast an 81 % growth in passenger numbers over the following five years.[1] And the Great Western Main Line was the last wholly diesel–operated route in the UK.[2] Diesel trains cost more to run than electric, and are less reliable. The route was not giving the value that it might to its passengers, its neighbours and its stakeholders. And a climate emergency has been declared.

Only by reducing carbon emissions can global warming be mitigated. Electrified railways play a key part in decarbonising our economy. Great Western electrification was originally planned to reduce journey times and operating cost, but it now plays an important role in helping decarbonise the UK too.

A decarbonising economy needs to remain productive and grow. A key feature of the distribution of economic activity is a tendency towards spatial concentration, or agglomeration. This produces benefits for organisations via positive external scale economies, giving rise to higher productivity and lower average costs.[3]

Transport improvements support agglomeration. Agglomeration economies can be intensified without increasing the physical concentration of firms and workers, but rather by improving transport connectivity.[4] Faster trains, operating more frequently, with more seats provide this.[5] To achieve this, the historic Great Western route required extensive modernisation—not just new trains, but also electrification to reduce journey times and operating costs, new tracks and flyovers to eliminate bottlenecks, longer platforms, new depots, and upgraded signalling.

The Great Western Main Line runs through a number of actual and potential agglomeration economies. London is well connected, along with the Thames valley, to which the Elizabeth line will soon contribute. The West of England[6] reports high agglomeration along the Bristol – Bath – Swindon – Thames valley corridor. Frequent trains on the routes between Taunton, Exeter, Exmouth, Newton Abbot and Paignton suggest another possible agglomeration economy. In each case rail—with its potential to carry more people than road, at higher speeds, and with greater safety and reliability—can (and does) play a major role. Calls for faster journey times between Plymouth, the Thames valley, Heathrow and London indicate a desire for broader agglomeration across the region—as does the Western Gateway which calls for greater connectivity between South Wales, the West of England, and Wiltshire.

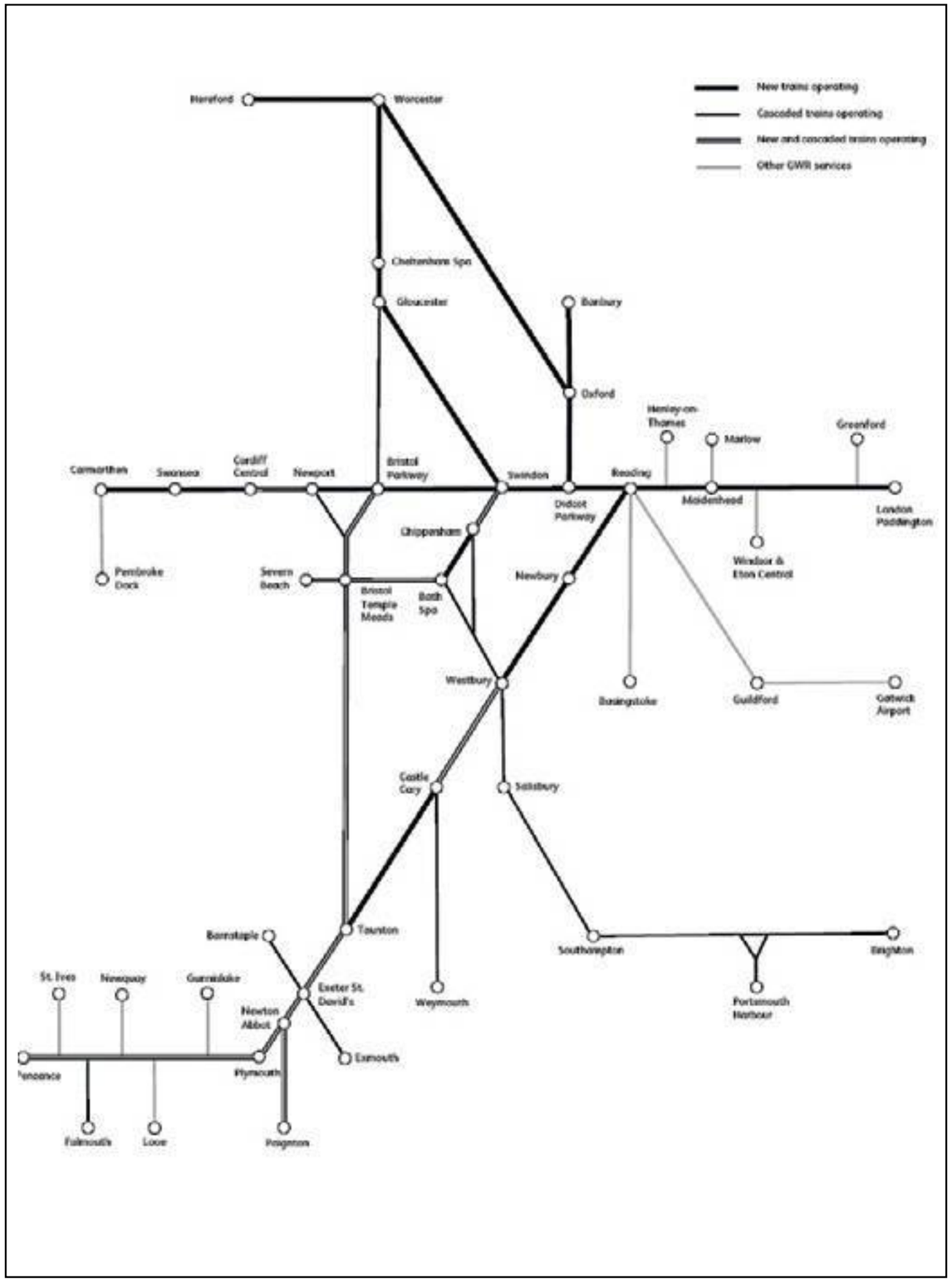
A two–hour journey has been taken as a threshold for convenient regular travel—HS2 will bring most English cities along its route within a two–hour journey from London.[7] Modernisation has brought more places on the Great Western route within a comfortable two–hour journey. And experience shows that fast, frequent train services can enjoy a high market share in extended agglomeration economies of this kind.[8]

Railways must be cost–effective. Electrification reduces the cost of operating a busy train service, a benefit that Great Western services have begun to claim, saving the UK taxpayer money.

Great Western Route Modernisation has helped Network Rail, GWR and other train operators to get people and goods to where they need to be—supporting our country's economic prosperity, and making the lives of millions of people better—whilst reducing the cost of operations, and contributing to decarbonisation.

1 This was not realised, in part due to delays to electrification.
2 The Midland Main Line remains diesel–operated north of Market Harborough. CrossCountry services also remain wholly diesel operated.
3 Quantifying Wider Economic Impacts of Agglomeration for Transport Appraisal: Existing Evidence and Future Directions, Daniel Graham, Imperial College London (2018).
4 This is because the generalised costs of travel largely determine effective economic concentration through their influence on access to economic mass.
5 Such agglomeration effects of transport improvements are classed as Wider Economic Impacts (WEIs) because they are viewed as additional to conventional user benefits—they extend beyond the traditional assessment of cost–benefit analysis.
6 *West of England* refers to the West of England Combined Authority, consisting of the local authorities of Bristol, South Gloucestershire, and Bath and North East Somerset.
7 Except Newcastle upon Tyne, which will be around 2¼ hours from London.
8 High Speed 1 reduced journey times between London, Pars and Brussels to under two hours, leading to over 70 % of passengers choosing to travel by train. High Speed Rail, DfT (2010).

What passengers see—new and cascaded trains in GWR service



2. Policy and strategy

2.1 Background

Electrification began with practical considerations. Before diesel traction, electrification was the only way to increase capacity beyond what steam could deliver. Of necessity London's deep tube lines were electrically operated from the start. Suburban railways were electrified for cleanliness, speed and capacity in an era of growing demand for mobility.[1] And, post–1945, it became harder to recruit staff to operate dirty steam locomotives.

Economics came into play: a densely–trafficked electric railway is cheaper to operate than diesel.[2] Britain's West Coast and East Coast Main Lines were electrified on cost:benefit grounds. Electric railways are easier to sell too—the clean and bright Underground; and fast, frequent Southern Railway electric services. And technically superior—ambitious high–speed development would have been impossible with diesel traction, let alone steam.[3]

But, before privatisation, passenger numbers were falling. Electrification in the UK had become a series of discrete schemes, between which engineering experience and supply chain capability were lost. When it was announced, after a period without electrification, the Great Western programme was a novelty.

2.2 The need for modernisation

British Rail developed the existing long–distance network, some of which was suited to speeds of up to 125mph with relatively moderate investment. For over thirty years, the iconic High Speed Train (HST) epitomised travel on the Great Western route—fast, frequent and comfortable. Indeed, the HST—along with electrification of the West Coast Main Line—may be credited with saving long–distance rail travel in the UK in the face of growing competition.

Long decline in train travel reversed in the early 1990s. As increasing numbers of people chose to travel on the newly–privatised rail network, a perfect storm loomed over Great Western—insufficient numbers of ageing trains crowded with growing numbers of passengers.

In July 2007 the Labour government published a rail White Paper, which stated that it would fund an additional 1,300 new carriages across the network. This included a commitment to deliver a fleet of Intercity Express Programme (IEP) Trains.[4] The initial intention was to replace Great Western HSTs with new diesel trains—indeed, the programme was initially called 'HST2'.

2.3 Electrification emerges

Against a background of growing international alarm at global warming, the Climate Change Act 2008 made it the duty of the Secretary of State to ensure that the net UK carbon account for all six Kyoto greenhouse gases for the year 2050 will be at least 80 % lower than the 1990 baseline.

On 23 July 2009 Prime Minister Gordon Brown announced a £1.1 billion programme to electrify the Great Western mainline, saying: "*This is the future. It is green, it is faster and it's more reliable. This is about making the railways fit for the 21st century.*"

His words acknowledged three of the four great benefits of electrification—electric trains are better for the environment, faster, and more reliable—only missing out the fact that they are also cheaper to operate.

Electrification proposals expanded. In March 2011 the Coalition government confirmed its intention to electrify commuter services on the GWML from London to Didcot, Oxford, Newbury, Bristol and Cardiff. However, it decided not to proceed with electrification to Swansea (as proposed by the preceding Labour government).[5]

The decision was later reversed and in July 2012 the government announced electrification of the Cardiff–Swansea line[6] and electrification of the lines between Acton and Willesden, Slough and Windsor, Maidenhead and Marlow, Twyford and Henley–on–Thames, and the Welsh Valley lines.

1 In 1902 the Great Eastern Railway developed an alternative narrative, supported by an impractically heavy steam locomotive, to oppose plans for a rival electric railway.
2 Electrification has progressed since the end of the 19th century because it provided a better economic approach to railway operations, and improved performance. There was not, at that time, any carbon reduction requirement—economic factors drove electrification widely across Europe. This fundamental principle remains today, now overlaid with the additional benefits to the environment. Electrification provides for lower maintenance rolling stock, and hence further lower operational costs.
3 The UK's Intercity 125 (which came to be known as the HST, or High Speed Train) was a rare example of a high–speed passenger diesel train in an era when European railways electrified for speed.
4 Delivering a Sustainable Railway, DfT (2007).
5 This was because there was "no evidence of a pattern of demand that would be likely to lead imminently to an increase in [service] frequency. Consequently … there is not, at present, a viable business case for electrification of the main line between Cardiff and Swansea".
6 As part of the High Level Output Statement (HLOS) for the rail planning period 2014-19.

2.4 Problems occur[7]

In June 2015 the then Secretary of State for Transport, Sir Patrick McLoughlin, told the House that "*electrification of the Great Western line is a top priority and I want Network Rail to concentrate its efforts on getting that right*".

But problems continued. High output plant failed to deliver the efficiency that Network Rail's schedule and budget depended upon.[8] Sir Peter Hendy's review addressed rising cost of Network Rail's infrastructure projects, and Network Rail and the Department jointly analysed the cost and scope of Great Western electrification.

In November 2016 the Railways Minister, Paul Maynard, announced his decision to 'defer' four electrification projects which form part of the GWML programme: Oxford to Didcot Parkway, Bristol Parkway to Bristol Temple Meads, Bath Spa to Bristol Temple Meads, and the Henley–on–Thames, Marlow and Windsor branches.[9]

Then, in July 2017 the Secretary of State, Chris Grayling, announced that the Government no longer intended to proceed with electrification between Cardiff and Swansea, arguing that: " … *innovative new trains switch seamlessly between electric and diesel power, delivering faster journeys and more seats for passengers without disruptive work to put up wires and masts along routes where they are no longer required*."

2.5 Desire for the outcome

The need to decarbonise the UK's economy remained.[10] Recognising this, the 2017 Conservative Manifesto announced that: "*The United Kingdom will lead the world in environmental protection … we are committed to leaving the environment in better condition than we inherited it. That is why we will continue to take a lead in global action against climate change, as the government demonstrated by ratifying the Paris Agreement … we are halfway towards meeting our 2050 goal of reducing emissions by eighty per cent from 1990 levels.*" [11]

Concern at global warming mounted. In May 2019, Parliament approved a motion declaring a 'national climate change emergency'.[12] And, on 27 June 2019, the UK became the first major nation to pass a net zero emissions law, setting a new target which will require the UK to bring all greenhouse gas emissions to net zero by 2050.[13]

2.6 Strategic alignment

Electrification of the Great Western Main Line has met legislative targets, Departmental policy, and sub–national transport body and local authority strategies. These include:

- "*achieve net zero carbon emissions by 2050, in accordance with the Paris Agreement.*" (Government Clean Air Strategy 2019)
- "*rail to play its part to drive down emissions and improve air quality throughout the whole sector.*" (Government Clean Air Strategy 2019)
- " *supporting the creation of a stronger, cleaner, more productive economy and making sure transport is sustainable.*" (DfT Single Departmental Plan, 2019)
- " *investing in schemes that will improve the sustainability of the network.*" (Rail Network Enhancements Pipeline, 2018)
- Clean air strategies, air quality action plans, and environmental policies published by local authorities
- Transport for the South East's aspirations to get powers to implement Clean Air Zones
- declarations of climate emergencies by councils across the route.

The National Audit Office (NAO) concluded that a good case existed for increasing passenger capacity on the Great Western Main Line.[14] Electrification was needed too, the NAO concluded, to give the full benefits of investments that the Department had already made, such as the Intercity Express Programme and the redevelopment of the Reading station area.

7 Chapter 9 examines the problems that occured in greater detail.
8 Reasons for this include inadequate surveys, buried lineside cables, and construction having begun before development and design were complete. High output plant is only effective long runs of production are available: this is disrupted when an individual electrification struicture cannot be erected because a piled foundation is not ready because, for example, a buried cable is found to be in the way.
9 Electrification between Reading and Basingstoke, a neighbouring part of the 'electric spine' proposal., was also cancelled.
10 The decision to reduce the scope of Great Western electrification preceded this, and was predicated upon a need to reduce cost whilst maintaining the majority of passenger benefits.
11 The 2015 Conservative Manifestoi had said: "*We will invest £38 billion in our railway network in the five years to 2019. Electrification of the railways is a key part of our investment programme, with work already underway across the North, the Midlands, and South Wales; there are plans to go further in the rest of the country, including East Anglia and the South West.*"
12 This does not legally compel the government to act, however.
13 Net zero means any emissions would be balanced by schemes to offset an equivalent amount of greenhouse gases from the atmosphere, such as planting trees or using technology like carbon capture and storage.
14 *Modernising the Great Western Railway*, National Audit Office (2019).

2.7 Implications and next steps

The Conservative manifesto promised to "*invest £100bn in additional infrastructure spending on roads, rail and other responsible, productive investment which will repair and refurbish the fabric of our country and generate greater growth.*" It also vowed to "*restore many of the Beeching lines*"—the 3,000 miles of railway closed after a review of the network begun by the Conservatives in the early 1960s and continued for the rest of the decade by the Labour Party.[15] The manifesto added—recognising the role that agglomeration plays in economic development: "A *key part of our plan to level up the UK's cities and regions is to connect them … European cities are often more productive than our own in large part because they have better infrastructure.*"

Emphasis has shifted from electrification to more general investment in rail and road. Recognition of the benefits of agglomeration is welcome, and has synergy with commentary elsewhere within this report. But we might conclude that the cost increases and delays associated with Great Western electrification have diminished government's appetite for further UK rail electrification. The railway needs to regain government's confidence.

The onus falls upon Network Rail and its industry partners to demonstrate that electrification is both useful and affordable. The lessons and legacy presented within this report show that Network Rail has gained valuable experience that equip it to deliver future electrification with greater certainty of cost and schedule. These lessons will need to be embedded in each of Network Rail's new regions where electrification is to be carried out.

The usefulness of further electrification has been considered. The Rail Industry Decarbonisation Task Force and the Rail Safety and Standards Board (RSSB) have stated that it will be possible to remove all diesel–only passenger trains from the network by 2040.[16] The report recommended that: "*Government should commit the railway to playing a major role in contributing to the national net zero carbon target by 2050. This means that rail will need to move well beyond `business as usual' in decarbonising its operations, to deliver a step change in planning, investment and delivery.*"

Network Rail's Traction Decarbonisation Network Strategy (TDNS), led by System Operator in collaboration with regional teams, Safety, Technical and Engineering (STE) and other industry bodies, will assess battery–powered trains, trains powered from electric overhead wires and hydrogen powered trains, and will present the case for deployment in the UK.

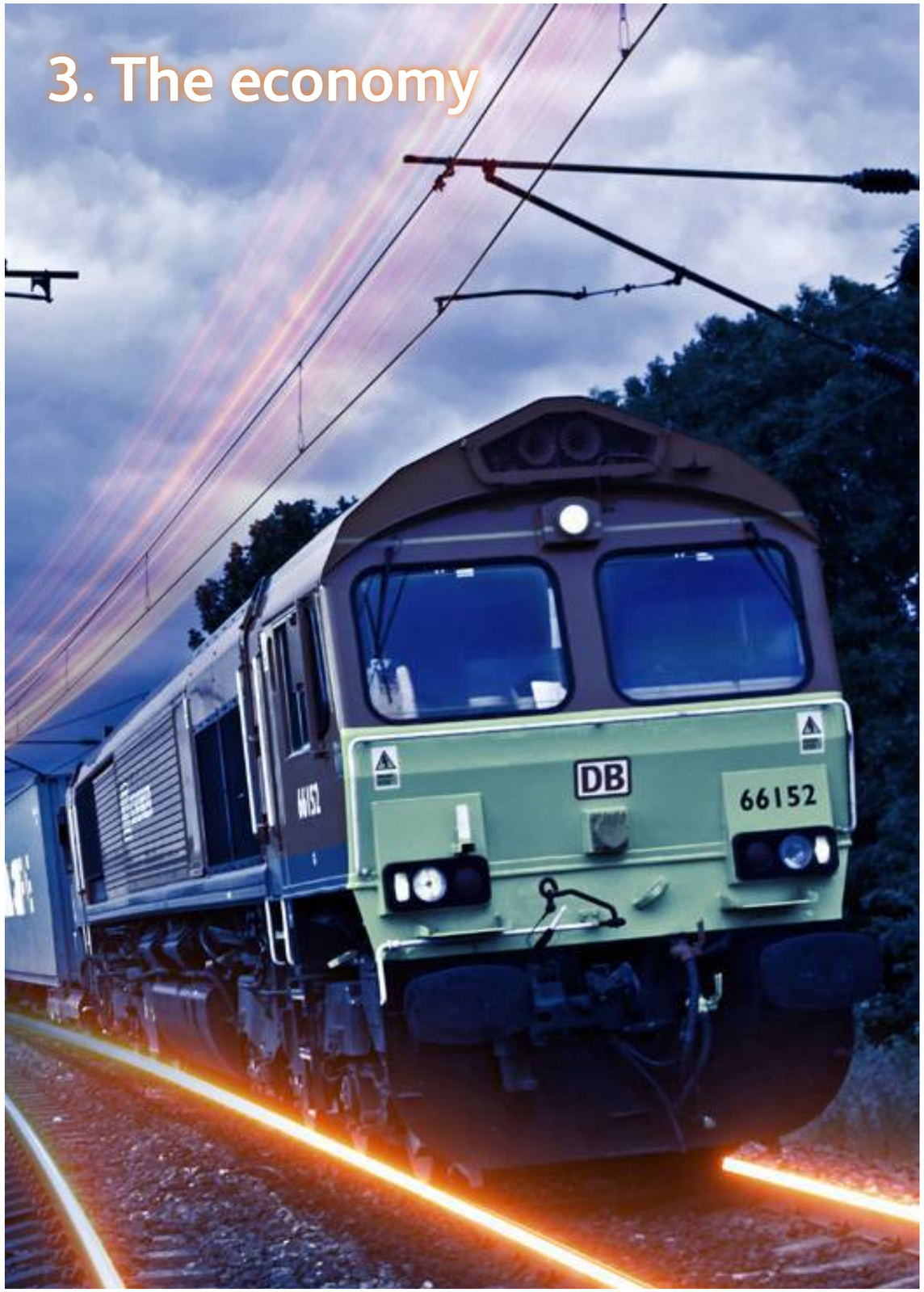
Affordability is being considered too. The TDNS will take the form of a five–case programme business case, in line with Her Majesty's Treasury (HMT) guidance, which will provide the strategic, economic, commercial, financial and management appraisals for each. It will identify which areas of the network should have which of the technologies deployed, alongside the strategic, technical and economic rationale for the proposals. The programme business case will be submitted to the Department for Transport (DfT), Transport Scotland and Welsh Government for endorsement.

Any business case depends upon sound assumptions. Network Rail has benchmarked electrification costs, as shown in chapter 10, providing policy–makers with greater certainty of cost.

And business cases will need to take into account all benefits, including those that government expects to see from better infrastructure connecting the UK's cities and towns.

15 The manifest said: "Connectivity is not just about the UK's great cities. To help communities across the country, we will restore many of the Beeching lines, reconnecting smaller towns such as Fleetwood and Willenhall that have suffered permanent disadvantage since they were removed from the rail network in the 1960s."
16 Rail Industry Decarbonisation Taskforce - final report for the Minister for Rail, RSSB. (July 2019). The removal of diesel freight trains is likely to be more complicated.

3. The economy



3.1 Supporting a stronger, cleaner, more productive economy[1]

The UK's economy depends upon efficient, cost–effective mobility of people and goods. A *strong* economy is quick to grasp opportunities and is robust against shocks, whilst a *productive* economy needs to maximise production versus overheads. A *clean* economy requires its activities not to pollute.

People seek *mobility*—the ability to move easily from one place to another—for work, leisure, shopping, and study. *Transport* provides a system for carrying people or goods from one place to another using vehicles (such as trains, buses, cars, bicycles and lorries) travelling on rights of way (such as railways, roads and cycleways). *Mobility–as–a–service* (MaaS) describes a shift away from personally-owned modes of transportation and towards mobility provided as a service.[2]

Delivered via an efficient mix of transport systems, good mobility is essential to the prosperity of our economy:[3]

- investment in transport systems can influence the functioning of labour markets, business productivity and competitiveness. These impacts interact over time and can lead to improvements in economic output and the geographical distribution of economic activity. They can also impact on the environment, quality of life and the overall attractiveness of towns and cities
- improvements in transport connectivity driven by increased network capacity, reduced travel times and reduced costs, together with improved reliability, generate improvements in productivity through what are sometimes referred to as 'agglomeration economies'
- where transport system investments are transformational, they can also influence the location of economic activity, for instance allowing businesses to relocate to more productive locations with better access to skills, other resources and customers. Investing in connectivity can not only influence the amount of economic activity in a region, it can also influence where it is located.

Covid–19 has demonstrated that online meetings can be effective, but face–to–face meetings enable relationships to be built, and many people will still need to travel to their workplaces.

3.2 Strength and productivity

Both strength and productivity depend upon transport systems that are effective (i.e. meet the needs of their users and stakeholders) and efficient (i.e. cost–effective and affordable to their users and funders).

A strong economy

A strong economy channels elements of antifragility[4] and robustness to make sure that it thrives in good times and weathers the storms that intersperse them:

- an antifragile economy responds to a boom by channelling labour and investment into areas of growth—it can benefit from change. Transport is key to this, enabling people to reach new and expanding places of employment in sufficiently large numbers, with minimal delay to accommodating patterns of growth
- a robust economy minimises damage during a downturn. Transport helps by providing flexibility, enabling people to travel to alternative jobs, which may be some distance away, whilst their home area recovers.

A productive economy

Productivity depends upon transport systems to bring people to work and transport goods at the lowest practical generalised cost (for passengers)[5] and financial cost (for goods).

1 The Department lists two elements under this heading: **Deliver infrastructure projects across road, rail and aviation**—which includes managing investment in the rail network in England and Wales on operating, maintaining and upgrading the existing network to improve performance and sustain growth, increasing reliability and punctuality for passengers. … work will include continuing the enhancement programme on the Great Western route; and **Deliver on transport elements of the cross government Industrial Strategy** — which includes making journey planning and payment simpler … assessing digital signalling and other digital technologies on the rail network … driving investment in quality skills and training. Department for Transport single departmental plan (2019).

2 This is enabled by combining transportation services from public and private transportation providers through a unified gateway that creates and manages the trip, which users can pay for with a single account.

3 The Transport Knowledge Hub. This is a free online resource aimed at providing Local Enterprise Partnerships (LEPs), local authorities and other local decision makers with tools and information to make transport investments that drive sustainable and inclusive local economic growth.

4 Antifragility is a property of systems that increase in capability to thrive as a result of stressors, shocks, volatility, noise, mistakes, faults, attacks, or failures. It is a concept developed by Professor Nassim Nicholas Taleb in his book, Antifragile. As Taleb explains in his book, antifragility is fundamentally different from the concepts of resiliency (i.e. the ability to recover from failure) and robustness (that is, the ability to resist failure). The resilient resists shocks and stays the same; the antifragile gets better.

5 the generalised cost is the sum of the monetary and non-monetary costs of a journey. Monetary (or "out-of-pocket") costs might include a fare on a public transport journey, or the costs of fuel, wear and tear and any parking charge, toll or congestion charge on a car journey. Non-monetary costs refer to the time spent undertaking the journey. Time is converted to a money value using a value of time figure, which usually varies according to the traveller's income and the purpose of the trip.

Value of agglomeration

Agglomeration provides two types of value:
1. better access to facilities, suppliers and business partners across the region—which support strength and productivity
2. more efficient provision of facilities, such as business districts, shopping centres, colleges and airports—which makes it easier, and more cost–effective, for developers and local authorities to catalyse economic growth.

The value of agglomeration tends to encourage greater confidence, both amongst investors who may be more likely to construct commercial property or open new businesses, and amongst potential employees who will not only seek good employment but pleasant, well–connected placed to live. These well–paid employees may be expected to make relatively high numbers of trips by train, for work and for leisure.[6]

Chapter 4 looks at the impact of better rail connectivity on our key stakeholders in Reading, Didcot, Cardiff, the West of England, and the South West.

Developing agglomeration economies

Improvement to train services—enabled by infrastructure enhancements—boosts the UK's regional economies.

The most recent attempts to drive geographic rebalancing in England have been based on cities. Both Northern Powerhouse and the Midlands Engine initiatives put cities at the core of their efforts to drive change. Towns have emerged as a new focus for economic and social policy over the last couple of years. Evidence exists that good rail links have encouraged companies to relocate to Reading. And construction of major commercial redevelopments adjoining Bristol Temple Meads and Cardiff Central stations cannot be coincidental.

The benefits of agglomeration to places vary by size and significance. The majority of places have less direct access to the benefits of agglomeration.[7] Bristol is an exception, its high levels of agglomeration with towns on the route to London driven in part by fast, frequent train services.[8]

Transformational change

Modernisation has enabled more trains to run, and longer trains, offering more seats and journey opportunities. Suppressed demand has been unlocked where crowding formerly dissuaded people from travelling by train, around Bristol for example.

Complementing Great Western Route Modernisation, the Elizabeth line will facilitate journeys, with a simple change of train, to Central London, the Docklands, East London, and Essex. A trip from Bristol to Canary Wharf, for example, will be quicker and simpler.

New electric trains are cleaner and quieter, and support stakeholders' aspirations to create Clean Air Zones.

3.3 Cleanliness

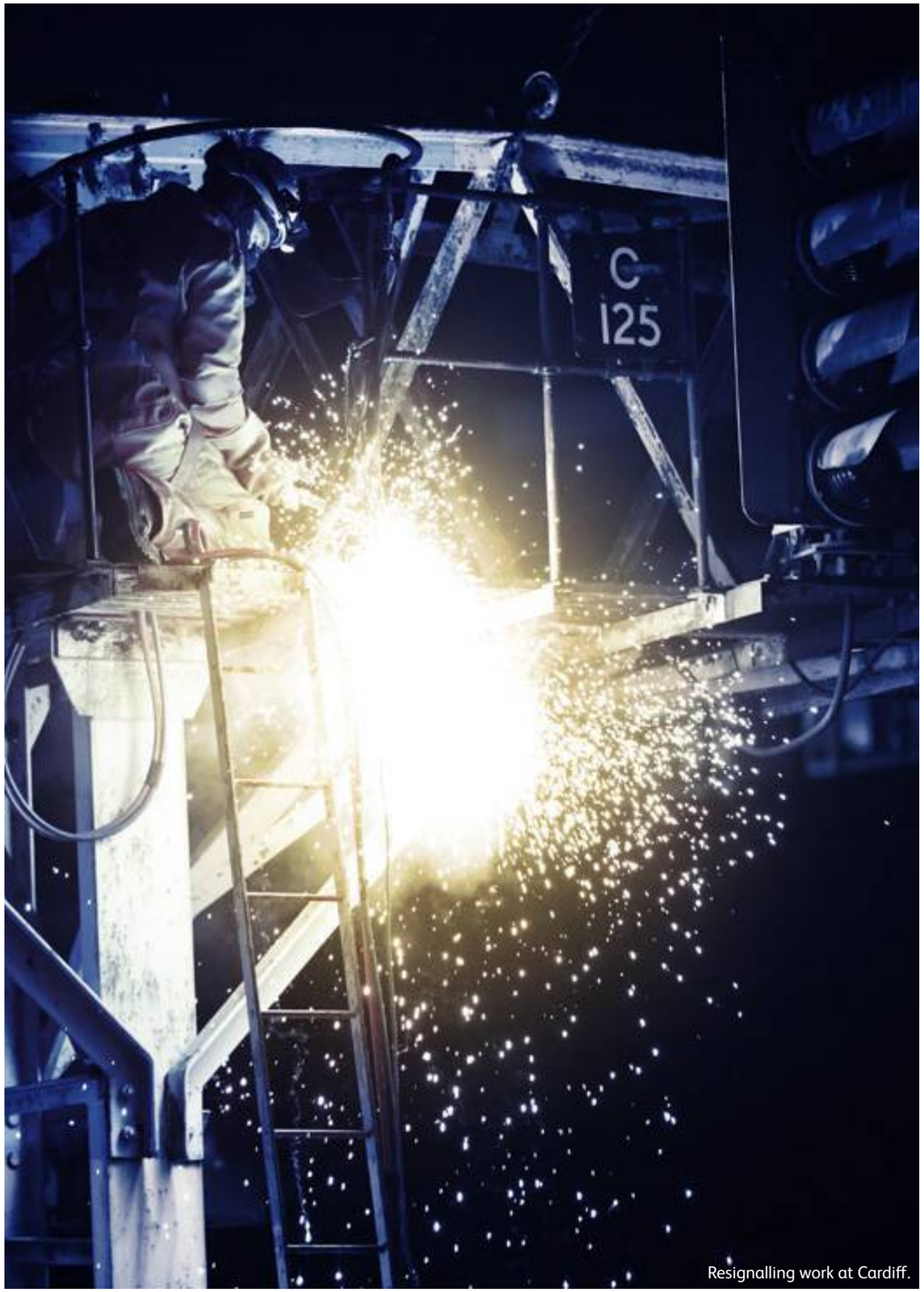
Transport is a major polluter across the UK, responsible for 33 % of the UK's CO_2 emissions in 2018.[9] Rail contributed 2 % of the UK's total transport CO_2 emissions in 2017.[10]

Electrification reduces the pollution from running trains. It does this through transferring power generation from diesel engines to the national grid, which draws power from an increasing proportion of renewable energy sources, and through the lighter weight of electric trains (which require less energy to move them).

Great Western Route Modernisation has increased the proportion of the UK's railway that is electrified by 8 %, enabling significant reductions in emissions of greenhouse gases, diesel fumes, particulates, and noise.

6 People in the highest income quintile made over three times more rail trips each on average compared to those in the lowest. Annual numbers of train trips by quintile from highest to lowest are: 42, 21, 15, 13, 13. Rail Factsheet, DfT (2018).
7 Agglomeration offers two types of benefit: urbanisation (firms gaining from sharing the specific common resources offered by large cities); and localisation (the ability for specialised firms to benefit from trade and interact with other firms in their industry that form part of the cluster). UK Regional Productivity Differences: An Evidence Review (2020).
8 West of England Local Industrial Strategy, WECA. (2019).
9 2018 UK Greenhouse Gas Emissions, Provisional Figures – Statistical Release, Department for Business, Energy & Industrial Strategy (2019).
10 Energy and environment: data tables, Department for Transport (2019).

Great Western Route Modernisation – Interim project completion report



Resignalling work at Cardiff.

4. The places we serve

Photo: GWR

4.1 Connecting people and places, balancing investment across the country[1]

Great Western Route Modernisation has given our passengers better journeys and greater choice. It has also improved choice for freight customers.

Better journeys

Modern new trains link London with cities and towns across the Thames valley, the Cotswolds, the West of England, South Wales and the South West. They provide connections between places remote from London too, supporting commuting, business and leisure travel across a broad geography.

Following modernisation, GWR provides 'metro–frequency' services between Paddington, Reading, Didcot Parkway, Swindon, and Bristol, where passengers can effectively 'turn up and go', whilst (as before) advanced fares are also available for pre–planned travel.[2]

GWR also provides regular hourly service or better on the majority of its network, including long–distance trains to Penzance and most of its branch lines. Figure 1 illustrates frequencies on the GWR network, and Figure 2 summarises the main changes made to GWR's timetable in December 2019.

Greater choice

Better rail services provide an alternative to car journeys, and enable journey time to be used productively. Even if electric cars become the norm, railways help avoid the economic costs associated with road congestion.[3]

Freight trains efficiently carry a variety of goods, reducing traffic on the region's roads. Through gauge clearance work, GWRM has expanded the routes available to major intermodal flows to and from UK ports such as Felixtowe, Southampton, and Tilbury.

Supporting investment across the country

Fast, frequent, modern, reliable train services encourages businesses to invest, including inward investment into the UK. With over £5bn spent on modernisation, electrification and new trains, businesses have the confidence to invest in cities and towns along the Great Western route, developers to build new homes, and people to live and work along the route. International businesses have cited excellent connectivity as a reason to move to Reading.[4]

Better access by train helps people to easily reach established centres of employment and leisure, such as Bristol, Oxford and Reading. Via the Elizabeth line, people will be able to easily reach Central London and the London Docklands. All of these will help people to reach jobs, employers to recruit staff, and leisure industries to flourish.

Easier journeys—faster, more frequent, more reliable, and with good wifi—encourage businesses to grow within economic corridors such as the Thames valley and Bristol to Cardiff. They help people to access a greater range of jobs, education and leisure activities.

Great Western Route Modernisation aims to help correct regional imbalance, spreading benefits to the West of England, the South West, and South Wales.[5]

1 The Department lists three elements under this heading:
- Work across the UK with local, regional and devolved partners to meet national and regional ambitions and maximise the value of public investment
- Work to develop the transport network across the country—DfT will help ensure transport investment complements Housing Deals …as well as supporting environmental objectives that will benefit local communities
- Work with the Ministry of Housing, Communities and Local Government to support the creation of new housing … including working with our arm's length bodies (Network Rail, Highways England and Homes England) to extend our joint approach and promote better integration of sustainable transport with new housing.

Department for Transport single departmental plan (2019).

2 'Metro–frequency' enables passengers to 'turn up and go', a transition believed to occur once frequencies reach four trains per hour.

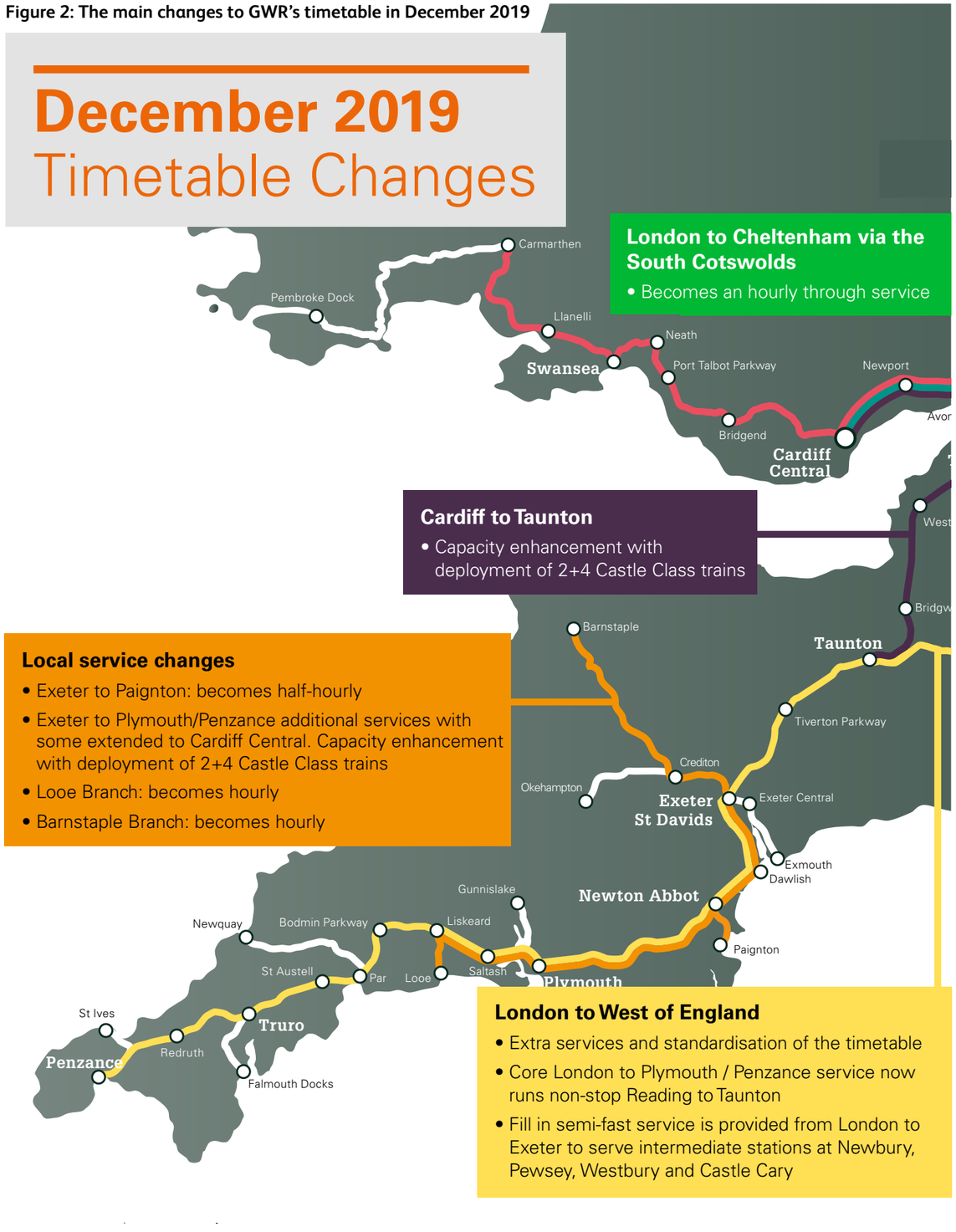
3 Both the generalised value of wasted in–vehicle time and the cost of building more roads to alleviate congestion.

4 For example, Bayer and Nokia: Living Reading (2020).

5 Despite the launch of at least 40 geographic policy initiatives over the last five decades, the UK remains one of the most regionally unbalanced developed economies. … Political power and resource allocations are centrally controlled to a significant extent and business is also very centred on London. It is therefore unsurprising that the UK is one of the most geographically unequal developed countries in the world. EY UK Regional Economic Forecast (2020).

Figure 2: The main changes to GWR's timetable in December 2019

December 2019 Timetable Changes



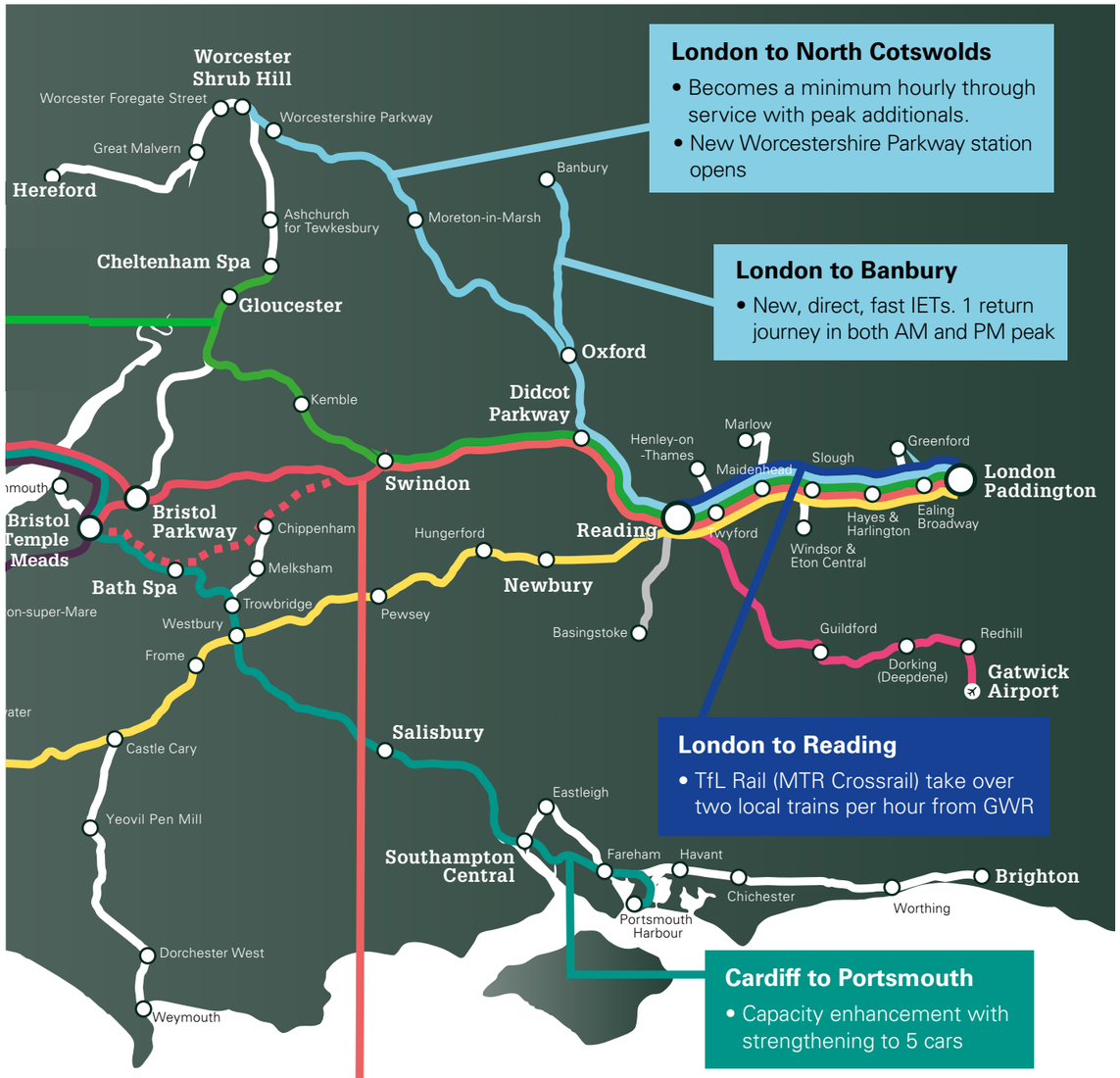
London to Cheltenham via the South Cotswolds
- Becomes an hourly through service

Cardiff to Taunton
- Capacity enhancement with deployment of 2+4 Castle Class trains

Local service changes
- Exeter to Paignton: becomes half-hourly
- Exeter to Plymouth/Penzance additional services with some extended to Cardiff Central. Capacity enhancement with deployment of 2+4 Castle Class trains
- Looe Branch: becomes hourly
- Barnstaple Branch: becomes hourly

London to West of England
- Extra services and standardisation of the timetable
- Core London to Plymouth / Penzance service now runs non-stop Reading to Taunton
- Fill in semi-fast service is provided from London to Exeter to serve intermediate stations at Newbury, Pewsey, Westbury and Castle Cary

Great Western Route Modernisation – Interim project completion report



London to North Cotswolds
- Becomes a minimum hourly through service with peak additionals.
- New Worcestershire Parkway station opens

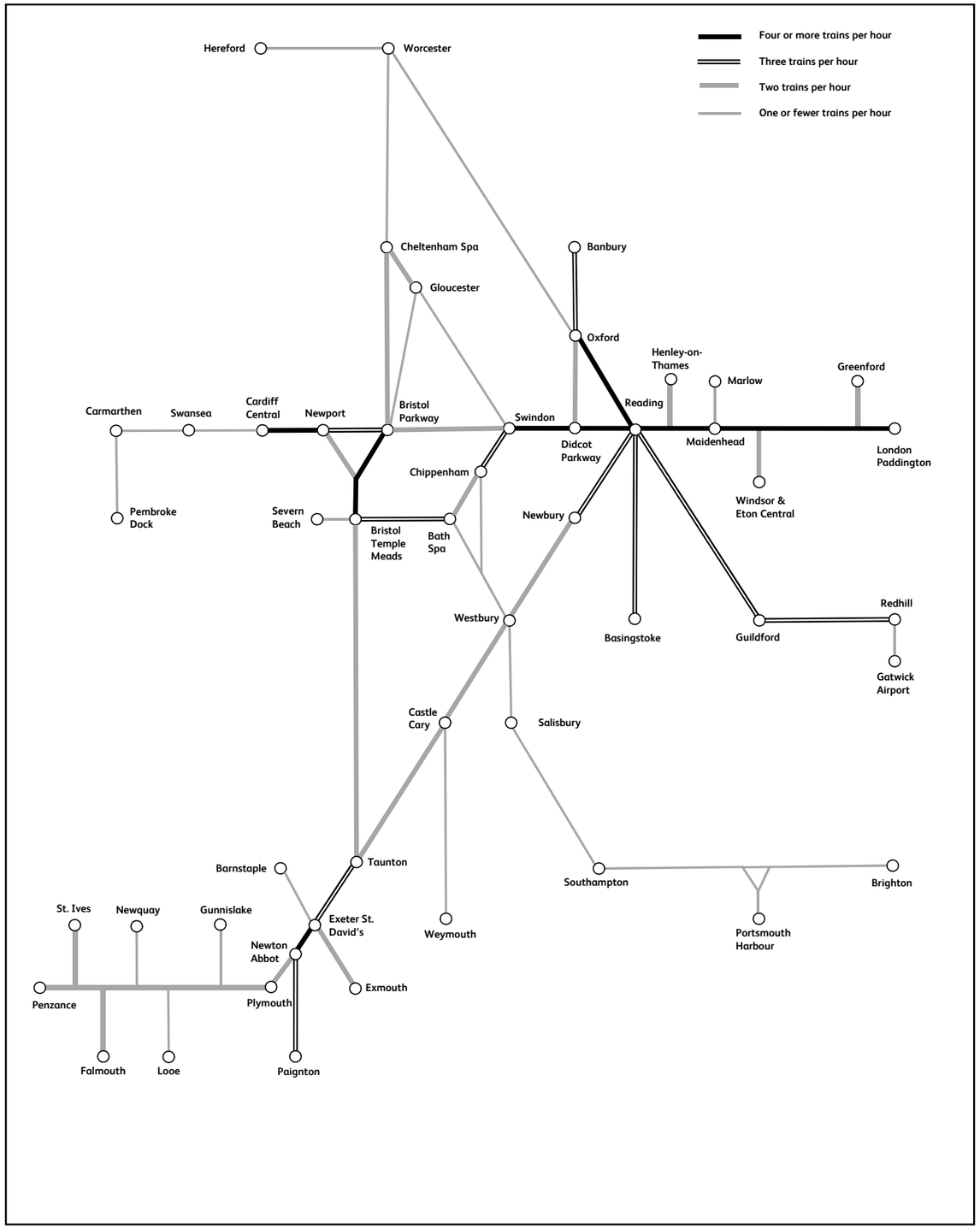
London to Banbury
- New, direct, fast IETs. 1 return journey in both AM and PM peak

London to Reading
- TfL Rail (MTR Crossrail) take over two local trains per hour from GWR

Cardiff to Portsmouth
- Capacity enhancement with strengthening to 5 cars

London to Bristol / South Wales
- Additional two trains per hour (tph) off-peak from London to Bristol Parkway, then Bristol Temple Meads. (start date TBC)
- At peak times an additional service per hour running between London Paddington and Bristol Temple Meads calling at Chippenham and Bath Spa only
- At peak times an additional service per hour running between London Paddington and South Wales, running non-stop to Bristol Parkway
- Changes to calling patterns to provide faster journeys

Figure 1: Frequencies of trains on the GWR network[1]



1 This map shows *typical* off–peak frequencies across the GWR network. The depiction is a simplification over sections of line where non–stop and stopping trains run—between Exeter and Newton Abbot, for example, where typically two stopping trains run hourly and two to four trains run non–stop or making selected calls. Not all trains on a particular section are operated by GWR—for example, CrossCountry provide a part of the service between Cheltenham Spa, Paignton and Plymouth, and between Basingtoke and Banbury. Where GWR provides a small part of the total service (e.g. east of Southampton, between Redhill and Gatwick Airport, and between Worcester and Hereford), other operators' trains are not shown.

4.2 Supporting regional economies

London and the Thames valley

Great Western Route Modernisation has helped increase the area's already high connectivity:

- more trains and seats between Paddington and Reading cater for growing numbers of passengers
- electrification enabing Elizabeth line services to operate between Maidenhead and Reading
- electrification will enable future services such as Western Rail Link services to operate on the GWML.

Figure 3 illustrates journey times between London Paddington and other places on the GWR network.

Bristol and the West of England

Bristol is well integrated with other economic centres and has high levels of agglomeration with neighbouring areas and towns on the route to London:[6]

- Great Western Route Modernisation has improved this, with faster trains, greater capacity, and a doubling of the frequency of services to London
- cascaded trains have increased the number of seats available on local services and services to Cardiff, Westbury, Southampton, Portsmouth and Weymouth.

Improvements to Filton bank, between Bristol Temple Meads and Bristol Parkway, will enable more trains to be run in future via Metrowest Phase 2.

The South West

Whilst electrification has extended no further west than Newbury, investment has reached across the regional rail network:

- new IETs extend the benefits of modern rolling stock and additional seats all the way west to Penzance
- signalling improvements in Cornwall have also allowed a doubling of frequency from two trains per hour between Plymouth and Penzance
- cascaded rolling stock has increased the volume of seats available in Devon and Cornwall, and has enabled regular hourly services to be introduced on the Barnstaple and Looe branch lines.

Regular, frequent services on the 40–mile route from Exmouth to Paignton via Exeter, Dawlish and Newton Abbot support commuters, students, leisure travellers and holidaymakers.

South Wales

Benefits of investment have extended beyond electrification to Cardiff:

- significant reductions have been made in journey times, and long distance services offer more seats
- new IETs now operate west to Swansea and Carmarthen.

Great Western electrification supports the proposed electrification of the core Valley Lines. The main line has been electrified between Newport and Cardiff Central, and the system will provivide a back–up power supply for electric trains running into the Valleys.[7]

6 West of England Local Industrial Strategy, WECA. (2019).

7 Power supply is a major cost component for railway electrification schemes. Network Rail's original intention was for GWEP to provide the main power supply for Valley lines electrification. Subsequently Transport for Wales decided to provide its own main power supply for the Valley lines.

4.3 Supporting future connectivity

The UK has not pursued agglomeration–based policies in a systematic fashion to cities other than London. Doing so could move productivity levels in the UK close to those found elsewhere in the developed world, benefiting people and businesses in the UK's cities and nearby rail–connected towns.[8]

Further development of regional rail networks, increasing their capacity and connectivity, will support agglomeration—a key step towards unlocking economic growth.

Great Western Route Modernisation helps enable future improvements:

- additional tracks between Bristol Temple Meads and Bristol Parkway support WECA's aspirations for Metrowest, which has potential to spread benefits as far as Bath, Gloucester, Portishead, Taunton, Westbury, and Weston–super–Mare
- electrification to Cardiff provides a high–capacity traction power supply that will reduce the cost of future electrification of the Valley lines. Electrification and resignalling of Cardiff Central station area has also been completed, reducing the work needed to electrify local train services.

4.4 Rolling stock cascades spread the benefits

Northwest England

Cascade of Class 150 and Class 153 DMUs is helping increase capacity and eliminate unpopular Pacer trains on busy routes around Manchester.

Scotland

ScotRail is in the process of introducing ex–GWR cascaded HSTs on Scotland's Intercity routes between Aberdeen, Inverness and the central belt cities of Glasgow and Edinburgh.

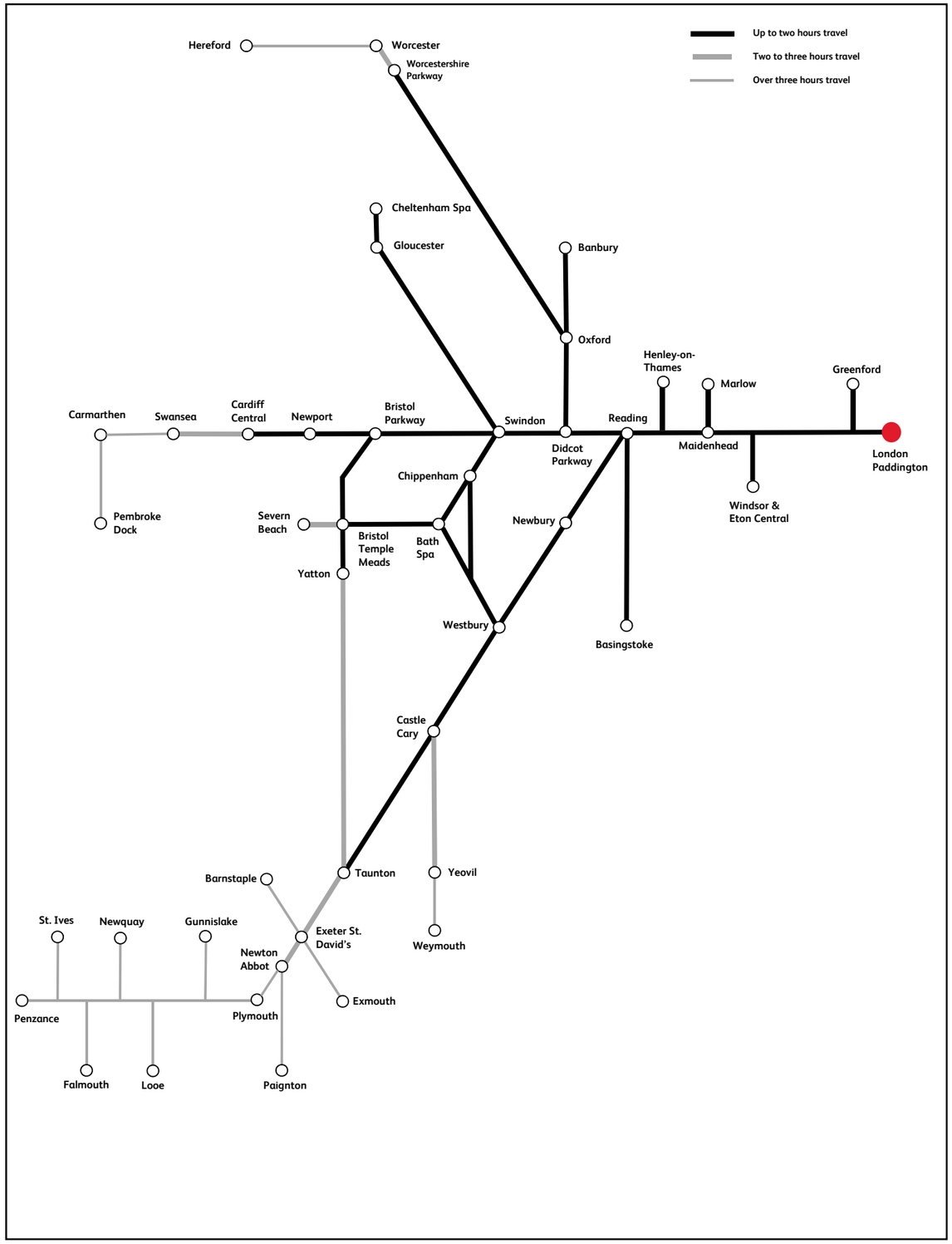
These are typically longer journeys for business or leisure, and the HSTs provide a much improved passenger experience in comparison to the 3–car class Class 170 DMUs that ScotRail previously used. They also provide more seating, which is important as the class 170s were regularly full.

The introduction of the HSTs, in additional to electrifying the busier corridors, means that ScotRail is able to target its rolling stock to specific markets (i.e. intercity services have HSTs, regional services have Class 170s, and commuter services have Class 385s). This has enabled passengers to benefit from more services, reduced journey times, and a better on–train environment.

Scotrail HST cascaded from the Great Western route

8 International comparisons suggest that England's cities outside of London have not achieved the agglomeration benefits of comparable European cities, with a lack of investment in intra-city transport advanced as a major reason Centre for Cities. Talk of the town: The economic links between cities and towns. Paul Swinney, Rebecca MacDonald and Lahari Ramuni. (2018).

Figure 3: Journey times between London Paddington and other places served by GWR



4.5 Ready for future growth

More people are forecast to use the railway, and more goods to be carried, once the Covid–19 pandemic has receded, as the UK's economy grows and decarbonisation results in modal shift.

Great Western Route Modernisation has unlocked opportunities to further increase passenger and freight capacity:

- IETs could be lengthened[9], and additional electric suburban trains bought, adding capacity to help meet forecast growth in passenger demand[10]
- electrification could be extended to deliver further journey time, capacity and decarbonisation benefits for both passenger and freight traffic
- electrically–hauled freight trains could be longer, and carry more goods, because more powerful locomotives could be used
- Filton bank four–tracking provides capacity to operate more MetroWest services, offering more frequent trains and more seats in the Bristol area
- electrification has provided an opportunity for Western Rail Link to Heathrow services to connect towns, cities and regions to the UK's main airport.

Lengthened platform at Trowbridge with cascaded train operating a Cardiff–Portsmouth Service

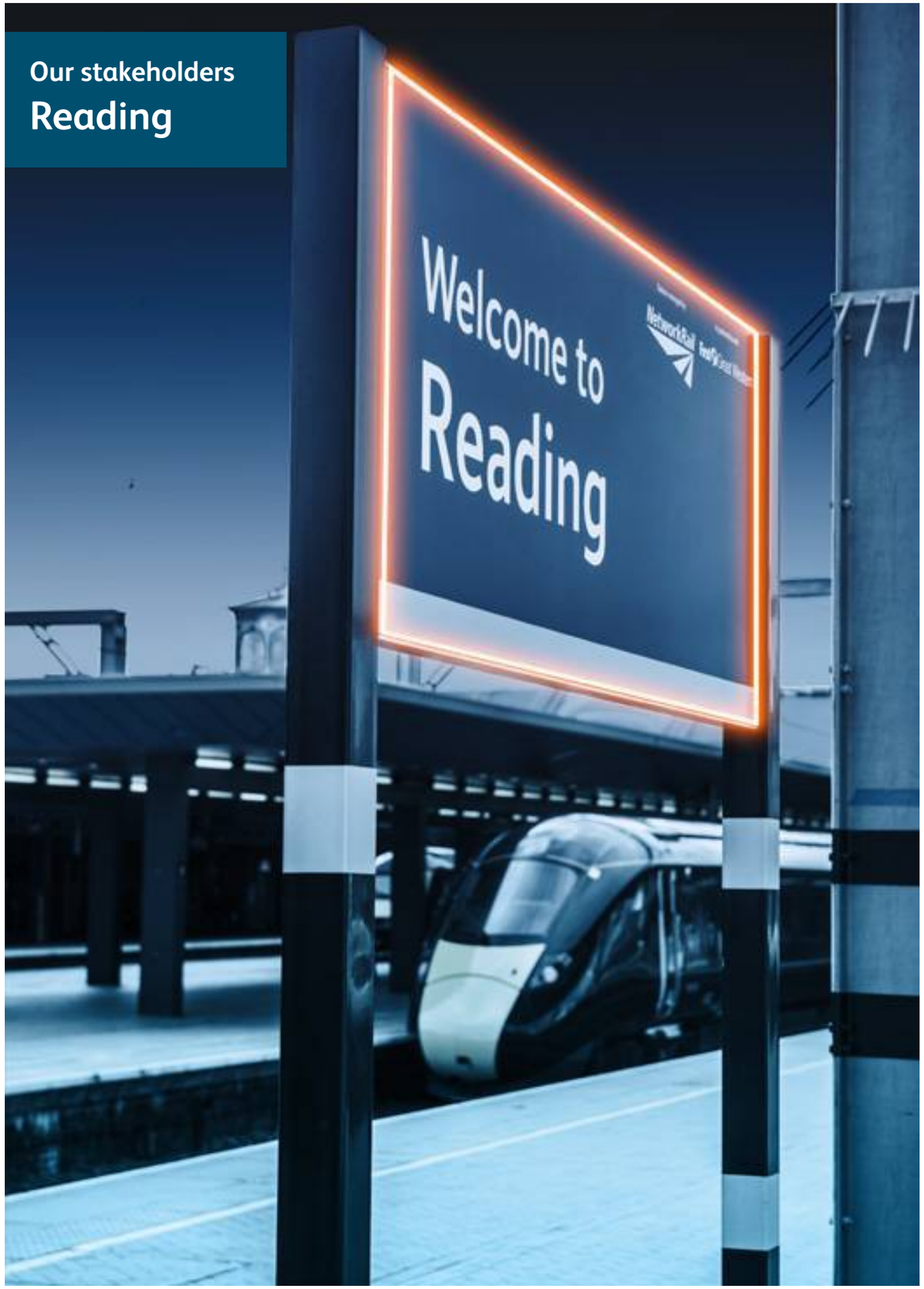
Photo: Paul Stanford

9 The IET specification requires that up to 12 carriages may be operated together. Currently, trains of 9 carriages and 10 (i.e. 2 x 5) carriages are operated. Train lengthening also requires improvements to infrastructure, and this may be costly and difficult.

10 For example, economic analysis predicts a 77 % growth in rail journeys from Reading between 2021 and 2050.

Great Western Route Modernisation – Interim project completion report

New escalators at Reading station.



Our stakeholders
Reading

Reading has the fastest growing economy in the Thames Valley:[1]

- prior to Covid–19, Reading's Gross Value Added (GVA) was expected to rise by 2.2 % between 2020 and 2023, outperforming both the regional average (1.9 %) and the UK (1.6 %). The information, communication, professional, scientific and technical sectors were expected to experience the fastest increase[2]
- Reading was named the second best place to live and work of the largest 36 economic areas in the UK, according to 10 key indicators key to economic success and well–being, including employment, health, income and skills[3]
- Reading has among the highest productivity per worker (GVA) in the UK, with an average productivity of £83,800 per job — the UK's fifth highest.[4]

Living Reading describes rail links at the top of the town's list of connectivity advantages.[5] Figure 4 shows some of the more important rail links from Reading.

A £900 million investment has transformed Reading station into a new gateway, unlocking a new wave of investment in Reading town centre. In 2019 Reading was the top scoring station managed by Network Rail in the UK with a 94 % passenger satisfaction score.
Nokia cited connectivity as a key factor in its relocation to Reading:

- following the consolidation of three satellite offices, Swindon, Newbury and Fleet, Nokia opened its new South East office in Arlington Business Park in 2018, employing 250 staff

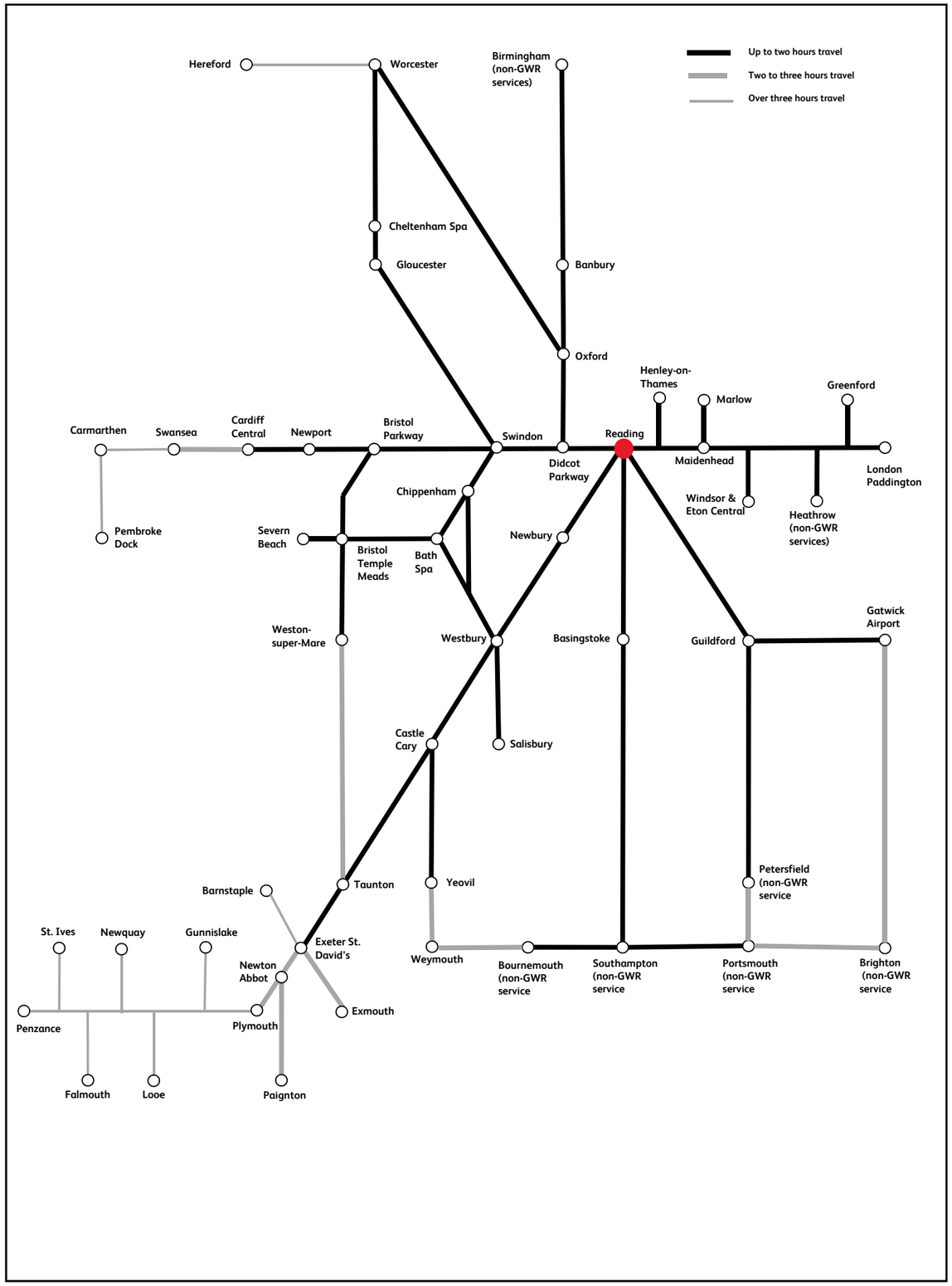
- Nigel Horton–Baker, Executive Director of Reading UK said: "*Nokia's decision to choose Reading is testament to the highly–skilled workforce located here and Reading's excellent connectivity*"
- factors highlighted by Nokia as influencing their decision to relocate to Reading included Reading's excellent transport links and airport access and the added benefit of many of Nokia's customers being located within easy reach.

Bayer relocated its UK and Ireland HQ to Green Park in Reading in 2016. The global pharmaceutical giant relocated around 500 employees to its £13m new HQ building on Green Park in Reading:

- Bayer reported a 250 % increase in applications for jobs at its headquarters since the move
- Bayer values being based close to Heathrow with excellent UK–wide connectivity through the M4, Great Western Main Line and the Elizabeth line. It notes that the planned Green Park station and Western Rail Access to Heathrow will further improve connectivity.

1 Data for 1997–2019, EY UK and Regions Economic Forecast (2020).
2 EY UK Regional Economic Forecast (2020).
3 Good Growth for Cities index. PwC/Demos (2019).
4 Centre for Cities, Cities Outlook (2020).
5 Reading is only 25 minutes non–stop from London by train. Over 200 trains a day link Reading's new £800 million station with London, just 22 minutes away. There are direct links to hub airports – Heathrow (40 mins) and Gatwick (75 mins) Crossrail will link Reading directly to central London from 2021. In addition, Reading boasts an award–winning bus company providing connections with trains. Living Reading (2020).

Figure 4: Journey times between Reading and other major destinations



- Central Reading has a substantial commercial property inventory of 4.4m sq.ft. / 2.7m sq.m.

This is set to increase through the Station Hill development, directly opposite the station, which will provide 600,000 square feet of office space, 100,00 sq.ft. of retail and leisure space, and 1,200 new homes.

As the developer, Lincoln MGT, says: "*Station Hill embodies the enormous potential that Reading has to offer; a thriving destination with remarkable opportunities and far–reaching benefits. Reading station couldn't be closer, and the arrival of Crossrail in 2021 will create direct access to London Underground, meaning you can have more time for the things that matter.*"

Lincoln MGT stresses the value of rail links from Reading, with its website quoting:[6] *"fast, frequent journeys to Paddington (26 mins), Bond Street (31 mins), Liverpool Street (36 mins), Canary Wharf (45 mins), Oxford (23 mins), and Bristol (54 mins)—all improved by Great Western Route Modernisation and/or Crossrail."*

6 Lincoln MGT's Station Hill website. The figures quoted do not appear to take account of interchange time.

Alison Webster, Chief Executive of Thames Valley Berkshire LEP, said:

"Berkshire is perfectly located in relation to the UK's national transport infrastructure, particularly through the Great Western Mainline and the M4 motorway. Moreover, through Crossrail and the impending Western Rail Link to Heathrow (WRLtH), much of Berkshire will see further enhancements in rail connectivity. The GW electrification project has been very well received by businesses in Newbury. For example, the investment in rail is helping to support the ambitions of the Newbury West Berkshire Economic Development Company (EDC) who are effusive about the improved rail connections the project has brought to the town. The LEP's investment, through the Local Growth Fund, in upgrading Newbury Station complements these improvements and will truly help to support economic and sustainable growth in Newbury. Developments such as this ensures that Berkshire remains a top UK destination for foreign direct investment—indeed Berkshire already has over 1,000 international businesses based within its borders, the highest number of any UK region outside London. Working with our local authority partners as well as Transport for the South East, our key focus is on enhancing sustainable economic growth to the benefit of business and local communities."

Paul Britton, Chief Executive of the Thames Valley Chamber of Commerce, said:

"An extra 10,000 seats in the morning peak into London Paddington is great news for businesses in the Thames Valley and London. Updated technology, new facilities and reduced journey times for business travellers and commuters will allow them to use their time more effectively."

Neil Gunnell, Henley Trains, said:

"We in the Thames Valley are finally reaping the benefit of the very big but delayed electrification of the Great Western Main Line and newer, bigger and better trains for the commute."

Great Western Route Modernisation – Interim project completion report

HM the Queen opens Reading station.

Our stakeholders

Didcot

Brunel's 19th century decision to extend the Great Western Railway to Oxford destined a rural village to become a regional hub, helping shape Didcot into what it is today. South Oxfordshire District Council's decision to seek garden town status for Didcot will, the council hopes, be instrumental in shaping the town's future.[1]

The promoters[2] envision Didcot garden town as: "*a sustainable and economically viable place, where the very best of town and country living have been brought together to create affordable, attractive homes within vibrant communities. Imaginatively designed, these energy efficient homes with gardens have ready access via green corridors to the surrounding countryside. Continuing the garden theme, the town centre apartments have garden terraces with views overlooking the Thames valley. Didcot is in high demand from professionals, families and those who have retired.*"

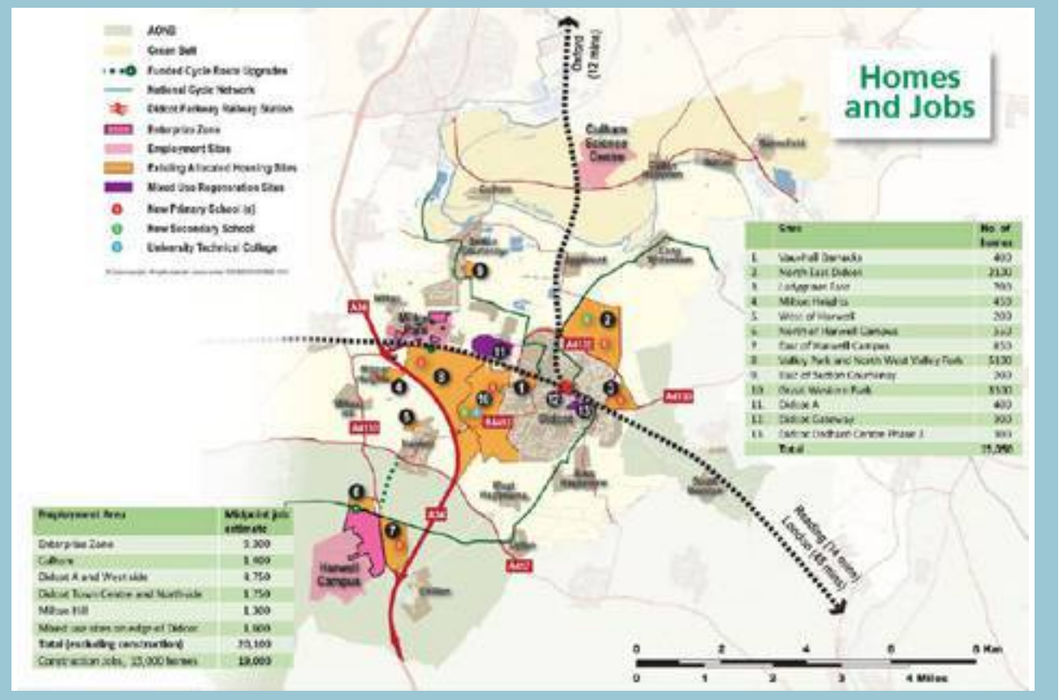
The promoters value Didcot's connectivity: "*By rail it is twelve minutes from Oxford and 35 minutes from central London. It is located at a crossroads on the main line to Bristol and on the Southampton to Birmingham line, affording optimum access to all UK destinations.*"

Great Western Route Modernisation has given Didcot more seats and quicker journeys on trains to London, Reading, Bristol and South Wales. Recognising that more people are commuting by train, GWR has opened a new multi–storey car park adjoining the station. Extensive cycle parking at the station encourages car–free access, and new bus and taxi stands support onward journeys.

Work has commenced with a £50m expansion of the Orchard Centre close to Didcot Parkway station. This is the first phase in the council's plan to deliver 20,000 new jobs and 15,000 new homes over the next 20 years.

A mix of affordable and private rented housing will be the focus of the council's future plans for the current Gateway site opposite the station, with smaller shops and places to eat and drink to support the new community there.

North of the station, the council's masterplan proposes developing a world class technology institute. This has potential to make Didcot a centre of excellence for the research and development in advanced technologies.



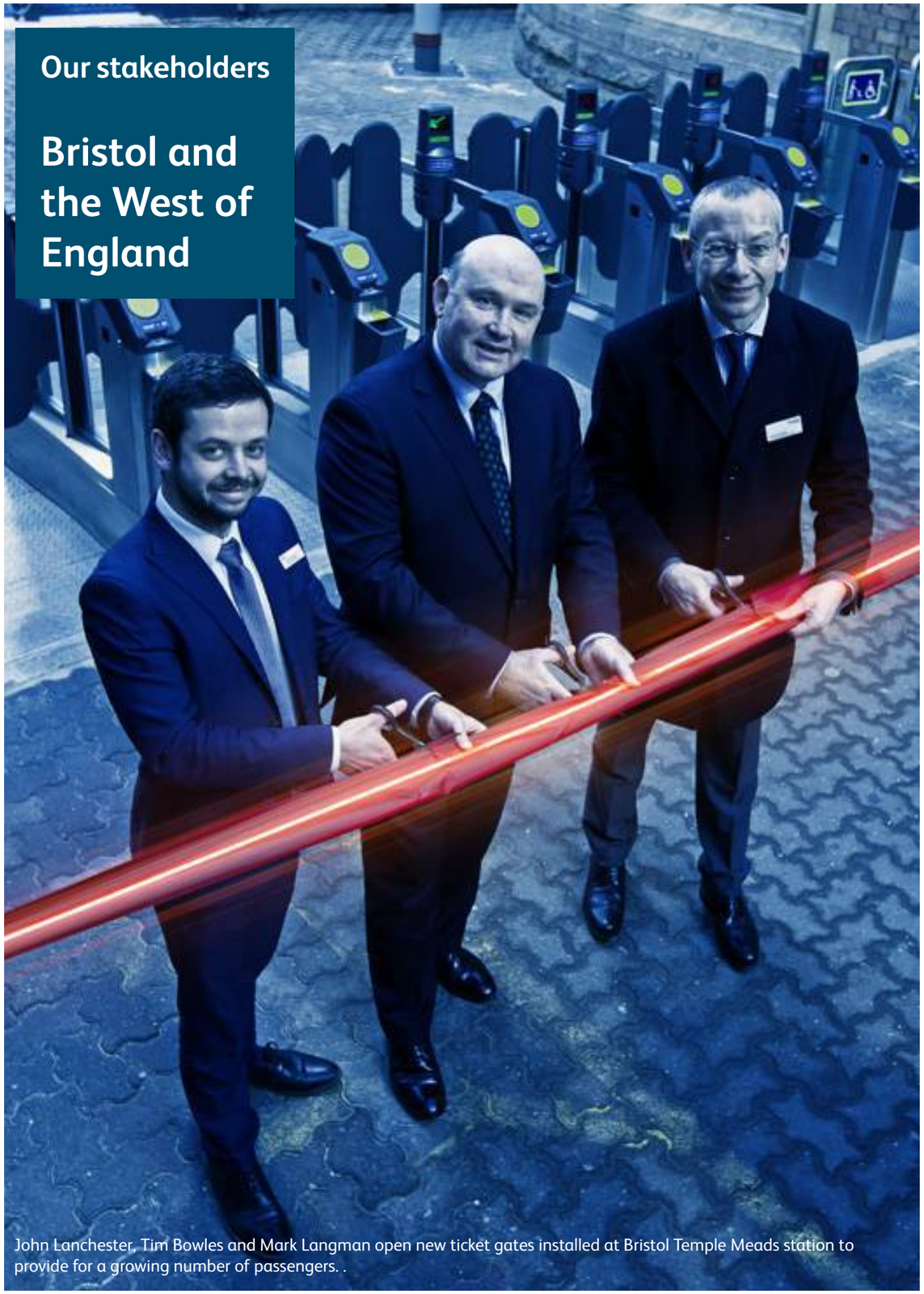
Site	No. of homes
1. Vauxhall Barracks	400
2. North East Didcot	2130
3. Ladygrove East	765
4. Milton Heights	450
5. West of Harwell	200
6. North of Harwell Campus	360
7. East of Harwell Campus	850
8. Valley Park and North West Valley Park	3330
9. East of Sutton Courtenay	200
10. Great Western Park	3550
11. Didcot A	400
12. Didcot Gateway	300
13. Didcot Orchard Centre Phase 2	300
Total	15,390

Employment Area	Midpoint job estimate
Enterprise Zone	3,300
Culham	1,400
Didcot A and West side	1,750
Didcot Town Centre and Northside	1,750
Milton Hill	1,300
Mixed use sites on edge of Didcot	1,900
Total (excluding construction)	15,100
Construction jobs, 15,000 homes	19,000

1 Didcot Garden Town Delivery Plan (2017).
2 South Oxfordshire and Vale of White Horse District Councils, Oxfordshire County Council, Oxfordshire Local Enterprise Partnership.

Our stakeholders

Bristol and the West of England



John Lanchester, Tim Bowles and Mark Langman open new ticket gates installed at Bristol Temple Meads station to provide for a growing number of passengers. .

The West of England is an economic leader with an economy worth over £33 billion a year. With a population of over 1.1 million people, one of the highest rates of employment in the country (79 %), and over 45,000 businesses, the West of England competes on a global scale. It's a region where highly–skilled people work, where ideas flourish, and where businesses grow. It's also a place that a diverse population of people call home.[1]

Total employment in Bristol is estimated to have risen by 6,600 jobs in 2019—equivalent to a year–on–year increase of 2.2 %. In the same year, the economy grew by 1.8 %, outperforming both the South West (1.4 %) and the UK (1.2 %). Over the period 2020 to 2023, employment growth is forecast to average 1 % per year, underpinned by gains in the professional, scientific and support service sectors.

The West of England Combined Authority (WECA) is a combined authority within the West of England area, consisting of the local authorities of Bristol, South Gloucestershire, and Bath and North East Somerset. The combined authority is led by the Mayor of the West of England.

WECA foresees a £10bn or greater improvement to the region's GVA over a thirty–year timeframe due to greater connectivity. This is anticipated to result from economic agglomeration, greater investor confidence, and attracting high value knowledge–intensive industries.[2]

Bristol is well integrated with other economic centres and has high levels of agglomeration with neighbouring areas and towns on the route to London.[3] Great Western Route Modernisation has supported this with new, faster, more frequent trains with more seats. Figure 5 shows typical journey times. Improvements include:

- new 'super–fast' trains to London—the full half–hourly service has been delayed by the Covid–19 pandemic
- faster journeys to Bath Spa, Swindon, Didcot Parkway and Reading
- more seats on regional trains to Cardiff, Gloucester, Portsmouth, Taunton, Westbury and Weymouth
- more seats on local trains via Filton Abbey Wood, and local trains to Severn Beach.

Commercial redevelopment has taken place near to Temple Meads station, and more is planned—including the Temple Quarter development and Bristol University's new campus.

Temple Quarter

Bristol Temple Quarter is a once in a generation opportunity to shape a new city quarter, with an ambition to create a place that is welcoming to all—to live, work, study, enjoy leisure time and build on Bristol's strengths as a world class city. Since 2012, over 3,000 people have come to work in the Enterprise Zone. The target is 22,000 jobs over the lifespan of the project.[4] All this will be just a short walk from Bristol Temple Meads station.

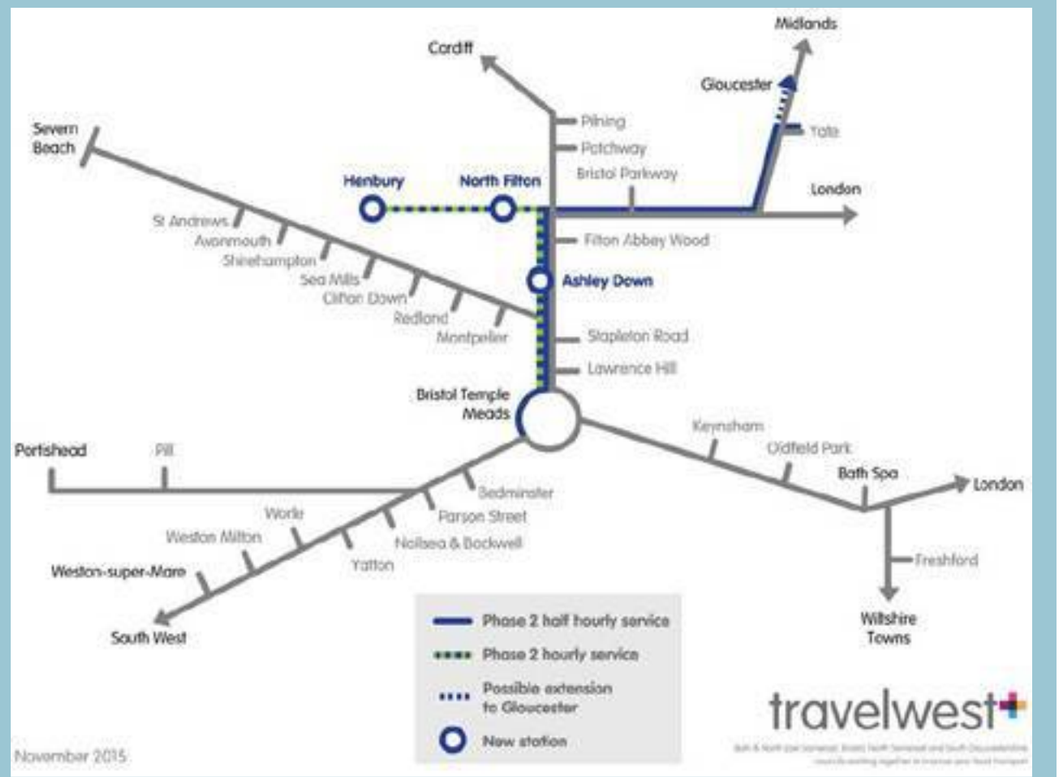
1 WECA website. WECA became the Transport Authority for the region when it was set up in 2017, taking responsibility for some operational public transport functions as well as strategic transport policy and planning.
2 Advice from David Carter, Director of Infrastructure, WECA (2020).
3 West of England Local Industrial Strategy, WECA. (2019).
4 Bristol Temple Quarter website.

University of Bristol

The University of Bristol is planning to build a new £300 million campus at Temple Meads. The development will transform a seven–acre site next to Bristol Temple Meads railway station into an open campus that will be part of the community, help to regenerate the area and benefit the whole city. Seven new buildings will transform the former Royal Mail sorting office and part of the adjoining island, providing a mix of flexible research and teaching facilities, accommodation for up to 1,500 students and a range of commercial outlets. The campus will initially cater for 3,500 students, the majority of whom will be postgraduates, and approximately 800 members of staff will be based there.[5]

Metrowest

Great Western Route Modernisation supports WECA's aspirations for Metrowest Phase 2. By increasing the number of tracks between Bristol Temple Meads to Filton Abbey Wood from two to four, GWRM removed a bottleneck, creating the capacity to operate a more frequent local service via Bristol Parkway to Yate and Gloucester, and to add a new station at Ashley Down. The opportunity to operate a new service to Henbury has also been created.



5 Bristol Temple Quarter website.

West of England Mayor, Tim Bowles, said:

"The modernisation and electrification of the Great Western Main Line is already benefiting residents right across the West of England, with more services to and from London. We now have a more frequent service from our key stations to London than some tube stops on the Metropolitan line. This is just the beginning and we're using the capacity that this has created to bring forward our plans for an enhanced suburban railway line for the region – MetroWest. I am grateful to Network Rail for keeping me informed and updated on the challenges to the programme as it developed. This £7.5bn investment in the West of England will enable our region to help recover from the Covid–19 crisis."

"This will help people switch from cars to public transport, reducing congestion and improving the air we breathe. The new timetable will support the new rail services we have planned across the region through MetroWest and it's great to see even more investment in both track and train."

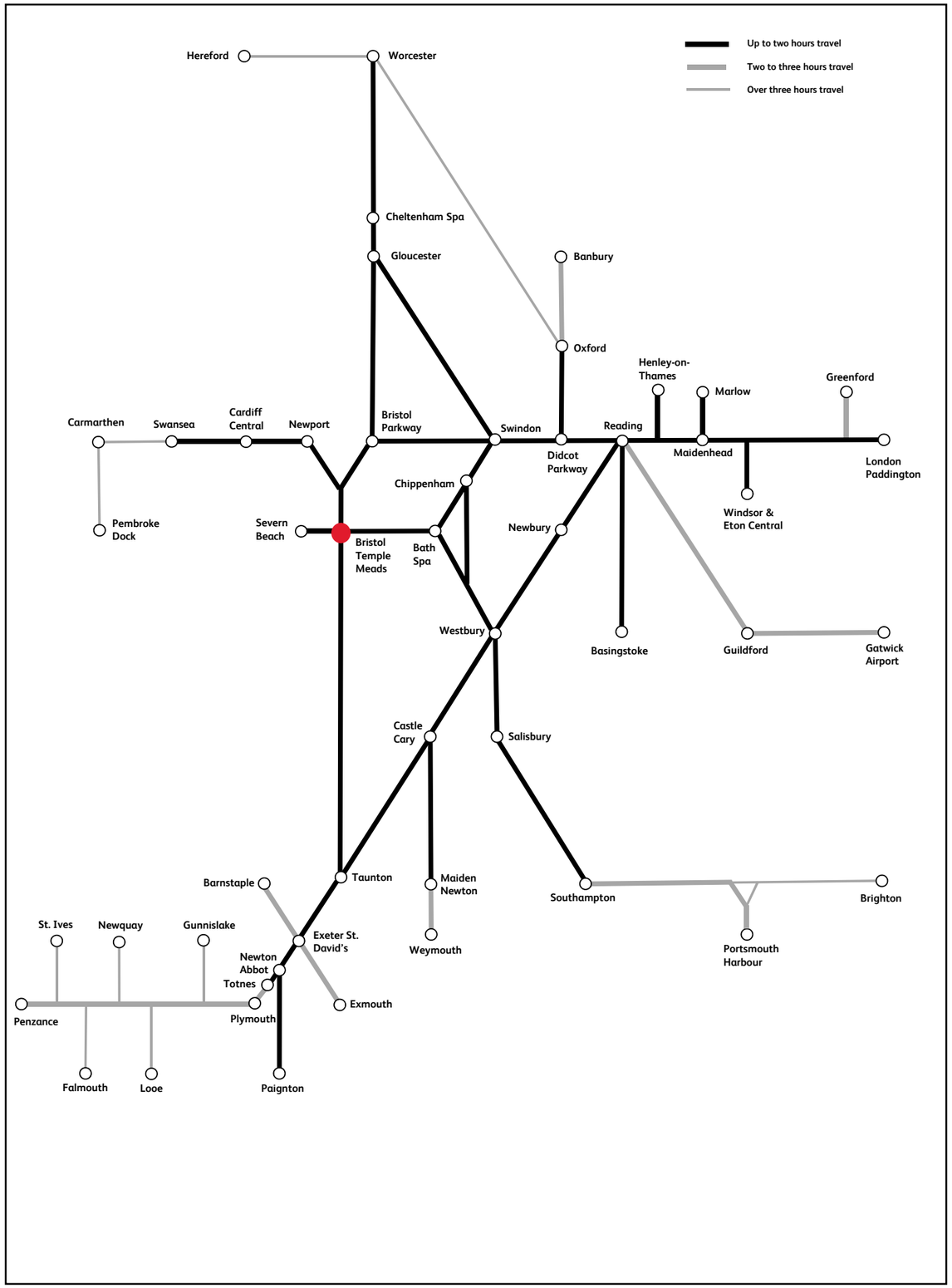
Patricia Greer, chief executive of the West of England Combined Authority, said:

"The West of England is the most productivity Core City region in the UK, which is down to a growing economy with private companies and public bodies working closely together. To continue this track record requires investment in infrastructure and skills, so that we can train people up for the jobs out there and then enable them to get to their workplaces. This significant investment has enabled a step change in railway capacity and shows that the West of England is the ideal location for businesses to start up in, or relocate to. We will continue with this investment through our MetroWest suburban rail project."

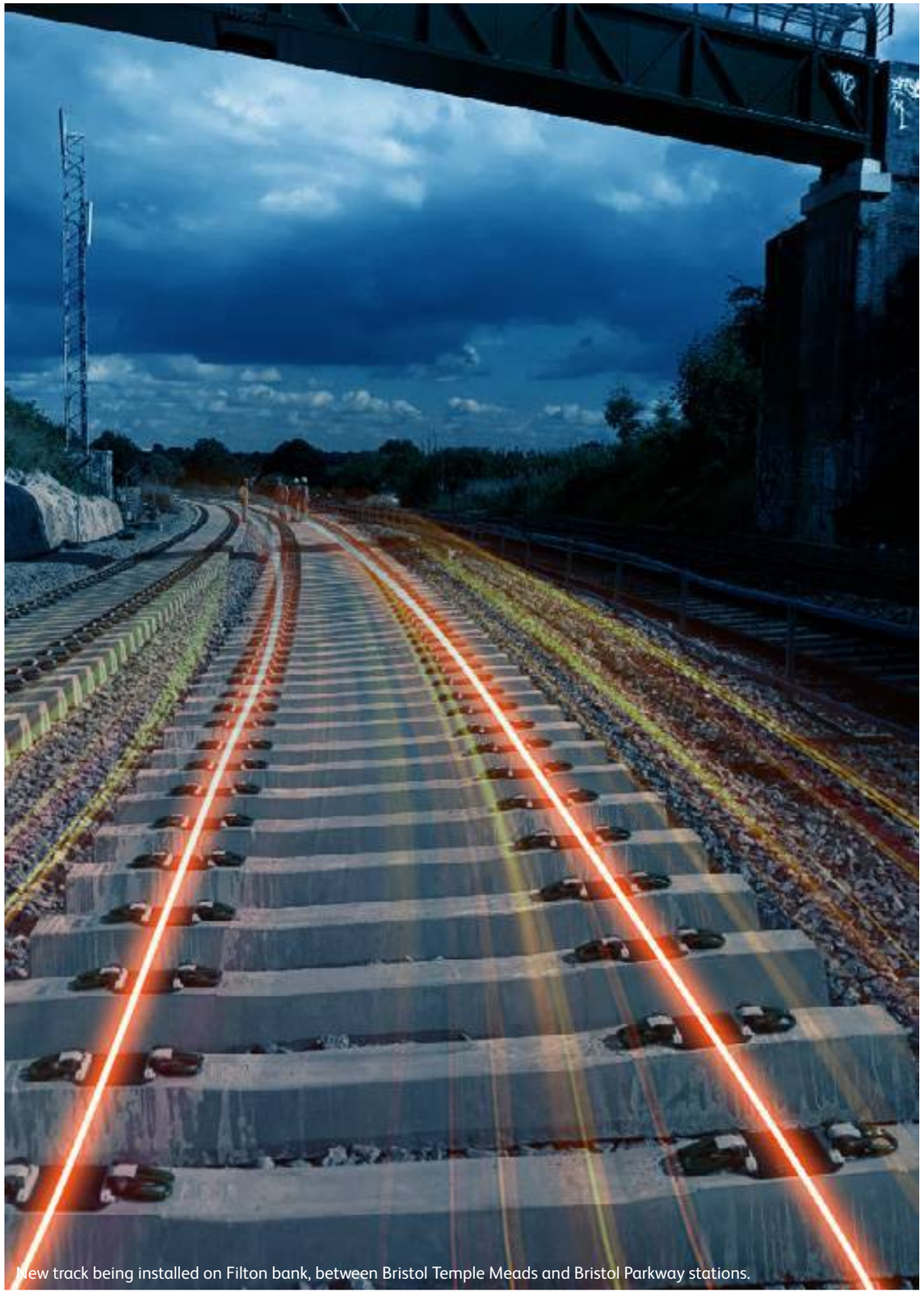
Alex Chalk MP, Cheltenham, said:

"This will support Cheltenham's future as the UK's premier cyber security hub. Sub–two hour services will boost investment and jobs for our young people."

Figure 5: Journey times between Bristol Temple Meads and other GWR destinations



Great Western Route Modernisation – Interim project completion report



New track being installed on Filton bank, between Bristol Temple Meads and Bristol Parkway stations.

Our stakeholders

Cardiff

The first electric train to arrive at Cardiff Central station in passenger service, Tuesday 7 January 2020.

Great Western Route Modernisation – Interim project completion report

Cardiff is the capital and focal point of Wales. Historically the city flourished, becoming the world's biggest coal exporting port. Following decline in the 1970s and 1980s, Cardiff moved towards a service–orientated economy. Now finance and professional services, creative industries and the public sector have become dominant employers in the city. It is one of the fastest–growing cities in the UK and has the strongest projected population growth in Wales over the next five years.[1]

The city's transport links are undergoing significant improvement. At Cardiff Central station, Network Rail has recently added a new platform and a modern entrance to the south side with further major redevelopment plans in the pipeline to create a modern transportation hub. The Great Western electrification scheme has provided an eco–friendlier and faster rail service and connect Cardiff to London in under two hours. Figure 6 shows typical journey times. The developments at Cardiff Central station align well with the on–going regeneration of key enterprise.[2]

Central Square

Central Square is a five–hectare city–centre development opposite Cardiff Central station. Comprising six new buildings which provide 85,500m² of new office space, it enables 10,000 people to work within 250m of Cardiff Central station. Developed by Rightacres Property, with funding from Legal and General, Central Square's flagship building is a new 14,000m² headquarters for BBC Cymru Wales. For businesses locating to Central Square, public transport has replaced car useage as the primary means of commuting.

Principality stadium

The 74,500–seat Principality stadium, the national stadium of Wales, is close to Cardiff Central station. GrElectrification allows GWR to bring its Class 387 trains to Cardiff to help carry large numbers of people to and from the stadium, in addition to IETs and cascaded HSTs and Class 16x trains providing more seats.

1 The Changing Face of Cardiff, Evolving Cities, GVA (2017). Much of the text in this section is taken from this source.
2 Development of Cardiff Central station will respond to demand generated by GWRM and Transport for Wales' improvements to the Valley lines. Resignalling in the Cardiff area was separate to GWRM.

Central Quay

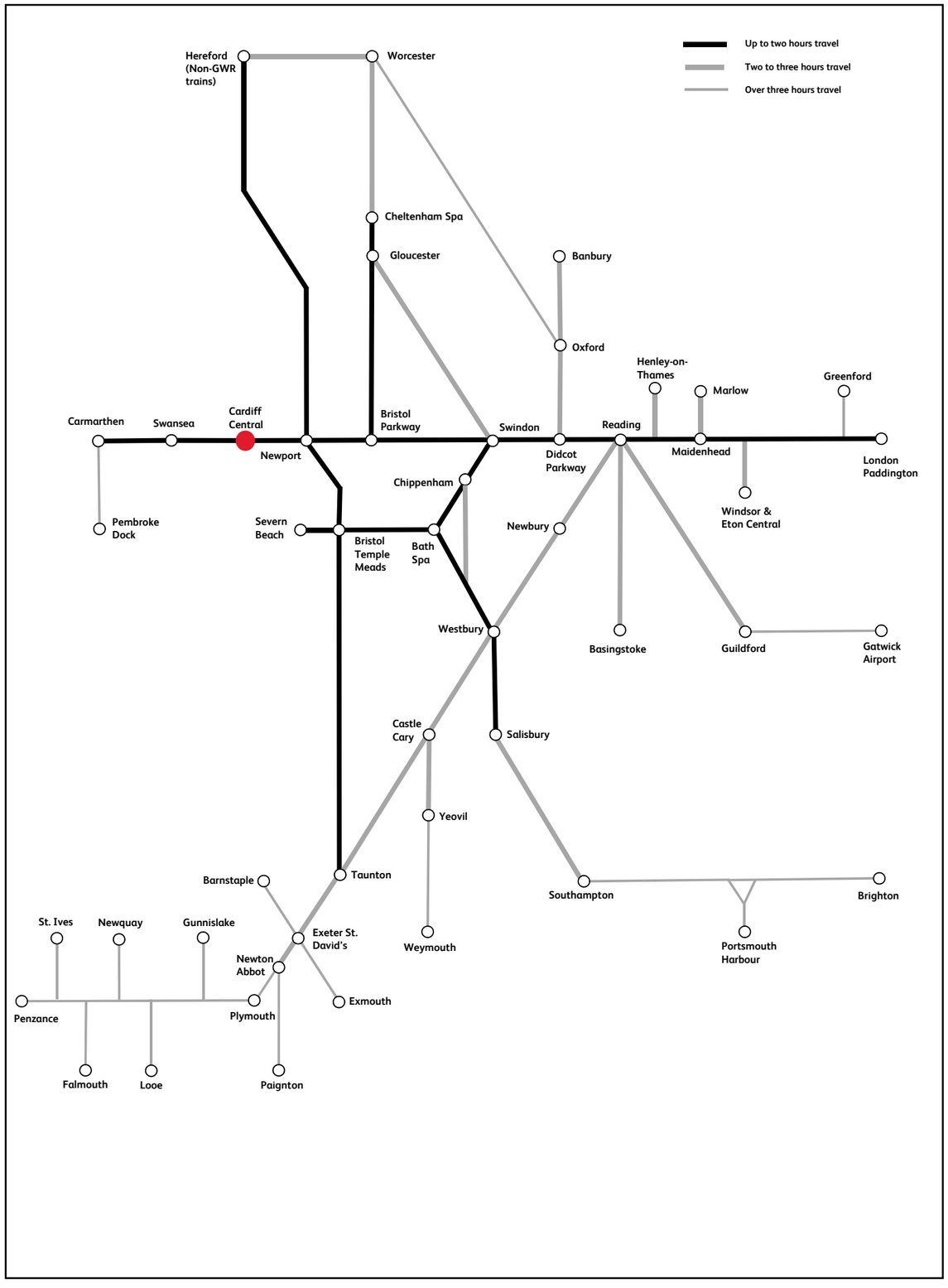
Central Quay is an ambitious 2.5m sq.ft. mixed–use regeneration at the River Taff waterfront and will be the largest commercial property regeneration scheme in Wales in conjunction with Central Square.

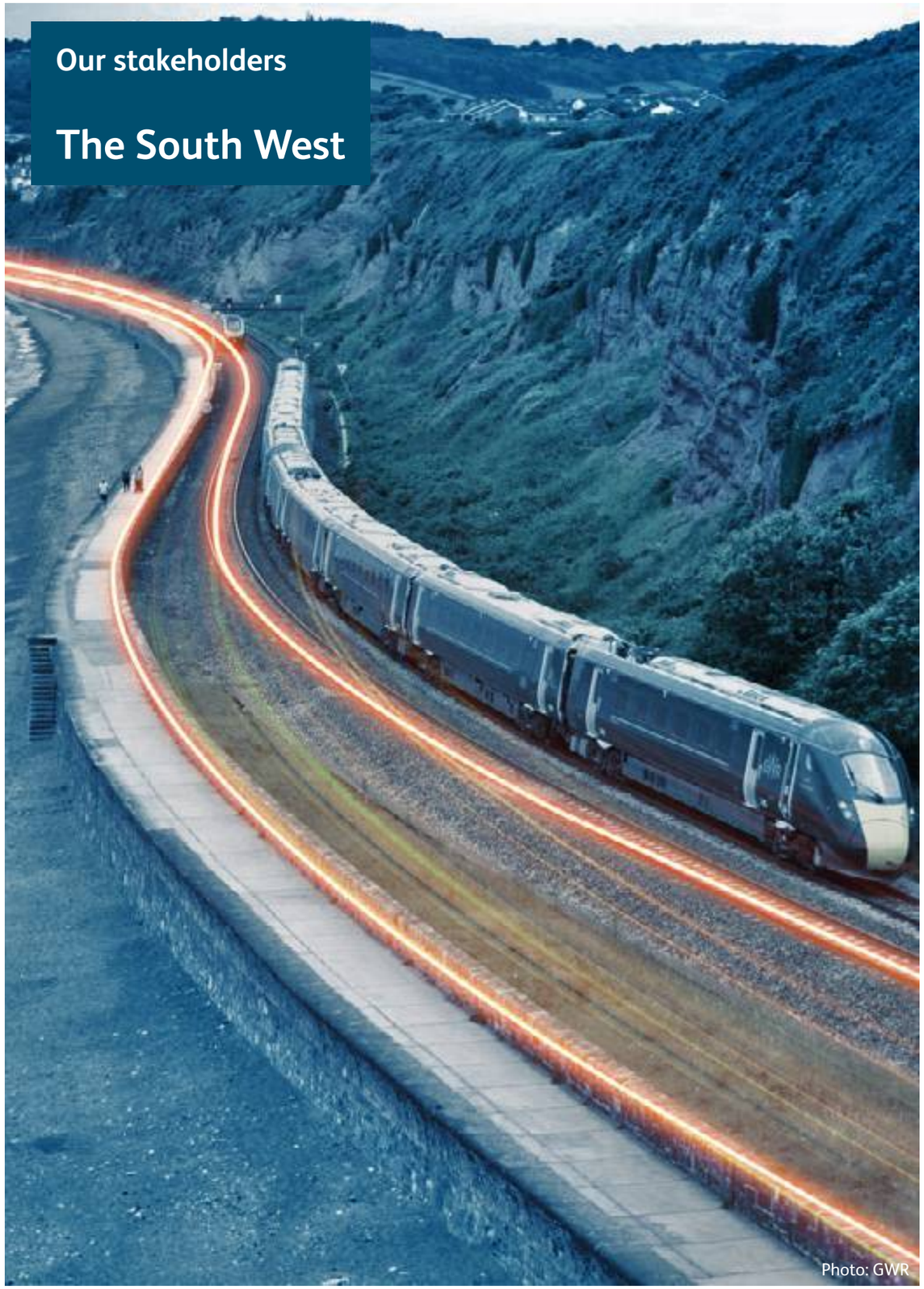
The regeneration site is located south of the Cardiff Central station and is just on the edge of the traditional city centre. It will complement plans to rejuvenate the Valley lines system and the station. Having a station close to the development will help unlock the growth potential to the south of the city centre and will provide a key improvement in the link between the city centre and the proposed redevelopment around Dumballs Road.

Professor Stuart Cole, Emeritus Professor of Transport (Economics and Policy), University of South Wales, said:

"This is great news for the economy of South Wales and for cross border rail customers. These new trains will be a great benefit for visitors and commuters alike and there is more to come as work is completed on electrification to Newport and Cardiff."

Figure 6: Journey times between Cardiff Central and other GWR destinations





Our stakeholders

The South West

Photo: GWR

Devon has the 19th largest economy in England out of the 46 ceremonial counties, whilst Cornwall is 43rd out of 46. Cornwall is one of the poorest areas in the United Kingdom with a GVA of 70.9 % of the national average in 2015.[1] Both are disadvantaged economically compared to other parts of southern England, owing to the decline of a number of core industries, notably fishing, mining and farming, and their geographical remoteness.

Since the rise of seaside resorts with the arrival of the railways in the 19th century, Devon's economy has been heavily reliant upon tourism. The county's economy has followed the declining trend of British seaside resorts since the mid 20th century, with some recent revival. The Great Western Main Line and its branches remain critical to the success of tourism in Devon and Cornwall.

The period of disruption to rail services seen in early 2014 at both Dawlish and across the Somerset Levels, cost the South West economy an estimated £1.2bn—an indication of the value of the Great Western Main Line.

The Peninsula Rail Task Force (PRTF)[2] has emphasised the value of connectivity, capacity, resilience, reliability, and faster journey times.

Connectivity

Following modernisation, an enhanced service of two trains per hour operates between Plymouth and Penzance—the best ever service along this stretch of line. This is complemented by a 2 to 3 trains per hour (tph) fast service between Plymouth and Exeter, continuing to Taunton where services towards Bristol and London diverge.

A metro–style service with up to 3 tph operates along the South Devon coast between Paignton, Newton Abbot, Teignmouth, Dawlish, Exeter and Exmouth, supplemented by a fast service of 2–3 tph calling at selected stations. This supports local agglomeration centred upon Exeter, where the economy grew by 1.4 % in 2019, at the same rate as the South West (1.4 %) and broadly in line with the UK (1.2 %). Figure 7 illustrates typical numbers of trains per hour at stations along the route.

Over the period 2020 to 2023, Exeter's GVA is expected to rise by 2 % per year in the forecast period, outperforming both the regional average (1.4 %) and the UK (1.6 %). The professional, scientific and support service sectors are expected to experience the fastest increase over this period, including higher–earning people who are likely to be attracted by a fast, frequent, modern train service.[3]

Capacity

Each 9–car IET contains 46 % more seats than the HST that it replaced, whilst cascaded diesel trains provide more seats on local services. More frequent trains between Plymouth and Penzance further increase capacity on this route. Cascaded trains provide more seats on local services, including branch lines in Devon and Cornwall.[4]

Resilience

Network Rail continues to invest in resilience of the railway between Dawlish and Teignmouth, following the 2014 breach which cut off rail services to the Peninsula for eight weeks. In June 2019 work began on a new, larger £80m sea wall that will protect the railway and the town for the next 100 years. Further plans are being developed for the section between Dawlish and Teignmouth.

Network Rail has also invested in flood alleviation measures at Cowley Bridge, just north of Exeter, where services were prone to disruption. This is one of a number of resilience projects across Wales & Western region.

Reliability

New IETs improve reliability on longer–distance services. Cascaded diesel trains will replace life–expired Pacer trains on local services, also improving reliability. With more seats for our passengers, crowding is lessened, reducing the delays that can occur due to extended dwell times at busy stations.

1 Office for National Statistics (2016).
2 The PRTF is a partnership of local authorities and Local Enterprise Partnerships (LEPs). These are Cornwall Council, Devon County Council, Plymouth City Council, Somerset County Council and Torbay Council, as well as the Cornwall and Isles of Scilly LEP and Heart of the South West LEP.
3 EY UK Regional Economic Forecast (2020).
4 Cascaded trains provide more seats on the Barnstaple, Exmouth, Looe, Newquay and Paignton branches. More seats were provided on the St. Ives and Falmouth branches prior to GWRM, and the latter benefited from a doubling in frequency. A new park–and–ride facility has been built at St. Erth serving visitors to St. Ives.

Faster journey times

New trains and a revised timetable place Exeter within approximately 2¼ hours from London and Plymouth within 3¼ hours. Journey times have been reduced, with fastest journeys taking 2 hours 10 minutes from Exeter to London (6 mins saving), 3 hours 7 minutes from Plymouth (11 mins saving) and 4 hours 59 minutes from Penzance (11 mins saving). Figure 8 illustrates journey times between Exeter St. David's and other places on the GWR network, and Figure 9 illustrates journey times between Plymouth and other places on the GWR network.

Figure 7: Typical frequencies in weekday trains per hour

Richard Burningham, Manager of the Devon & Cornwall Rail Partnership [1], said:

"The ease of getting to Devon and Cornwall by train led to the two counties becoming the massively popular tourist destinations they are today and, as this very welcome research shows, the railway continues to play a huge role in bringing visitors to the region's seaside towns and villages, to the year–round benefit of the local economy. The new trains now being introduced by GWR on the London route plus significant increases in local services in Devon and Cornwall coming in 2019 will see the railways' contribution to the region grow further still and will also encourage even more people, local residents and visitors, to leave the car at home and take the train."

Simon Fishwick from Visit Devon, said:

"Rail tourism is critical to the success of the tourism industry within the county. Devon is relatively lucky with a mainline bisecting the county and several branch lines enabling tourists to access and visit the North, East, South and West of the County. The railway also provides a greener solution to travel in the region and takes pressure off the roads. The routes are also some of the most iconic rail journeys to be had in the UK passing through beautiful countryside with far ranging views. A rare treat and well worth the effort."

Geoff Brown, Portfolio Holder for Transport at Cornwall County Council., said:

"Cornwall resignalling made a huge difference for the county … I am delighted with the new timetable introduced … on time and on budget."

The scenic Looe branch line

1 A non–profit partnership between local authorities, the rail industry and the University of Plymouth.

Figure 8: Journey times between Exeter and other GWR destinations

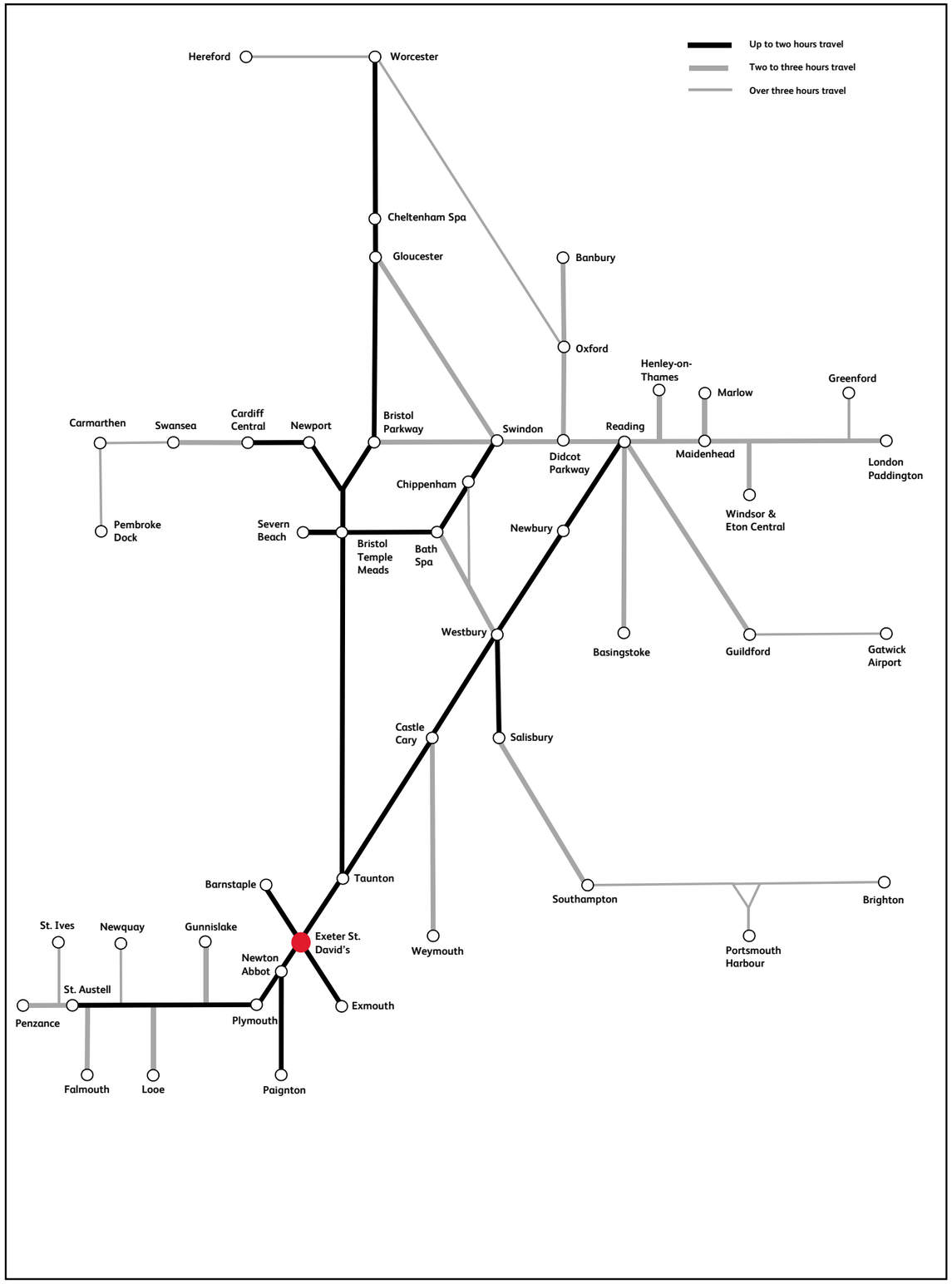
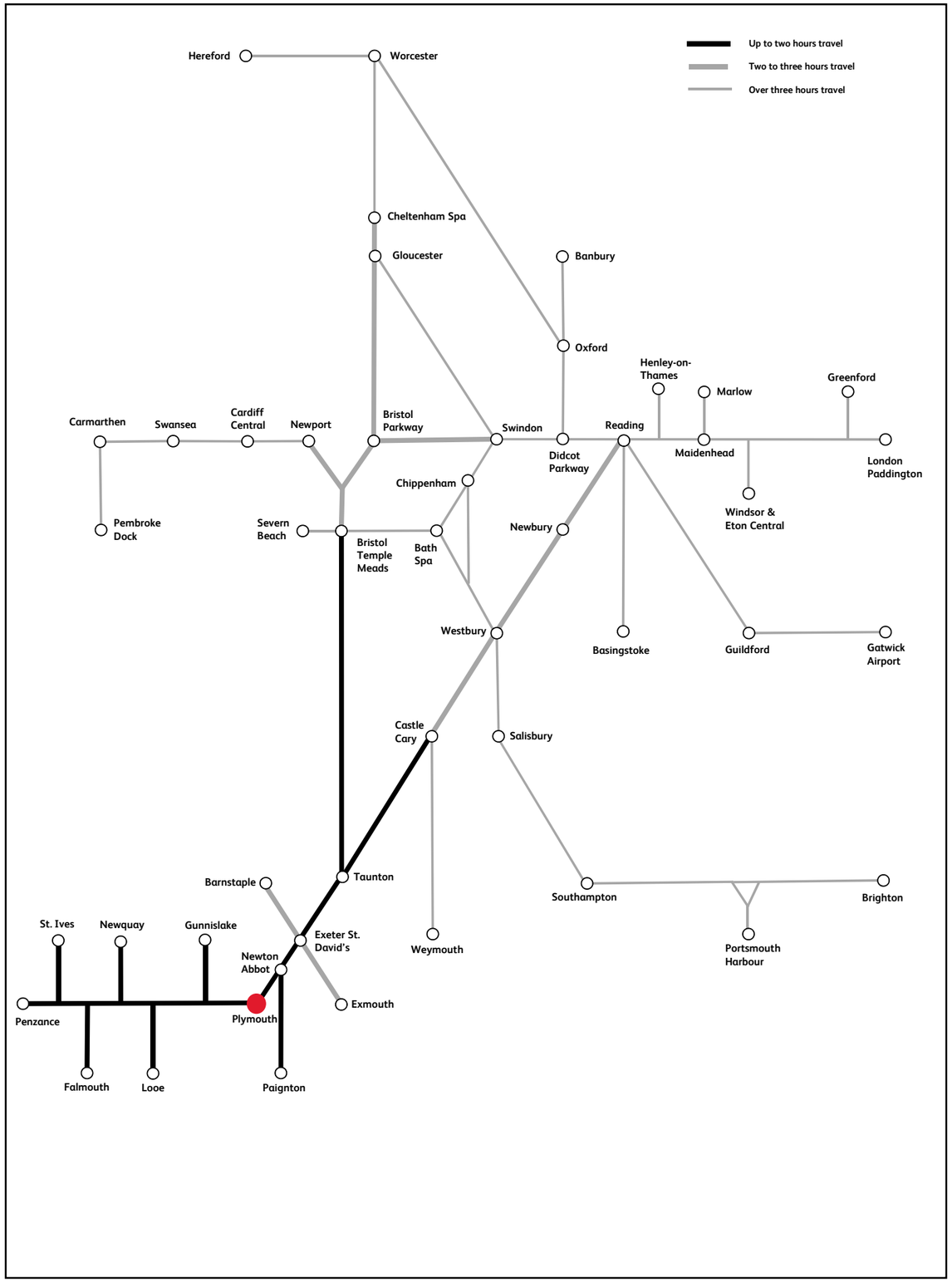


Figure 9: Journey times between Plymouth and other GWR destinations



5. Our passengers

Passengers join a new Class 387 train at Maidenhead station.

5.1 Helping make journeys easier, modern and reliable[1]

Prior to modernisation, the Great Western Main Line was the last long–distance railway route in the UK wholly operated by diesel traction. Indeed, Wales was the only European nation without an electrified railway line.[2]

Great Western Route Modernisation replaced 1970s trains which retained antiquated slam–doors and deposited toilet waste onto the track.

The programme also provided new electric trains to operate stopping services between Paddington, Reading, Newbury, and Didcot Parkway.

5.2 Ease of travel

The new trains are easier to board and alight, including for people with reduced mobility. They offer:

- improved stepping between platforms and trains
- power–operated doors
- compliant manoeuvring space for wheelchairs
- accessible toilets.

Platforms have been extended at stations across the Thames valley, North Cotswold line, the South West and the West of England to accommodate new longer trains.

New passenger lifts have been installed at several stations, providing step–free access between street and platform. These have been installed by the GWRM, Crossrail and Access for All programmes.[3]

New passenger lifts at Goring & Streatley station

1 The Department lists three elements under this heading:
- Support the delivery of new digital technology to improve journeys
- Put the citizen and business user at the heart of a reliable, accessible and cost–efficient transport network
- And invest in road and rail maintenance and renewals.

Department for Transport single departmental plan (2019).

2 Excluding Andorra, Cyprus and Malta (which have no railways) and Vatican City. Strictly speaking, the cable–worked Great Orme Tramway is electrically powered.

3 The Department's Access for All programme was launched in 2006 to address the issues faced by disabled passengers and passengers facing mobility restraints (such as heavy luggage or pushchairs) when using railway stations in Great Britain. Stations served by GWR that have benefited include: Bridgend, Burnham, Chippenham, Exeter Central, Fareham, Fratton, Gloucester, Havant, Keynsham, Neath, Slough, St. Austell, Severn Tunnel Junction, Swindon, Taunton, Totnes, Twyford, Westbury, and Wokingham.

5.3 Modernity

New trains now operate all long–distance services between London Paddington and Bristol, Cardiff, Swansea, Worcester, Hereford, and the South West peninsular including Exeter, Paignton, Plymouth and Penzance.[4]

The new trains provide more and better wifi, so passengers can make better use of their journey time, whether working or relaxing.

Information displays on the outside of each new carriage tell passengers where the train is destined for, and the next stop, plus the carriage letter to help passengers with seat reservations.

The new train fleets—new Class 387 trains operating Thames Valley commuter services and the longer–distance IETs—have reduced GWR's average fleet age by more than half.[5]

Cascaded DMUs give our passengers in Devon and Cornwall more seats and greater comfort. Out–dated Pacer trains are being replaced.

As a result of the Crossrail programme, new Class 345 trains operate Elizabeth line services to Reading, using new electrification installed by GWRM between Maidenhead and Reading.

1980s Pacer trains are being replaced …

Figure 10 shows that new and cascaded trains operate across the majority of GWR's routes.

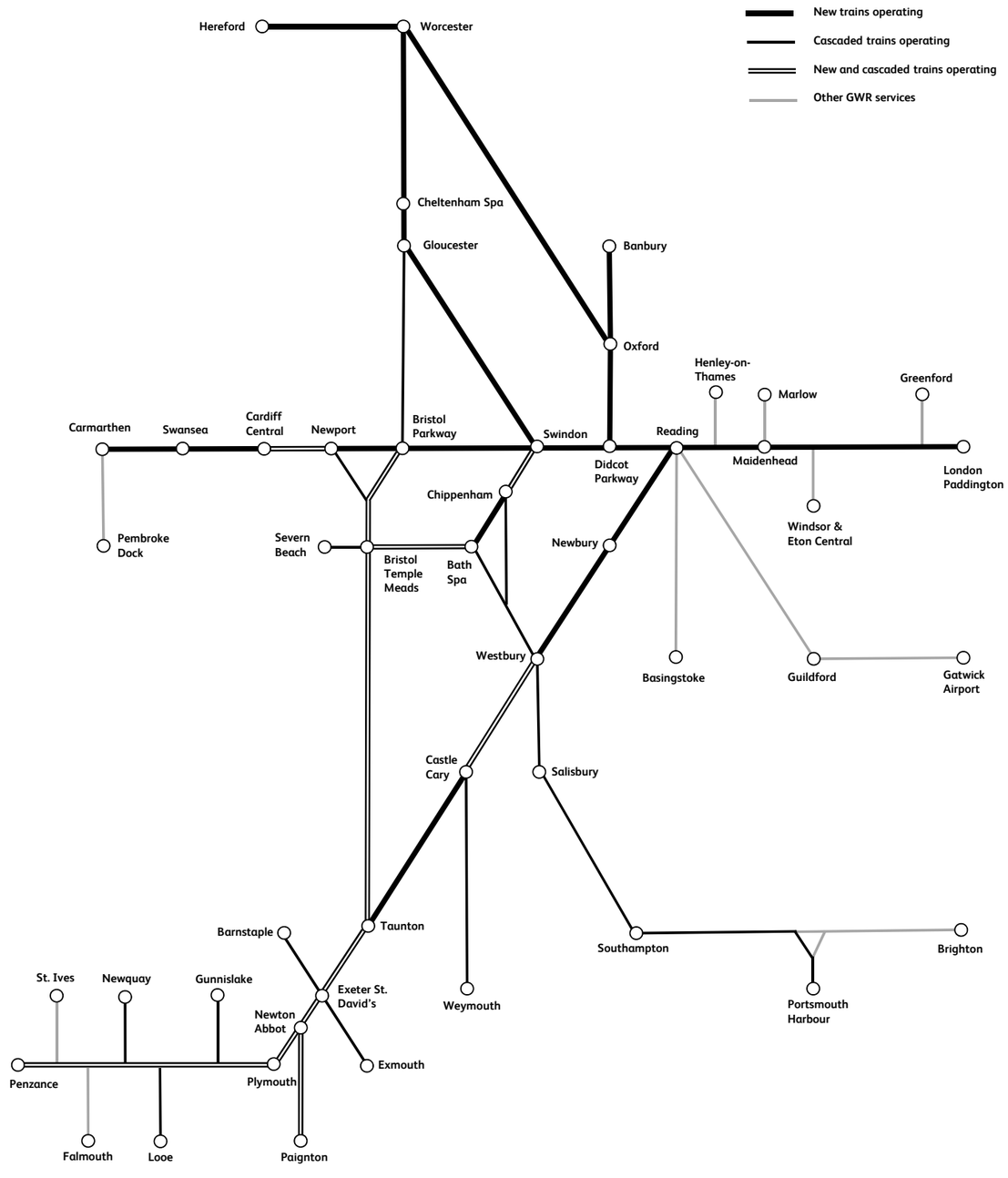
5.4 Reliability

New electric trains are more reliable than the diesel trains that they replaced, leading to fewer cancellations and delays. The autumn 2019 National Rail Passenger Survey (NRPS) demonstrated a 13 % improvement in passenger satisfaction with punctuality / reliability (i.e. the train arriving / departing on time). At 80 % this was higher than the

4 Services between London, Bristol, Cardiff, Swansea, Oxford, Worcester and Hereford are operated by Class 800 IETs provided by GWRM. Services between London and the West of England are operated by Class 802 IETs procured by GWR. The GWR sleeper service is operated by older Mark 3 carriages.

5 Martin Garrett, CEO Agility Trains via GWR press release (2017).

Figure 10: Where new and cascaded trains run following Great Western Route Modernisation[1]



1 This map shows where GWR operates new trains and cascaded trains as a result of GWRM. The St. Ives branch has more seats in winter as a result of the cascade. The Falmouth branch received a doubling of frequency prior to GWRM. Cascaded trains operate a small number of trains elsewhere (e.g. between Swindon and Cheltenham). GWR has a separate plan to introduce Class 769 trains between Reading and Gatwick.

national total of 74%.[6]

5.5 What our passengers think

Transport Focus surveys more than 50,000 passengers a year to produce the National Rail Passenger Survey (NRPS), giving a network–wide picture of passengers' satisfaction with rail travel. Passengers' opinions of train services are collected twice a year from a representative sample of journeys.

The Autumn 2019 NRPS demonstrated significant improvements to passenger satisfaction across the board on GWR services following introduction of new electric trains and the associated rolling stock cascade. Figure 11 summarises the improvements across two years.

GWR's 8% in overall journey satisfaction is especially noteworthy, along with a 10% increase in overall satisfaction with trains and an 8% improvement related to crowding. The quality of the new trains, and the additional seats that they provide, clearly are appreciated. Figure 12 shows the improvements in passenger satisfaction associated with the train service, and Figure 13 shows data for the trains themselves.

The 2019 NRPS preceded the December 2019 timetable, which introduced further improvements including GWR's 'super–fast' services.

6 Satisfaction with punctuality/reliability by individual routes within TOCs varied between 52 per cent and 95 per cent.

Figure 11: National Rail Passenger Survey (NRPS) – autumn 2017 vs. autumn 2019

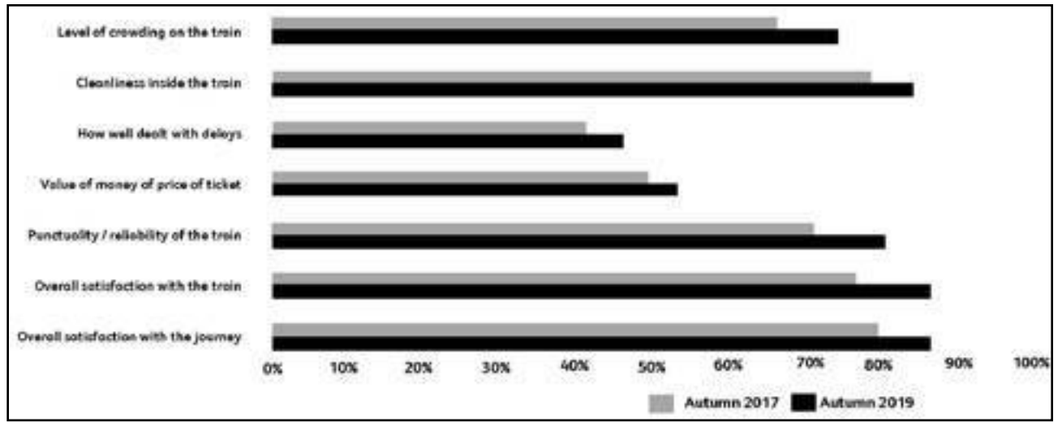


Figure 12: National Rail Passenger Survey (NRPS) – train service autumn 2018 vs. autumn 2019

Factor	Change (%)
Overall satisfaction with the train	+10
Frequency of the trains on that route	+8
Punctuality / reliability (i.e. the train arriving / departing on time)	+13
Length of time the journey was scheduled to take (speed)	+7
Connections with other train services	+11

Figure 13: National Rail Passenger Survey (NRPS) – train facilities autumn 2018 vs. autumn 2019 [7]

Factor	Change (%)
Overall satisfaction with the train	+10
Upkeep and repair of the train	+5
Space for luggage	+9
Toilet facilities	+10
Comfort of the seats	+4
Step or gap between the train and the platform	+1
Cleanliness of the inside	+5
Cleanliness of the outside	+3
Level of crowding	+8
Reliability of the internet connection	+8
Availability of power sockets	+11

7 Results for Thames valley services operated by Class 387 trains include *comfort of seats* (+7%) and *space for luggage* (+12%), which are higher than the overall train operators scores of +4% and +9% for these categories, suggesting that passengers travelling on IETs perceive lesser improvements in these categories.

Our alliance partner

GWR

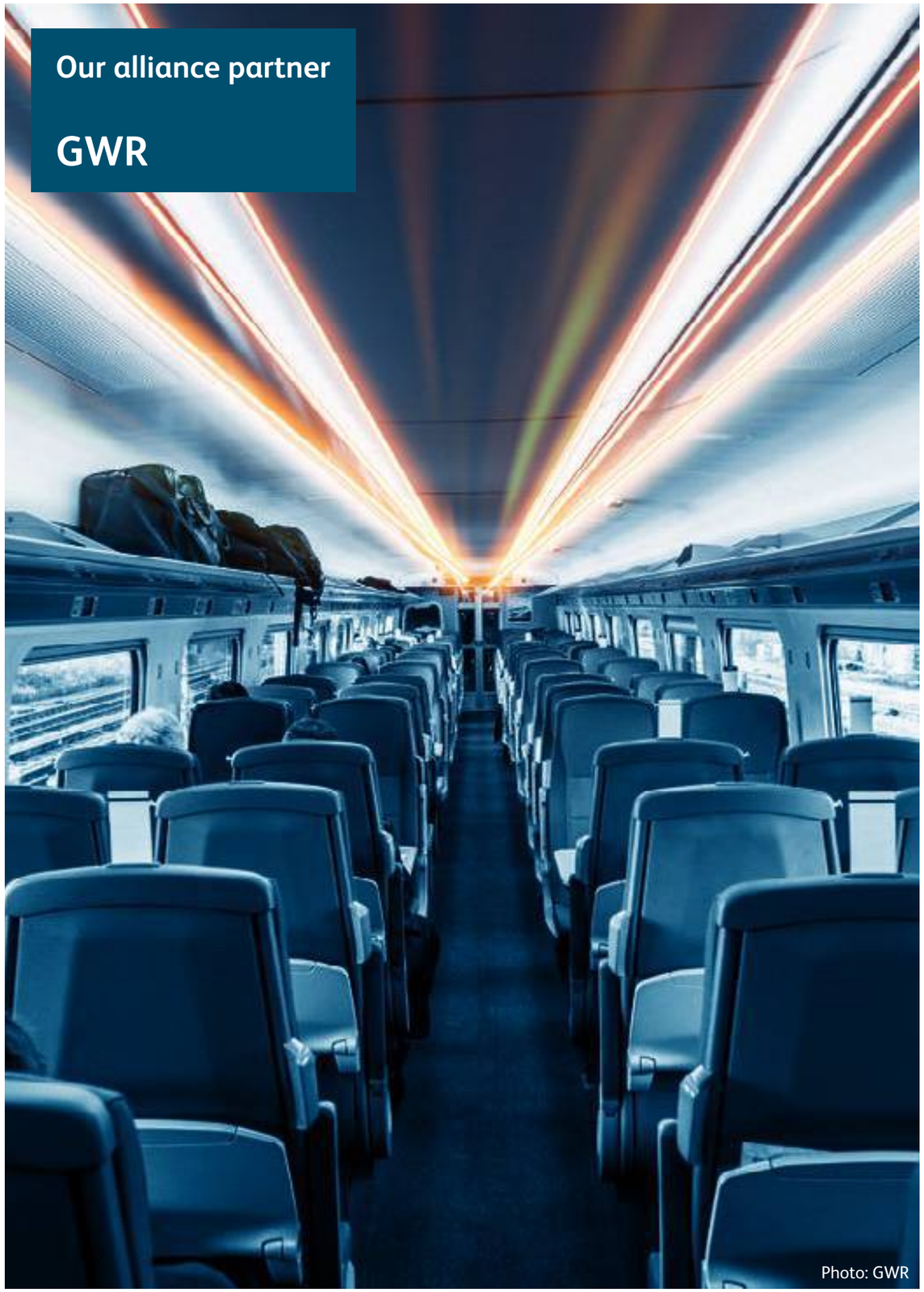


Photo: GWR

Commitment

Mark Hopwood, GWR's Managing Director from December 2008 to January 2020, said[1]:

"Our customers rely on us for predictable, punctual services. They also expect us to invest in improvements and to work with the rail industry, with national Government and with local partners to deliver new and improved services. This December sees the start of the biggest timetable change on the Great Western network since 1976."

"Three–quarters of our services change. There will be more seats, more services and faster journeys. Delivering these benefits to our customers is something my team and I have been working towards since we were awarded the Great Western franchise in 2015. To achieve it we have delivered two brand new train fleets; bringing electric and bi–mode trains onto the network for the very first time. We have cascaded newer, better trains to South Wales, the Cotswolds, the West of England and the South West, and next year we will add a further new fleet with tri–mode trains on our Basingstoke and North Downs routes."

"You would have seen the work that has been done over the last 10 years preparing the network for our new trains and the ability to run more trains and faster trains and is testament to the efforts we've put in with Network Rail, the Department for Transport and industry partners. We have recruited hundreds of extra drivers and onboard crew; trained and retrained existing and new staff on the new and upgraded trains; and have developed and improved station information and dispatch."

"We have also made it easier to buy and use tickets, with mobile ticketing and smartcards and improving our website GWR.com and the GWR app. The new timetable will mean improved journeys to work and to school and college, it will mean better journeys for business and greater connectivity for communities, and it will make it easier to travel for leisure to visit some of the great places on our network."

"There will always be more to do, but the December 2019 timetable change is another major step forward in delivering for our customers, and for the communities that we are proud to serve."

Partnership

In 2016 Network Rail and GWR signed a formal alliance agreement—the Western Alliance partnership—with the aim of delivering a better travelling experience for passengers by working more closely together.

The agreement covers five key areas of working and commits both companies to a more aligned approach to further improve performance and increase efficiencies.

At the 2019 Rail Business Awards—the industry's most recognised awards scheme—GWR and Network Rail were named as the *Rail Team of the Year* for their Western Alliance partnership.

Growth

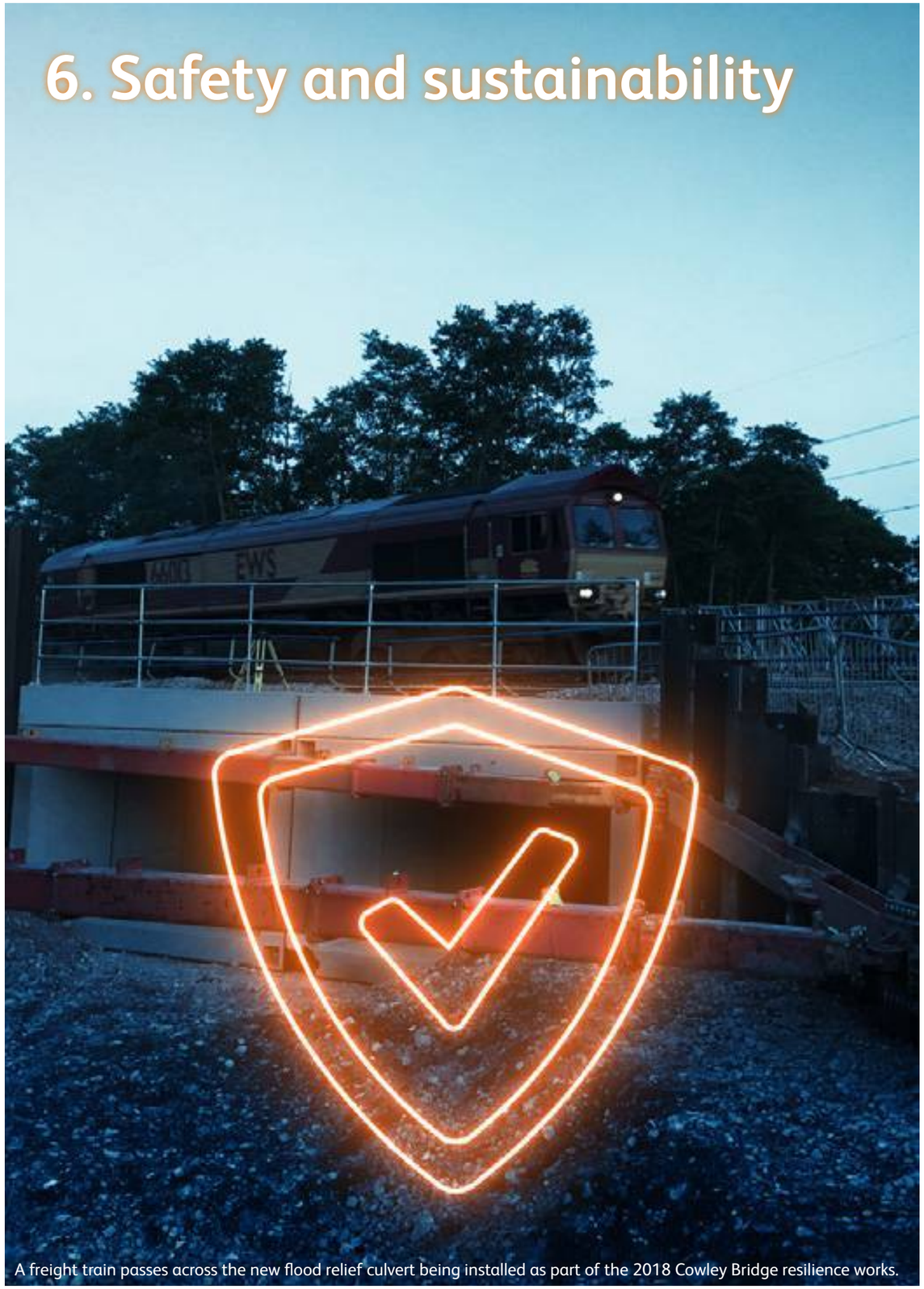
GWR reports significant growth in ridership on many of the improved services over the twelve months to February 2020 (i.e. including the impact of new and cascaded trains, and the May 2019 and December 2019 timetables), with some routes showing growth levels of 20 % or more.

Highlights include strong growth between Berkshire and South Wiltshire / Somerset, on the North Cotswold line, between Gloucestershire / Oxfordshire and North Wiltshire, and between Berkshire and Devon / Cornwall. There was significant growth within Devon and Cornwall, between London and South Wales, and elsewhere.

Whilst these represent a 'snapshot' pre–Covid–19, the implication of greater passenger satisfaction is clear.

1 Times Are Changing, GWR (2019).

6. Safety and sustainability



A freight train passes across the new flood relief culvert being installed as part of the 2018 Cowley Bridge resilience works.

6.1 Making sure that transport is safe, secure and sustainable[1]

Safety, security and sustainability are important to passengers, staff, neighbours and stakeholders alike.

In the case of sustainability, we are all stakeholders, as we are all impacted by the climate emergency. And sustainability is a matter of law, because the UK government has signed legislation to commit the UK to a legally binding target of net zero emissions by 2050.

6.2 Safety

Safety is a state of being protected from harm. Railways provide the safest mode of surface transport, with a lower likelihood of death or injury per kilometre travelled than car, bus or coach travel. But safety also applies to people who work on the railway, the railway's neighbours, people who need to use level crossings, trespassers, and people who may wish to take their own lives.

Great Western Route Modernisation has helped make our railway even safer:

- GWRM has closed a number of level crossings and footpath crossings, providing alternative bridges or diverting routes. At Uffton Nervet, a new bridge replaced the level crossing where a train driver, six passengers and a road user were killed on 6 November 2004
- new IETs have also eliminated drop–light windows, which passengers on HSTs needed to lower to open the doors. Whilst centralised locking prevented the doors of a moving HST from being opened, passengers could place themselves at risk by leaning from an open window[2]
- measures to reduce suicides have been implemented at stations, including fences segregating platforms where non–stop trains pass through at speed from those where stopping trains call
- new metal palisade fencing along the railway boundary helps exclude trespassers.

GWRM made a number of safety improvements for maintenance staff:

- installation of new lineside access points that reduce the distance maintenance staff need to walk along the operational railway to reach assets[3]
- new signage at access points to enable staff to accurately identify assets[4]
- new lineside walkways where it is necessary to walk to assets remote from access points.

Protection from harm is more than avoiding risk of death. It includes protecting people from anything that might cause injury, illness or psychological shock:

- New IETs have finally eliminated the discharge of toilet waste onto the track, creating a safer and less unpleasant working environment for track–based and depot–based staff.

6.3 Security

Security is freedom from, or resilience against, potential harm (or other unwanted coercive change) caused by others.

Transport has often been the target of terrorist attacks. In the past the infrastructure was threatened while more recently transport hubs have been targeted because of the crowds of people who make daily use of them:[5]

- major stations are now surrounded by security bollards that exclude vehicle–borne terrorist attacks
- Network Rail and train operator staff are also trained to help identify potential threats.

Security also refers to harm caused by trespass and vandalism, including theft of signal cables and other materials, deliberate damage to operational assets, and even attempts to derail trains:

- new metal palisade fencing along the railway boundary helps exclude trespassers
- extensive CCTV at stations and depots helps deter trespass and detect criminal acts.

Security is distinct from resilience, which refers to a capability to keep adapting to existing and emerging threats such as flooding by creating robustness and redundancy.

1 The Department lists three elements under this heading: maintain the safety and security of the transport system; ensure sustainability underpins future transport investment including promoting new technologies to reduce emissions; and increase the number of cycling and walking journeys. Department for Transport single departmental plan (2019).
2 Bethan Roper, passenger on a GWR HST suffered fatal injuries on 1 December 2018 when leaning from a an open drop–light window.
3 Network Rail's Crossrail programme also installed access points between Paddington and Reading.
4 Misidentification of tracks has been a historic cause of risk to maintenance staff in situations where some tracks are taken under possession and others remain open to trains. Similar considerations apply to OLE.
5 National Counter Terrorism Security Office, 2012.

6.4 Sustainability

Traditionally, sustainability has been seen as a means to reduce waste of materials and harm to the natural environment. GWRM followed this approach successfully, and applied *Biodiversity No Net Loss* as a guiding principle to halt the loss of biodiversity within the railway landscape. The programme measured its impact using the DEFRA metric, applying the mitigation hierarchy and delivering biodiversity projects off–site as a last resort.

But there is more to sustainability. The Institution of Mechanical Engineers (IMechE) recommends two definitions:[6]

1. *"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their needs"*; [7] and
2. *"Sustainability can best be defined as the capacity for continuance into the long–term future. Sustainability depends upon maintaining, and where possible increasing our stocks of certain assets, so that we manage to live off the income without depleting the capital. Sustainable development is the process by which, over time, we succeed in managing all the different capital flows in our economies on a genuinely sustainable basis."* [8]

Meeting needs without compromise

Meeting the needs of the present involves providing a fast, frequent, reliable trains service with sufficient capacity for passengers and freight: a requirement fulfilled locally through GWRM delivering its remitted outputs.

Not compromising the ability of future generations to meet their needs is more complicated:

- decarbonisation will require a shift from more energy–intensive modes. As the economy is likely to grow leading to more people travelling and goods needing to be moved, the railway needs to be capable of carrying greater numbers of passengers and more freight on existing routes
- the energy impact of rail travel will need to reduce, so the railway needs to be readily adaptable to accommodate more zero–emission vehicles. This will include both traditional overhead electrification and alternatives such as batteries and hydrogen fuel cells
- the railway will need to fit into an emerging 'mobility as a service' paradigm, offering ready interchange with other modes—feeder services such as electric cars, buses and taxis, cycling and walking, and light rail—as well as providing convenient work spaces near key stations and interchanges
- expansion is likely to be needed, adding new rail routes to the existing network.

GWRM provides a building block for the first of these. Today's railway supports measures to increase capacity, including lengthening trains and increasing their frequency. These measures are defined by Network Rail's strategic planning process.

GWRM also supports the second. GWR's bi–mode trains can operate on electric mode wherever new overhead electrification is provided. When a whole service can be operated on electric traction, diesel power packs could be removed from the IETs operating that service.

Mobility–as–a–Service (MaaS)[9] extends far beyond GWRM's remit. Some of GWR's complementary investments support greater interchange—for example, the new bus and taxi forecourt, and multi–storey car park, at Didcot Parkway station. In general, GWRM does not preclude further investment of this type.

Long–term continuance

Continuance into the long–term future involves halting—and preferably reversing—global warming. Again, this requires a shift from more energy–intensive modes, and an increase in passenger and freight traffic on the railway. In the IMechE's second definition, *assets* include the means to generate clean energy, whilst capital refers to our planet's resources—both those that can be mined, and those (such as sunlight and wind) which are renewable. We are directed, therefore, towards a railway powered entirely by renewable assets. The materials used to create physical assets, such as buildings, tracks and trains, will need to be recycled.

As stated above, GWRM provides a building block: capacity could be increased—up to a limit which requires definition—and more of the railway could be electrified.

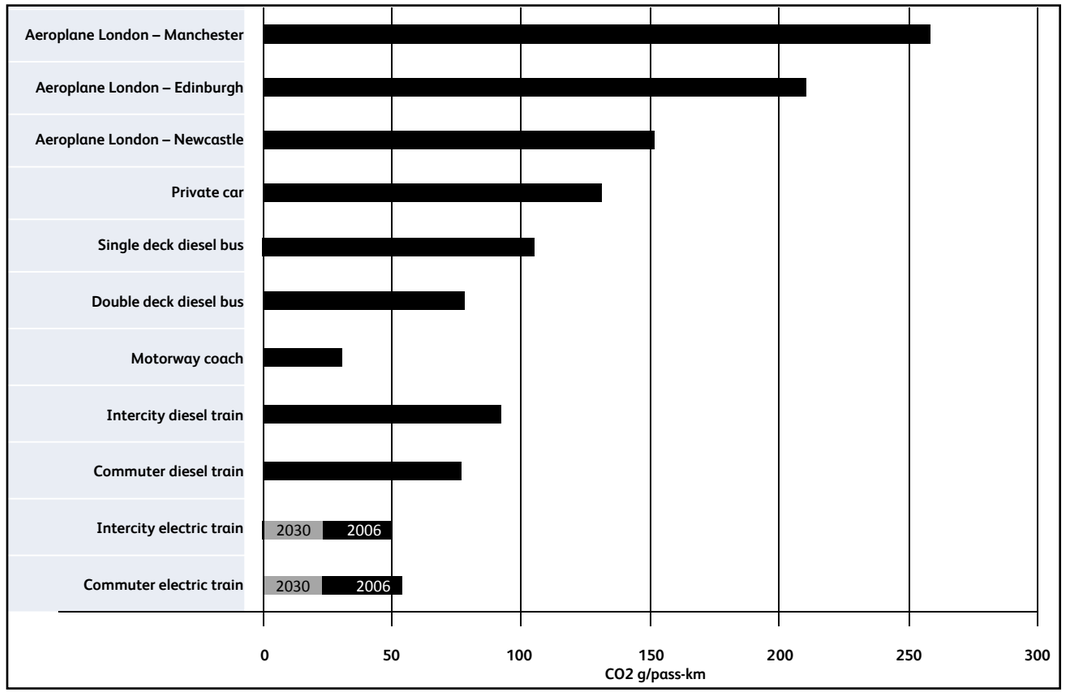
6 IMechE Energy Environment and Sustainability Group (EESG).
7 Brundtland Report (1987).
8 The Engineer of the 21st Century Inquiry (2000).
9 Mobility–as–a–Service (MaaS) describes a shift away from personally–owned modes of transportation and towards mobility provided as a service. This is enabled by combining transportation services from public and private transportation providers through a unified gateway that creates and manages the trip, which users can pay for with a single account.

Decarbonisation

Professor Kemp[10] reported that the least polluting means of transport are electric trains (almost irrespective of speed) and intercity buses. Decarbonising the UK grid mix will further improve rail's performance.[11] The worst performers are aeroplanes, private cars and diesel–powered trains, in that order. In terms of the priority of modal shift, moving travellers from fossil fuel–powered cars, and particularly aeroplanes, to electric rail must be the priority.

Figure 14 illustrates the relative emissions of a selection of means of transport in 2006, with additional data (in light grey) showing estimated rail performance in 2030 based upon an improved UK grid mix. By 2030, based upon this data, rail will be the best–performing UK travel mode in terms of CO_2 emissions.

Figure 14: Domestic intermodal comparison of CO2 emissions[12]



Kemp made assumptions based upon then–current load factors. Rising demand for rail travel, combined with load management (such as demand–responsive sale of advanced fares), will further improve rail's performance.

Kemp concluded that transferring 10% of current road passenger–km to rail would be possible, but far from straightforward, requiring substantial investment.[13] Greater modal shift would not be practical because some people live in areas without railways where population density and/or topography do not support construction of new lines.

It might be inferred that, in a decarbonised economy, many more people *might* travel by train *if* government policy were to support modal shift.[14] It is realistic to assume that the current Great Western route *could* be enhanced to increase its capacity. Therefore, we may conclude that GWRM *does* support a sustainable future.

Great Western electrification enables traction power for the electrified sections to be generated using an enhanced grid mix including a rising proportion of energy from renewable sources. Here again it supports a sustainable future. New routes connecting with the Great Western route could also be electrified: East West Rail, for example.

10 Prof. Roger Kemp, Scope for reduction in transport CO2 emissions by modal shift, Lancaster University (2016).
11 Battery and hydrogen technology may also improve the carbon performance of local bus services.
12 This chart amalgamates two charts by Kemp. Data assume the following load factors: urban bus 20%, intercity coach 60%, intercity rail 40%, all other trains 30%, domestic airlines 70%, and cars 30%. Road, air and diesel–powered rail vehicles emissions have been increased to take account of refinery losses and electric powered vehicles take into account losses in the grid. The aviation figures include a factor for radiative forcing. From Kemp (ibid).
13 Kemp looked at commuter travel (i.e. changing an 80% car / 13% rail mix to 70% car / 23% rail).
14 Kemp considered an increase in rail modal share of 77% (i.e. from 13% of trips to 23%). Coincidentally, passenger demand for main line services departing Reading is forecast to increase by 77% between 2021 and 2050. The two are not equivalent: Kemp considers diverting current trips, whilst economic analysis by Network Rail and the Department includes background growth to trip rates, new travel choices that will become available, and modal shift. Adding deliberate policy-driven modal shift might result in a greater increase to rail trips.

The challenge to decarbonise the remainder of human mobility within the UK is clear. Many electric cars and buses, vast numbers of bicycles and cycle lanes, and much improved IT systems to reduce the need to travel, will all be needed. An electrified Great Western could plug into this via cycle parking and bus interchange at stations, electric bus charging facilities at interchanges, electric car charging facilities at station car parks, and mobility–as–a–service schemes. Network Rail's Traction Decarbonisation Network Study presents the case for deployment of electric, hydrogen and battery trains in the UK, and provide a map of the UK rail network identifying where each technology should be deployed, along with the strategic, technical and economic rationale.

6.5 The Energy Hierarchy

The Energy Hierarchy[15] sets out a hierarchy of five steps through which decarbonisation may be achieved, arranged in terms of their sustainability:

1. energy demand reduction—***most sustainable***
2. energy efficiency
3. use of renewable, sustainable resources
4. use of other, low–greenhouse gas–emitting resources
5. use of conventional resources as we do now —***least sustainable***

Energy demand reduction

Reducing the overall demand for energy is most effective: humanity does not have to clean up what it does not use. From a transport perspective, for example:

- people may travel less through greater home working
- train consists could be tailored to demand (i.e. trains run with a higher proportion of seats occupied)
- the ability to split and join multiple unit rolling stock helps to avoid 'moving empty seats'.

Energy efficiency

Energy efficiency presents a mixed picture:

- electric trains are lighter than diesel equivalents, and use less energy as a result
- but the growing weight of modern rolling stock remains an issue, not least for bi–mode trains that carry heavy power packs for long distances 'under the wires'
- trains use less energy per passenger kilometre than private cars or commercial aviation, but more energy is needed to travel faster. Kemp suggests that the energy impact of increasing speed is relatively small at typical operating speeds on Great Western
- electric trains offer potential to recover much of the energy removed during braking, particularly for densely–trafficked metro–style services
- faster trains also encourage modal shift from less energy efficient modes such as car and air.[16]

Utilisation of renewable, sustainable resources

Utilisation of renewable, sustainable resources entails improving the UK grid mix, a matter subject to UK government policy—and, in terms of the 2050 target, UK law. Greater rail electrification multiplies the benefits of a greener grid mix. If significant modal shift is also obtained, there may be an added benefit from less carbon embedded within electric car batteries and road infrastructure.

Utilisation of other, low–greenhouse gas–emitting resources

Network Rail's Traction National Decarbonisation Strategy concludes that bio–fuels are unlikely to assist the rail sector: the commercial aviation and marine sectors are harder to decarbonise and will have greater call upon these scarce resources.[17]

Utilisation of conventional resources as we do now

Operating bi–mode trains represent an element of 'doing what we do now', whilst—hopefully—rolling out a further electrification. Ecologically, the bi–mode has to be seen as a stepping stone towards full electrification, with the advantage that diesel power packs could be removed to convert the trains to full electric operation.

15 Energy Hierarchy, Energy, Environment and Sustainability Group, IMechE (2020).
16 For example, commercial aviation between London and Manchester, and between Paris and the South of France, has all but ceased as a result of rail journey time improvements. Likewise, rail enjoys a relatively high modal share between London, Glasgow and Edinburgh.
17 There is a trade off between land use for food and for bio–fuel production. With growing population, the former could be expected to dominate.

6.6 Cycling and walking

In 2018 the average person in the UK made 262 trips on foot, of which 96 % were under two miles.[18] 17 trips per person were made by bicycle, 93 % of these shorter than 10 miles. 602 trips per person were made by car or van, as a driver or passenger, and 22 by train—the majority between 10 miles and 100 miles in length.

We can see that people are relatively likely to walk up to a mile, sometimes as far as two miles. In smaller communities, walking is therefore a good access mode for rail travel. Along the Great Western route, places such as Didcot are especially accessible on foot. In larger communities, for example Swindon, access by bus, car and taxi is more important—however, scope may exist to boost cycling.

Large cycle storage areas at stations—such as Didcot Parkway and Swindon—are notably busy. This suggest

New cycle parking at Didcot Parkway station (with new taxi rank to the right)

potential to expand cycle access, facilitated by the local authorities responsible for cycling infrastructure.

18 Department for Transport (2019).

7. Programme outputs

Photo: GWR

7.1 Capacity

Great Western Route Modernisation provided additional capacity in two ways: through additional rolling stock to operate on routes into London Paddington station; and through displacing (or cascading) some of the trains that formerly operated those routes to provide extra seats in the South West and the West of England.

With the new IETs, our passengers have a choice of more seats on the four service groups operating into Paddington:

- Bristol Temple Meads – Paddington: 20,000 additional weekday seats
- South Wales – Paddington: 15,000 additional weekday seats
- Cotswolds – Paddington: 6,000 additional weekday seats
- Plymouth – Paddington: 3,840 additional weekday seats.

Main line into London Paddington

One of the principal challenges facing GWRM was to provide additional peak–hour capacity into London Paddington station. This is the largest single passenger flow carried on the Great Western Main Line, and comprises a mixture of commuters and business travellers.[1]

Figure 15 sets out headline data based upon a forecast completed before the Covid–19 pandemic, in November 2019, as part of a further assessment of main line demand into London Paddington.

December 2021 was used as the baseline for these forecasts to take account of two major changes: the December 2019 timetable change; and the assumed implementation of Elizabeth Line Stage 5 services in 2021. Individually and taken together these significantly change the travel choices available to passengers.[2] Forecasts also include assumed background growth.

Figure 15: Comparison of high peak–hour demand versus peak standard class capacity into London Paddington on the sixteen services into London Paddington classified as 'main line arrivals'[3]

2021 demand (forecast)	Pre–modernisation (Autumn 2017)		Post–modernisation (December 2019)	
	Seats provided	Surplus / (deficit)	Seats provided	Surplus / (deficit)
10,170	7,555	(2,615)	9,162	(1,008)

Without modernisation, one in four peak–hour passengers—26 %—would have to stand. Modernisation has increased peak–hour seats by 21 %, leaving an estimated 10 % of peak–hour passengers without seats.[4] The forecast shortfall reflects limited capacity into Paddington—current technology permits a maximum of 20 trains per hour to run, and these are apportioned between GWR (16tph) and Heathrow Express (4tph).

Further work is ongoing to assess options for further increases to main line seating capacity to make further progress in bridging the capacity shortfall.

West of England

Cascaded trains provide more seats on all GWR's routes centred on Bristol, including services to Cardiff, Gloucester, Portsmouth, Severn Beach, Taunton, and Weymouth.

South West

Cascaded trains provide more seats on many of GWR's routes in Devon and Cornwall. These include services linking Exeter to Barnstaple, Exmouth, Paignton, and Plymouth. Services between Plymouth and Penzance have doubled in frequency. Most of GWR's Devon and Cornwall branch lines have also benefited, with more seats to Gunnislake, Looe, and Newquay.[5]

1 Separate forecasts concern Elizabeth line services via Paddington low level station.
2 The associated uncertainty in the 2021 forecast must be borne in mind. Passengers could take different routes. Or the extra choice might stimulate further growth.
3 The December 2021 demand forecast assumes a high–peak hour between 07:30 and 08:30 because count data showed this to be the busiest time for travel into London Paddington. Autumn 2017 data assumed 08:00 to 09:00 to be the high–peak hour. This occurred because of a change to planning methodology, and is not considered to make a significant difference to the Paddington data.
4 In reality, trains will tend to load unevenly because they travel from different destinations with a variety of stopping patterns which inevitably represent the compromises necessary to create an operable timetable. Therefore busier trains will see more than 10 % of passengers standing, and quieter trains fewer. Most standing occurs on the short (around 25 minute) journey between Reading and Paddington.
5 The branch line to St. Ives has more seats in winter. Frequency on the Falmouth branch was doubled prior to the rolling stock cascade.

7.2 Reducing journey times

Point to point journey times

Within the Department's business case, two–thirds of the benefits of Great Western Route Modernisation comprise journey time savings.[6]

The Department's High Level Output Specification (HLOS) set challenging targets for shorter journey times between Paddington and eight key GWR destinations.[7] Five of the eight have been met in both peak and off–peak timetables. Figure 16 summarises the outputs.

Decisions about how railway capacity is allocated within the timetabling process have affected some peak journey time targets. Where necessary to accommodate the mix of train operators on the network, Network Rail is required to flex services to give effect to the contractual rights of all parties and to any operator seeking capacity in expectation of rights. The mix of services which are bid by timetable participants is not wholly within the control of either Network Rail or the Department.

Of the targets not met, two relate to the Paddington to Cheltenham via Gloucester service, where the December 2019 timetable represents a 9 to 12 minute improvement upon the pre–electrification journey. The Paddington to Swansea off–peak target is missed by only two minutes. Paddington to Exeter targets are also missed: in this case the majority of the journey is under diesel traction where an IET offers no performance advantage. Introduction of one peak service, Paddington to Bristol Temple Meads via Bristol Parkway, has been delayed by Covid–19.

Figure 16: Attainment of HLOS targets in the December 2019 timetable

Route	HLOS Journey Time output	Fastest off–peak journey time (mins)	HLOS target met at peak times?	Fastest peak journey (mins)	HLOS target met off–peak?
Paddington to Bristol TM via Bristol Parkway	83	79	Yes	No service	N/A
Paddington to Bristol TM via Bath Spa	93	90	Yes	87	Yes
Paddington to Cardiff	115	107	Yes	102	Yes
Paddington to Swansea	159	165	No	157	Yes
Paddington to Worcester Shrub Hill via Oxford	126	124	Yes	119	Yes
Paddington to Gloucester via Swindon	100	103	No	104	No
Paddington to Oxford	49	48	Yes	44	Yes
Paddington to Cheltenham via Swindon	117	117	No	120	No
Paddington to Exeter	118	123	No	123	No

These journey times represent significant improvements upon the pre–electrification timetable, setting a new standard for speed between London and key cities and towns in the Thames valley, Wiltshire, Avon, Gloucestershire and South Wales, as shown in Figures 17 and 18.

Timetable efficiency

Electric passenger trains offer opportunities to deliver a superior timetable, both in terms of reduced journey times and making better use of network capacity. Figure 19 illustrates the relative performance of IET and HST rolling stock[8] on a sample non–stop journey between Swindon and Reading. The exceptional acceleration of the IET under electric traction is evident, reaching 125mph in just five miles from rest. The HST takes 15 miles to reach 125mph, representing the approximate limit of diesel traction, whilst the IET under diesel power takes a similar distance to reach its top speed. The dip in speed around the 30 mile mark is due to a reduction in line speed.

6 Updated business case, CH2M / Dft (2017). The PV of journey time savings is £2,747bn, which represents 68 % of the net PV of benefits which is £4,029bn.
7 It is worth bearing in mind that the HLOS targets were compiled prior to testing of new rolling stock, detailed train performance modelling, or development of a workable timetable. The December 2019 timetable involved trade–offs between schedules for 'super–fast' trains, stopping trains and freight trains, trade–offs between speed and inclusion of station calls to provide local capacity, and consideration of station and junction working. Some compromise of journey times, especially peak, is inevitable.
8 The graph compares nine–car bi–mode IET and 2+8 HST trains. Fastest modelled times are 22 mins 20 secs (IET electric), 23 mins 49 secs (HST) and 24 mins 52 secs (IET–diesel 'unmuzzled').

Because electric trains accelerate faster, timetable headway at London Paddington has been reduced from 2.5 to 2 minutes. This provides a greater margin to accommodate perturbed services. Because of this, passengers on inbound services are more likely to experience less time outside the station 'waiting for a platform to become available'.[9]

Electrification also increases the disparity in performance between passenger and freight trains, providing additional challenges in generating a superior passenger timetable that is equitable towards freight customers.[10] Primarily this constraint applies between Didcot and Wootton Bassett junction, limiting the ability to run more trains in the future.

Figure 17: Improvements to peak journey times between London and key GWR destinations

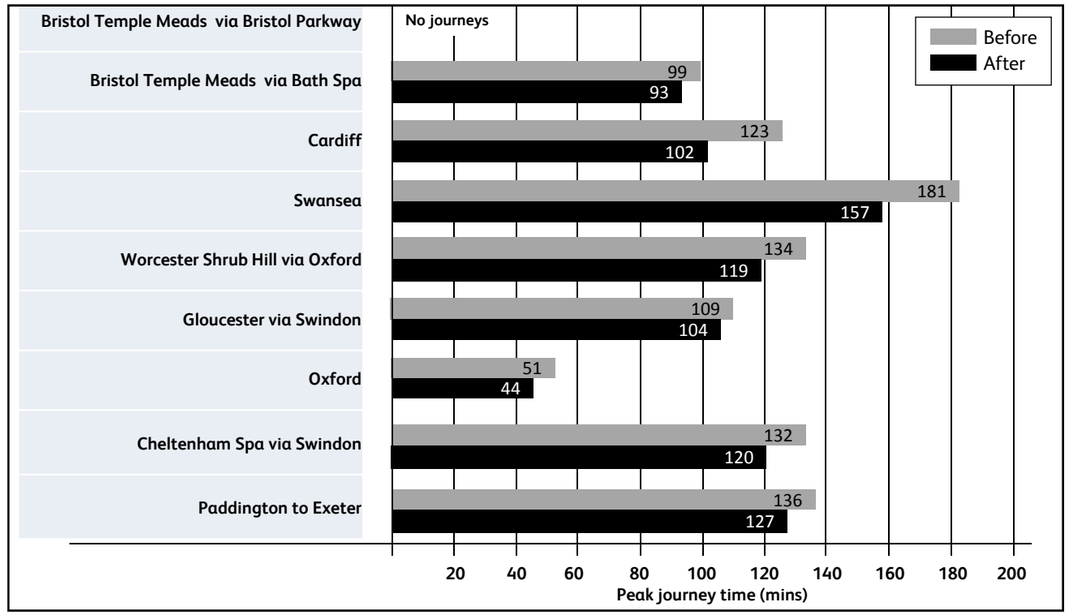
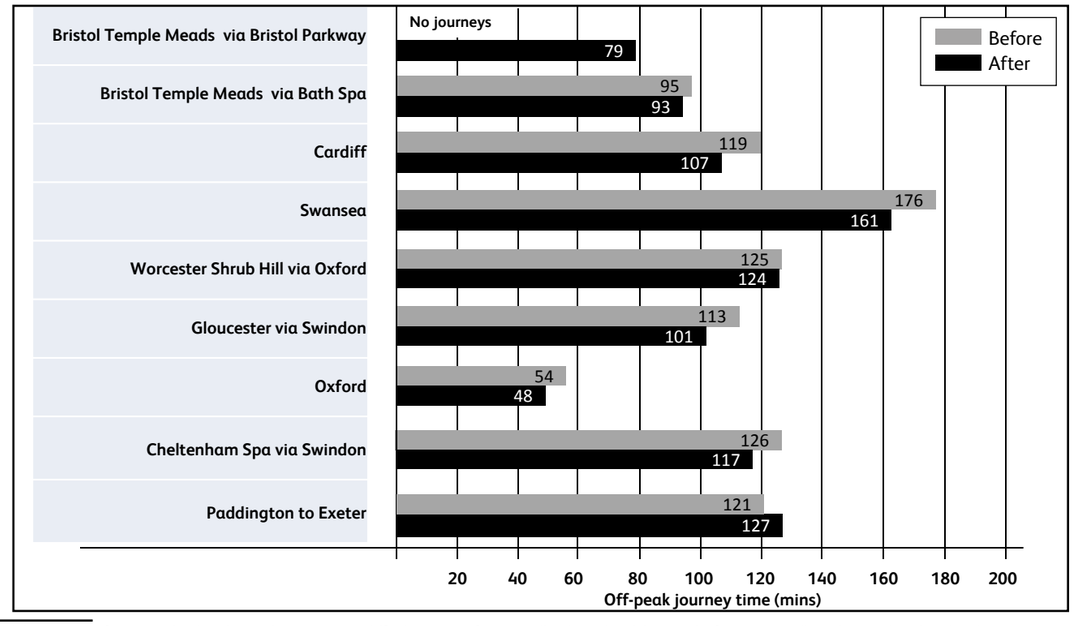
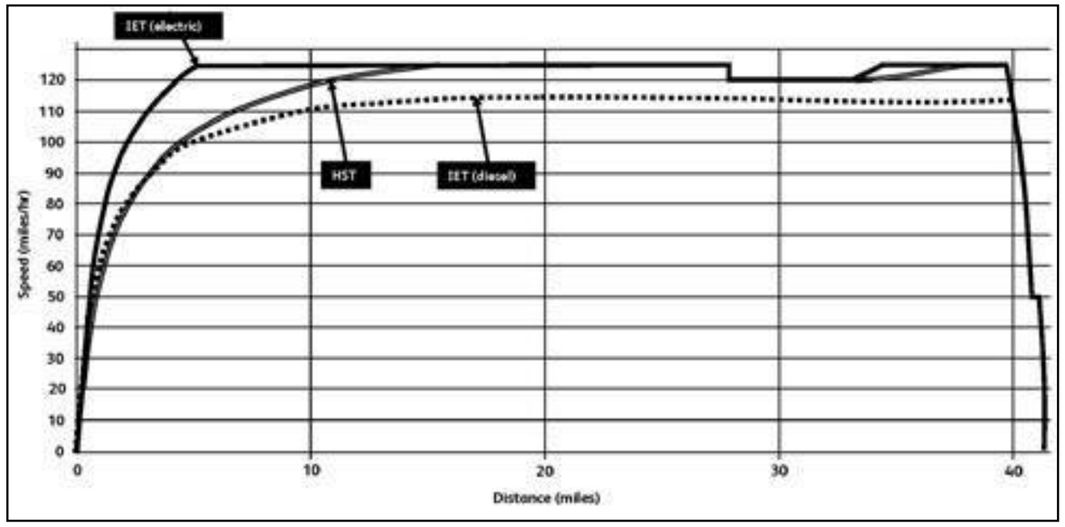


Figure 18: Improvements to off–peak journey times between London and key GWR destinations



9 Whilst apparent from anecdotal evidence, this outcome is difficult to quantify, especially where the 'delay' results from marginally early arrivals rather than lateness.
10 This might be mitigated if freight trains change to electric traction, however GWEP has not facilitated electric freight operation because the connectivity needed for through haulage 'beneath the wires' has not been provided. The national freight strategy is considering this issue.

Figure 19: relative performance of IET and HST rolling stock[11]



7.3 Improving service reliability

Electric trains are intrinsically more reliable than diesel trains since they have fewer moving parts:

- the Mean Time per service affecting Incident Moving Annual Average (MTIN MAA) is 30–40 % higher for electric versus bi–mode IET, with the reliability gap widening as the electric fleet beds in[12]
- the contrast is starker for commuter trains, with GWR's MTIN MAA over300 % higher for EMUs versus DMUs.

Figure 20 illustrates modelled performance for typical electric and diesel trains.

Figure 20: Reliability of GWR diesel and electric trains[13]

	Rolling stock	MTIN (MAA)	Traction
IET	GWR Class 800	12,311	Bi–mode Diesel / Electric
	GWR Class 802	9,389	
	LNER Class 801	16,707	Electric
EMU / DMU	GWR Class 387	19,906	Electric
	GWR Class 158	5,184	Diesel
	GWR Class 165/1	5,937	
	GWR Class 166	4,174	

The greater availability of electric rolling stock allows GWR to operate a greater volume of services for a fixed fleet size, maximising capacity and connectivity benefits to passengers.[14]

It is too early to quantify long–term improvements in performance of the timetable in terms of Public Performance Measure (PPM) and Cancelled and Significantly Late (CaSL) data. This is because both rolling stock and timetable were still 'bedding in' when Covid–19 struck. However, the National Rail Passenger Survey has demonstrated a substantial jump in the score for 'punctuality / reliability of the train' (see section 5.5).

However, data published by the ORR indicates that GWR's punctuality and cancellation metrics both improved in the year to Quarter 3 of 2019/20, a period coinciding with full operation of new IET and Class 387 trains. Figures 21 and 22 show that GWR demonstrated the greatest improvements across all train operating companies in the period.

11 Performance was modelled using RouteRunner software, which calculates theoretical maximum performance taking into account characteristics of the train and route.
12 For the purposes of comparison, the bi–mode IET operating under diesel power is taken to represent a modern equivalent diesel train.
13 Source: Technical MTIN and Primary DPI report, Period 12, 2019/2020.
14 GWR has stated this to be the case. Quantification is not available.

Figure 21: Change to On Time MAA performance in the year to 2019–20 Q3[1]

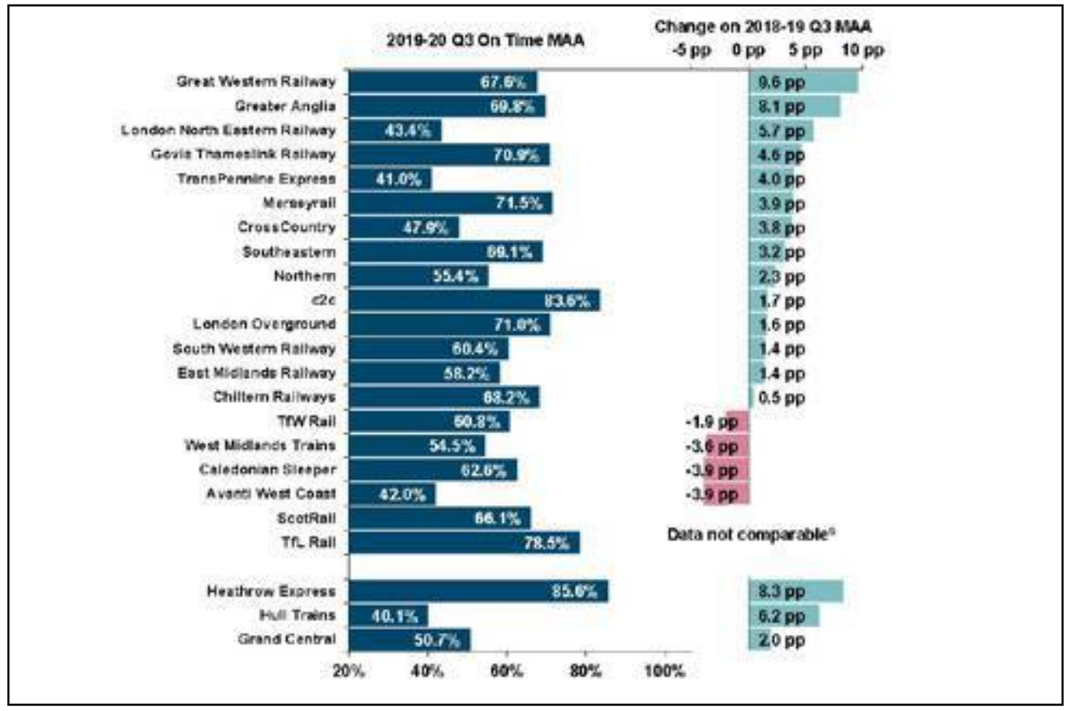
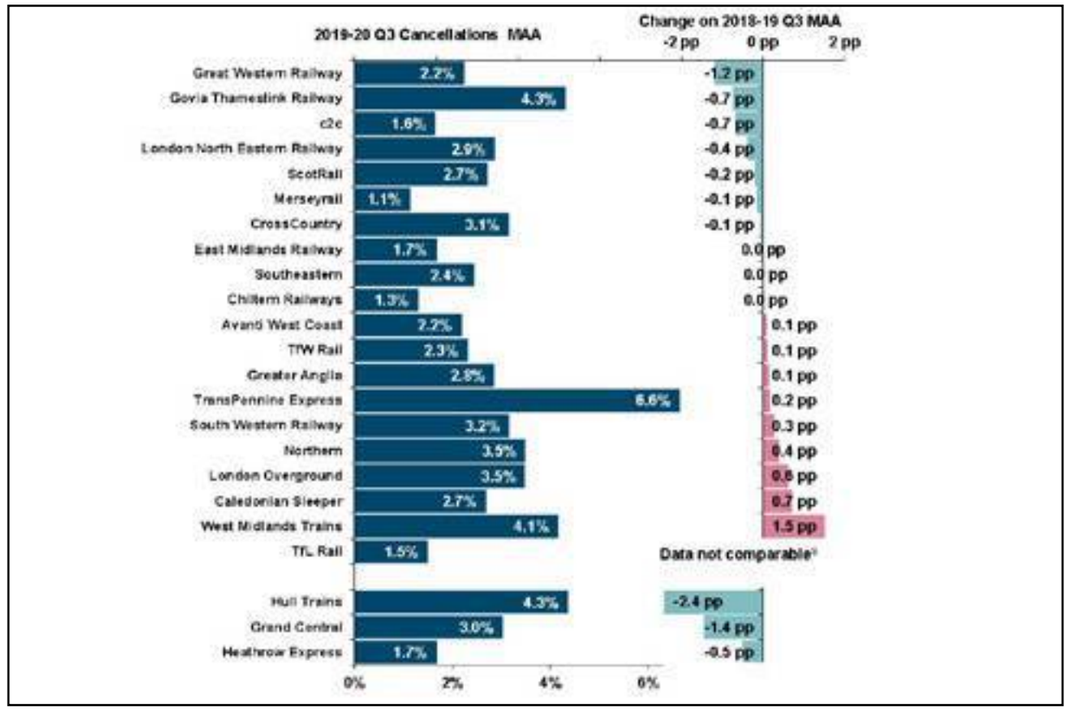


Figure 22: Change to Cancellations MAA performance in the year to 2019–20 Q3



1 Both tables are taken from Passenger Rail Performance 2019-20 Q2 Statistical Release, Office of Rail & Road, (December 2019). The data precedes the December 2019 timetable change. Whilst the data might be seen as a like–for–like comparison of 'old trains versus new', it is important to remember that new trains are still 'bedding in', hence not attaining their final mature levels of reliability.

7.5 Reducing operational costs

Direct operating cost

New electric rolling stock is delivering worthwhile savings:[15]

- an IET operating on electric mode saves 44 % compared to the equivalent diesel mode cost.[16] A nine–car IET also offers 46 % more seats that the High Speed Train (HST) that it replaced
- class 387–operated services give a 28 % saving compared to the equivalent Class 16x diesel cost per kilometre, and also offer 27 % more seats on average.[17]

These costs include train leasing costs, energy charges, and track access costs (which include Network Rail's maintenance costs).

Asset maintenance cost

The electrified railway is more complicated, with more assets to maintain.[18] Overhead wires restrict maintenance and renewal activities, including taking access (many activities need the current to be switched off) and using cranes, and these result in increased costs.[19]

No reduction in track maintenance cost is anticipated because, whilst electric trains are lighter and hence reduce wear and tear[20], a more intense timetable is being operated by bi–mode trains.[21] The impact upon track maintenance costs of the lighter weight of the electric IET, and the extra weight of diesel engines on the bi–mode fleet, does not appear to have been clearly understood—as evidenced by responses to questions by the Public Accounts Commitee in 2017.[22]

Other costs

Modernisation has opened new opportunities to base some trains remote from London:

- new facilities at Reading, Stoke Gifford and Swansea enable trains to stable overnight and be maintained closer to where they start and finish daily service. This could reduce the cost of empty mileage run, and reduce the impact of empty movements on maintenance activities[23]
- these new facilities were constructed on railway land, avoiding the need to buy land adjoining the railway that might otherwise be used for housing or commercial purposes
- new sidings for electric commuter trains was constructed at Swindon at a lower cost than would have been possible closer to London, and this was facilitated directly by electrification.

15 These estimated savings are based upon preliminary operating cost information given by GWR, and may be revised when more data becomes available.
16 For the purposes of this assessment, IETs operating on electric and diesel mode are assumed to represent comparable modern electric and diesel rolling stock.
17 Calculations take into account that services typically operated by 5 or 6–car Class 16x consists have been replaced by 8 or12–car Class 387 consists. The percentage saving is lower because Class 16x trains had high–density seating in a 3+2 layout whilst Class 387 trains have more comfortable 2+2 seating layout, requiring more carriages to accommodate a given number of passengers.
18 The direct maintenance cost for Wales and Western Region electrification systems is approximately £11m. An estimated £7.5m of this relates to maintenance of new assets installed by GWEP.
19 The CP6 business plan for Wales and Western Region includes £6.72m per annum for the cost impact of electrification on taking access and on maintenance and renewal costs of earthworks, structures and track.
20 Network Rail's 2009 Electrification Route Utilisation Strategy quoted a 13 % reduction in track wear and tear.
21 The bi–mode IET has a relatively high 15 tonne axle load versus 13 tonnes in pure electric mode and 9 to 11 tonnes for a suburban EMU (source: Wikipedia).
22 In 2017 the Public Accounts Committee questioned a number of senior figures about Great Western Route Modernisation, recording the following questions and answers:
Q61 Chris Evans: "So you have no concerns about the new stock being significantly heavier than the old stock?" **Mark Carne**: "No. In fact, quite the opposite: the new stock is lighter than the existing stock."
Q62 Chris Evans: " So why does the FT report that there is going to be damage to the railway lines? Could you talk that through? Is that just a spurious piece of journalism?" **Mark Carne**: "I'm afraid I can't comment on that specifically. The bi-mode trains are heavier than the electrified trains, but I don't think that is a material factor in this."
Q98 Chair: "Mr Etheridge, I just wanted to ask you this: Mr Rutnam said earlier that among the various benefits of electrification were reduced journey times, lower operating costs, less pollution and reduced wear and tear on the track. That was with fully electric trains. The bi-modal ones cause more wear and tear on the track than fully electric ones. What is the financial benefit—or rather, what would have been the financial benefit— of reduced wear and tear on the track if you had gone for the fully electric option? Now that there is going to be more wear and tear, because they are bi-modal, what's the reduction in the benefit? Or is it an added cost?" **Brian Etheridge**: "I am not sure I can quantify that exactly, in the way that you set out. I am sure we could give you a note on that if necessary."
Q99 Chair: "You might not have it in front of you, but do you produce such numbers and put them into your business case?" **Brian Etheridge**: "Yes, absolutely. The business case will include the overall cost of the project."
Q100 Chair: "Including the maintenance, and the maintenance of the track?" **Brian Etheridge**: "What I understand is that the bi-modes are heavier, as you would expect, than the electric trains, because they have diesel motors on them. However, they are actually lighter than the old HST trains, so there are still improvements to be made from where we were."
Q101 Chair: "So, you put in a number, but it's a different from the HST and a different number from the fully electric?" **Brian Etheridge**: Yes. That is the complex nature of business cases … ".
23 Empty trains run before and after normal public timetable hours limit the ability of maintenance staff to take possession of the track, reducing the time available for maintenance with a negative impact on efficiency that increases its cost.

7.6 Improving environmental performance

Environmental performance is improved on electrified route sections. Figure 23 shows which sections have been electrified, and where electrification has been deferred or cancelled.

Carbon emissions

Electric trains emit zero carbon at source. Taking into account the current UK grid mix, electric trains typically emit between 20 % and 35 % less carbon per passenger mile than a diesel train. This benefit will improve as the electricity generation industry reduces its carbon emissions. Figure 24 shows current and potential future reductions in carbon emissions, taking an IET under diesel mode and a Class 16x DMU as base cases.

Initial assessment shows that 34 % less CO_2 is emitted by IETs using the electrification delivered, compared to diesel operation throughout.[24]

Figure 24: Carbon emissions associated with electric and diesel trains[25]

Long distance operation	IET (9–car diesel)	IET (9–car electric, current grid mix)	IET (9–car electric, assumed 2050 grid mix)
Percentage of base carbon emissions per train–km	100 %	40 %	4 %
Suburban operation	Class 16x (6–car)	Class 387 (8–car electric, current grid mix)	Class 387 (8–car electric, assumed 2050 grid mix)
Percentage of base carbon emissions per train–km	100 %	66 %	7 %

Diesel fumes

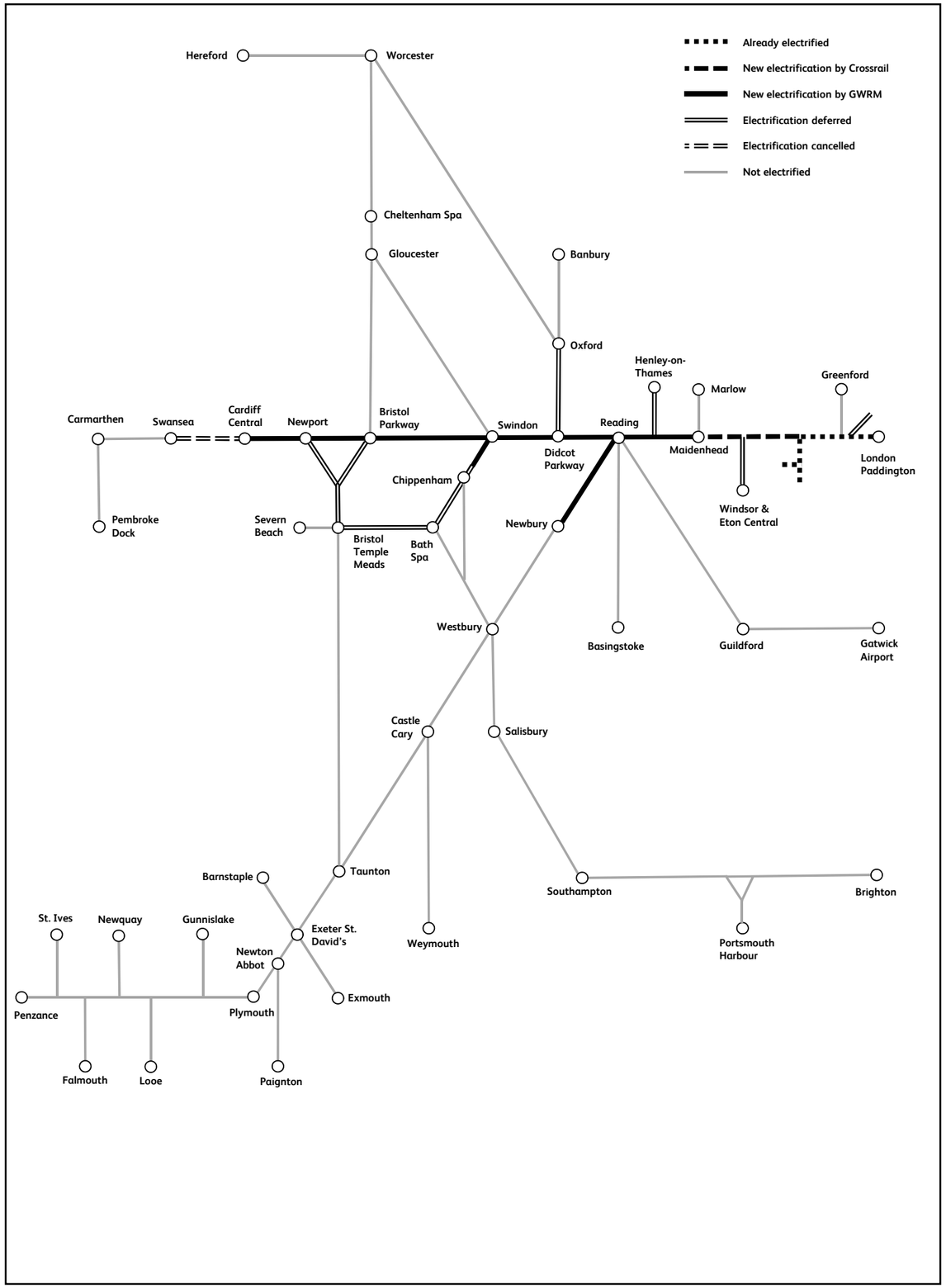
Diesel fumes can accumulate in major stations, especially those enclosed within overall roofs. Measurements at Paddington prior to electrification in 2015 noted high levels of combustion gases.[26] Monitoring undertaken after GWEP was substantially complete in 2019 indicated that chemical constituents associated with diesel engine exhaust emissions have fallen to low levels that do not risk harm to health.[27]

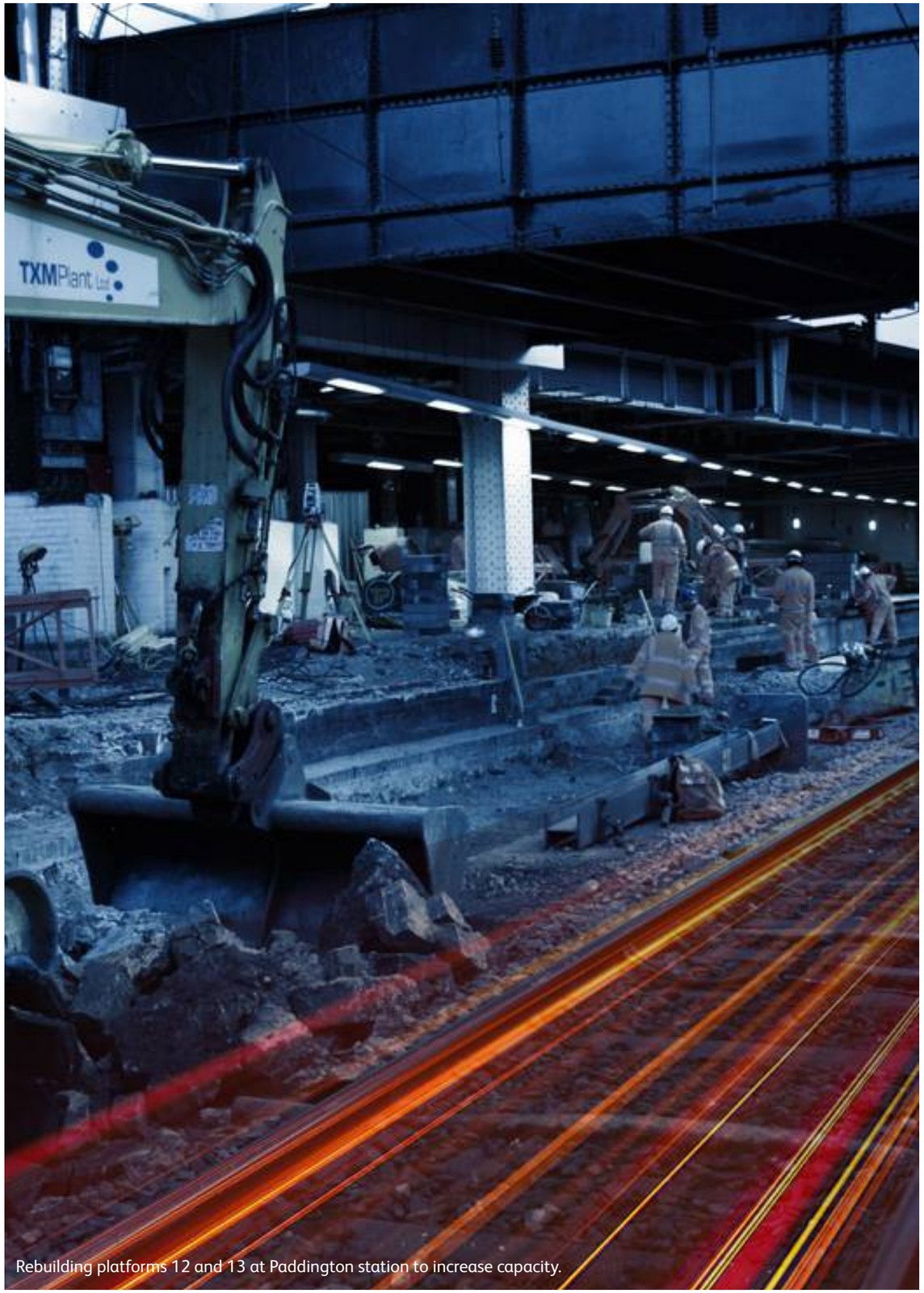
Noise

Electric trains are intrinsically quieter than diesel trains, particularly during acceleration when full power is applied. Following electrification, stations are significantly quieter for passengers and staff, and nearby tracks for neighbours. The difference at Paddington station is substantial. Passengers also enjoy a quieter environment during their journeys. There could be some benefits for line–side neighbours away from stations, although wheel–rail noise and aerodynamic noise will remain significant factors.[28]

24 This figure is based upon December 2019 trail diagrams. and reflects the fact that IETs generally operate more frequently on electrified tracks than non–electrified.
25 Carbon emissions data was provided by the Network Rail Economic Analysis unit. The 2050 figures were generated using grid mix data from the Department's Transport Appraisal Guidance.
26 The report stated that high levels of combustion gases were recorded on the footbridge and, more seriously, at the north–west end of platform 12 (where nitric oxide levels were found to be very close to exceeding the recommended level of 1ppm over an 8–hour working day. Passengers passing through the station were unlikely to experience any health effects other than short term irritation and a perception of diesel fume due to its distinctive odour. Exposure levels for station staff, however, would be higher. It was recommended that in the short term, staff rotation be employed with regard to staff working on the station overbridge and especially on Platform 12, and that health monitoring be considered for staff with asthma or a predisposition to respiratory diseases.
27 Whilst the vast majority of trains at Paddington are now electrically operated, a small quantity of diesel fumes from nearby roads and the taxi deck enter the station.
28 Before and after measurements are not available for GWEP, so noise away from stations cannot be claimed as a benefit.

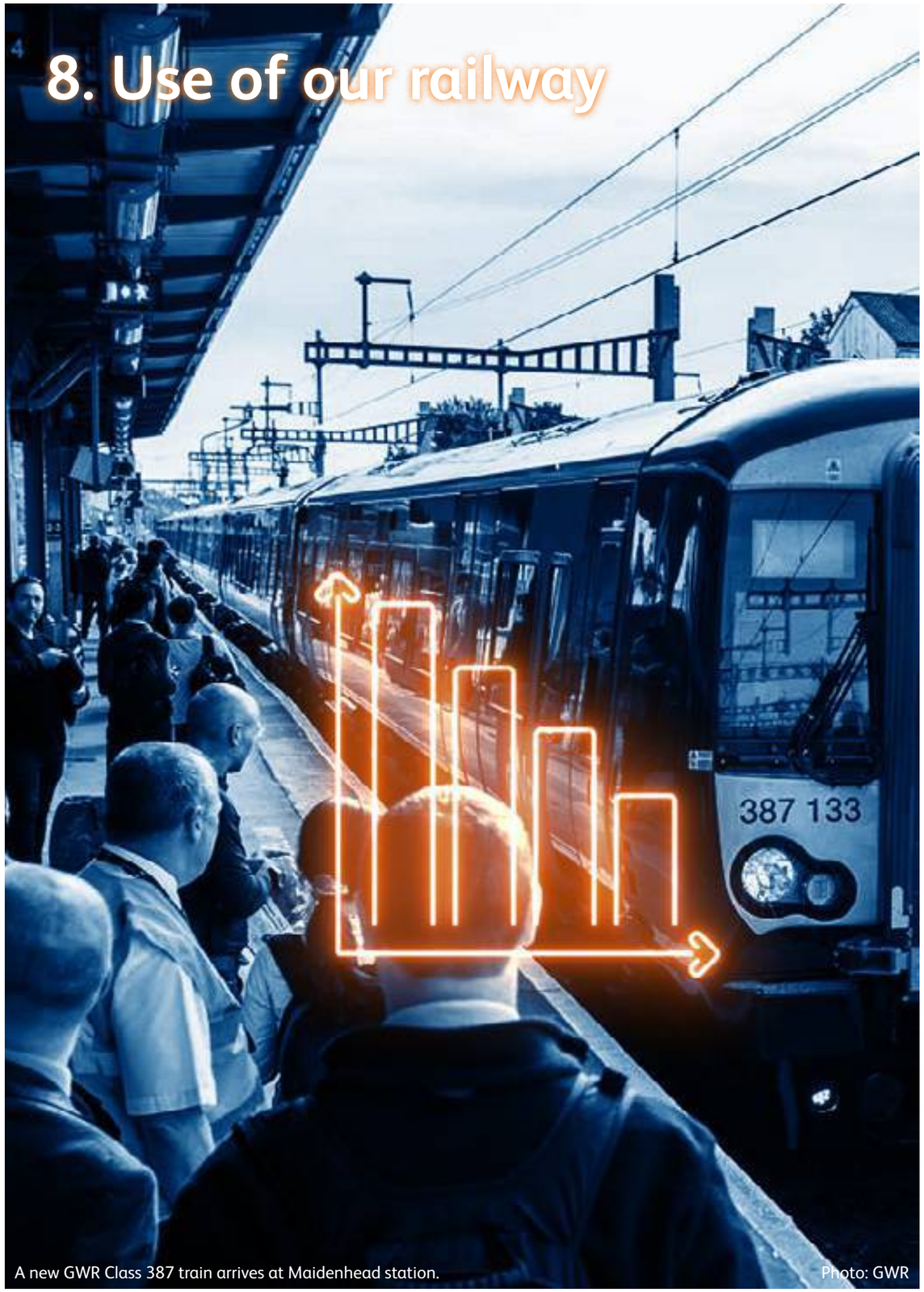
Figure 23: Electrification delivered, deferred and cancelled





Rebuilding platforms 12 and 13 at Paddington station to increase capacity.

8. Use of our railway



A new GWR Class 387 train arrives at Maidenhead station. Photo: GWR

8.1 Passenger demand

The Intercity Express Programme and Great Western electrification—the core components of Great Western Route Modernisation—were conceived against the background of strong forecast growth in passenger demand.

Ridership has grown strongly across the GWR network, and nationally, although in some cases at a lower rate than forecast.[1] Figure 25 summarises performance for London Paddington, Bristol and Cardiff.

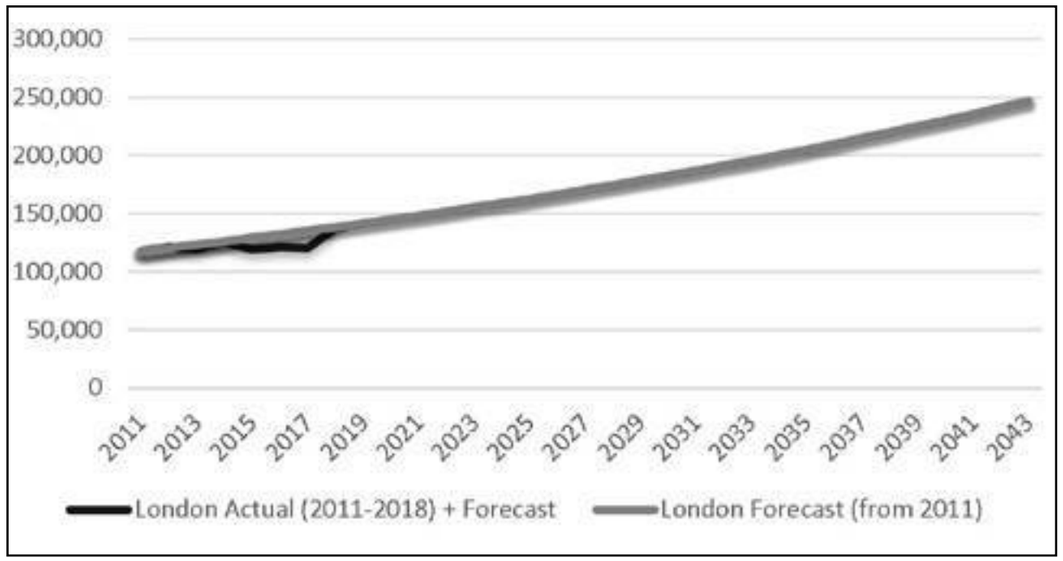
Figure 25: Comparison of actual versus forecast growth in passenger demand (2012–2019)[2]

Route / destination	Forecast annual growth	Actual annual growth	Difference
London Paddington	2.3 %	2.3 %	Nil
Bristol	4.0 %	2.1 %	(1.9 %)
Cardiff	2.7 %	1.5 %	(1.2 %)

London Paddington

Demand growth into London has proven strong, as shown in Figure 26, with passenger numbers increasing by around a quarter over the seven years from 2011 to 2018. Actual demand corresponded closely with the forecast. The extra capacity provided by the new IET and Class 387 fleets will be fully used.

Figure 26: Growth in passenger demand at London Paddington (2011 to 2043 all day demand)

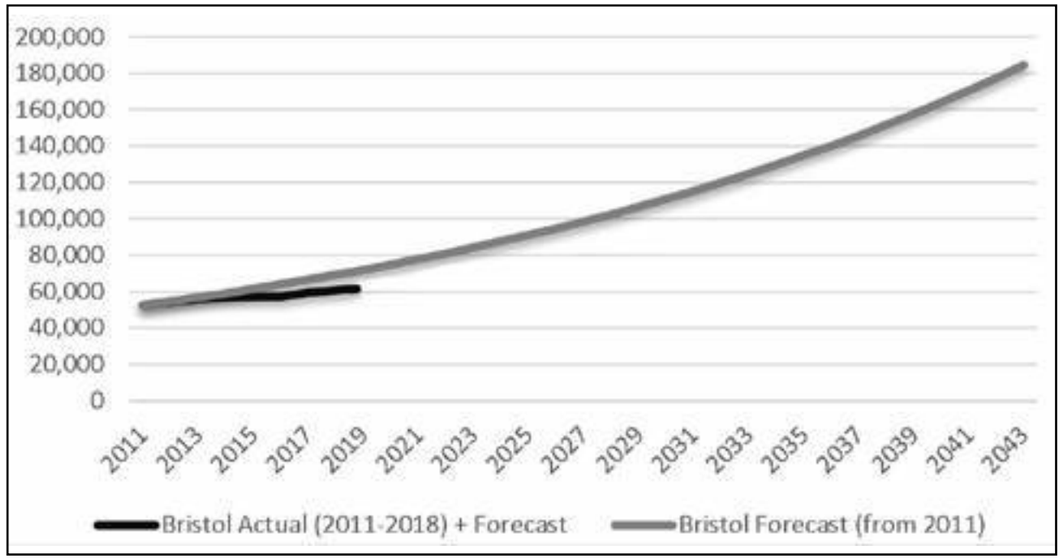


Bristol

Passenger numbers at Bristol rose by approximately 15 % , or roughly half of the forecast increase, as shown in Figure 27. Whilst actual demand has grown at a lower rate than forecast, the increase is significant. The shortfall could reflect crowding on local services, which had only just begun to receive cascaded rolling stock at the very end of the period for which data exists. Disruption caused to passengers over several years by electrification work could have suppressed growth in demand. The shortfall could also reflect the relatively low frequencies which operated on Bristol suburban railways. The period for which data exists precedes the introduction of GWR's new 'super–fast' services, which might be expected to boost ridership.

1 Network Rail adopted the most optimistic of four forecasts as the basis for its assumptions.
2 Data and all charts in this chapter were supplied by the Network Rail Economic Analysis team.

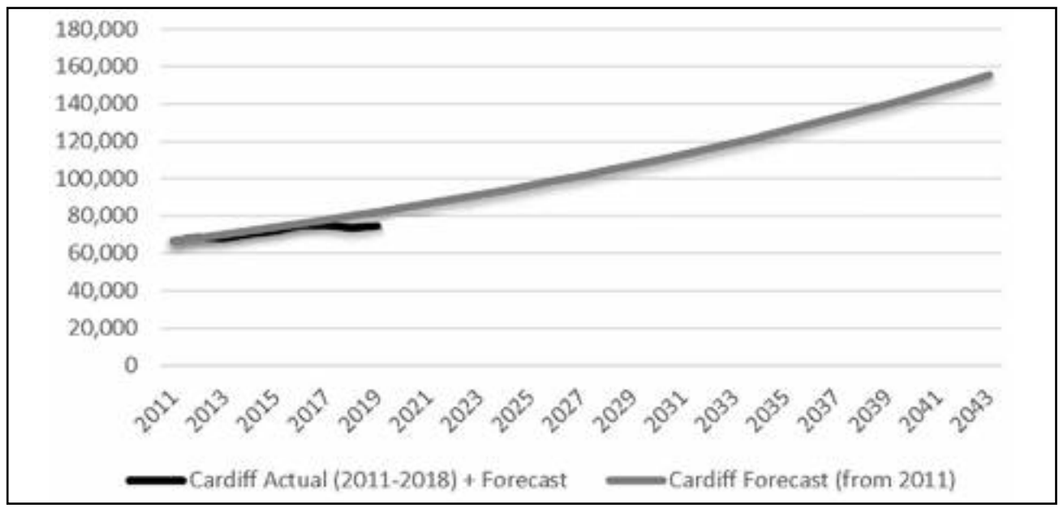
Figure 27: Growth in passenger demand at Bristol (2011 to 2043 all day demand)



Cardiff

Passenger numbers at Cardiff rose by approximately 10%, or roughly half of the forecast increase, as shown in Figure 28. Whilst actual demand has grown at a lower rate than forecast, the increase is significant. The shortfall could reflect crowding on Valley lines services, which carry the majority of commuters into Cardiff. Disruption caused to passengers over several years by electrification work could have suppressed growth in demand too. The period for which data exists precedes the introduction of GWR's new 'super–fast' services, which might be expected to boost ridership.

Figure 28: Growth in passenger demand at Cardiff (2011 to 2043 all day demand)



GWR's experience

GWR reports increases to revenue on services where frequencies have increased, including a 'spectacular' increase between Plymouth and Penzance where frequency has been doubled.

Great Western Route Modernisation – Interim project completion report

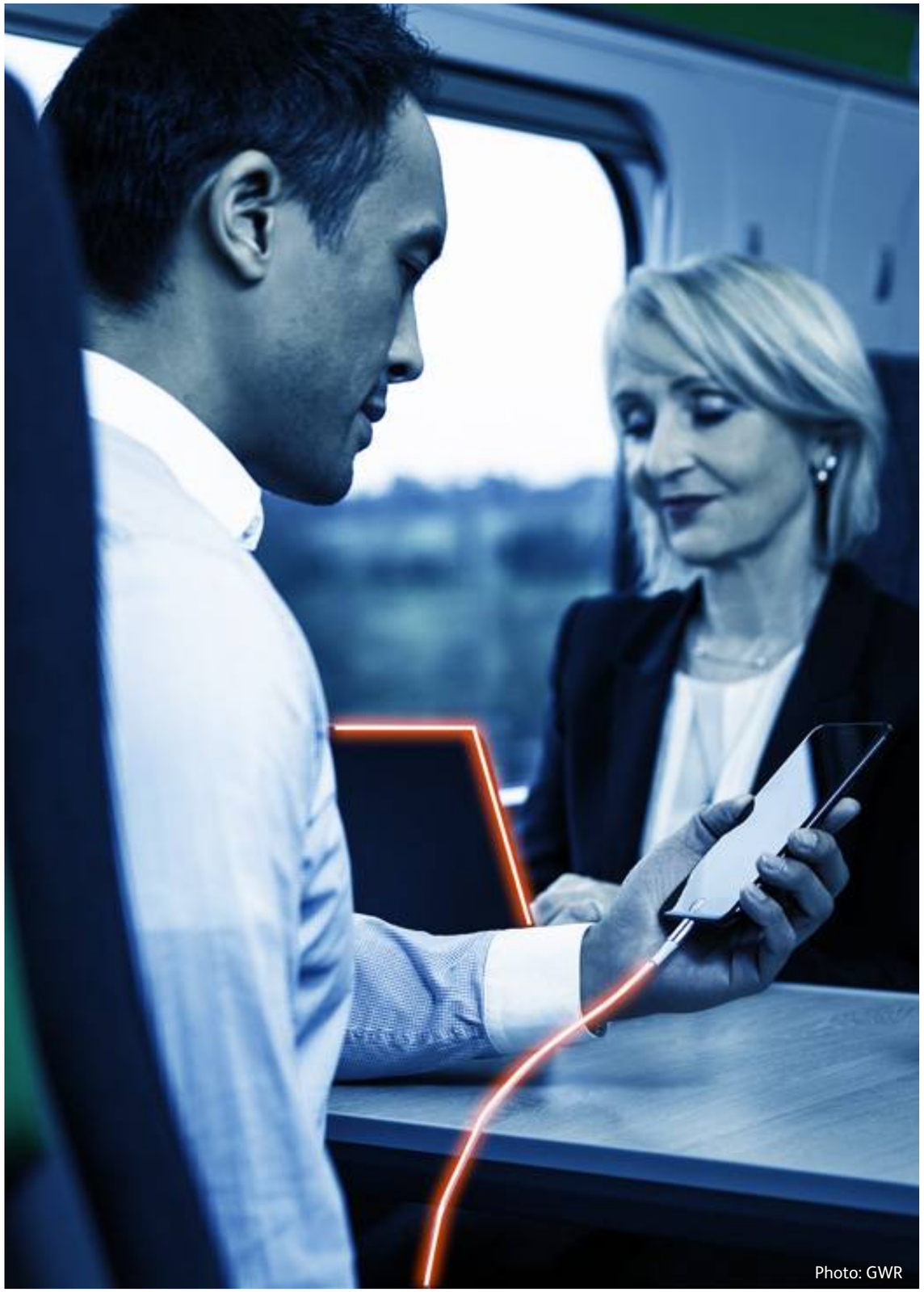
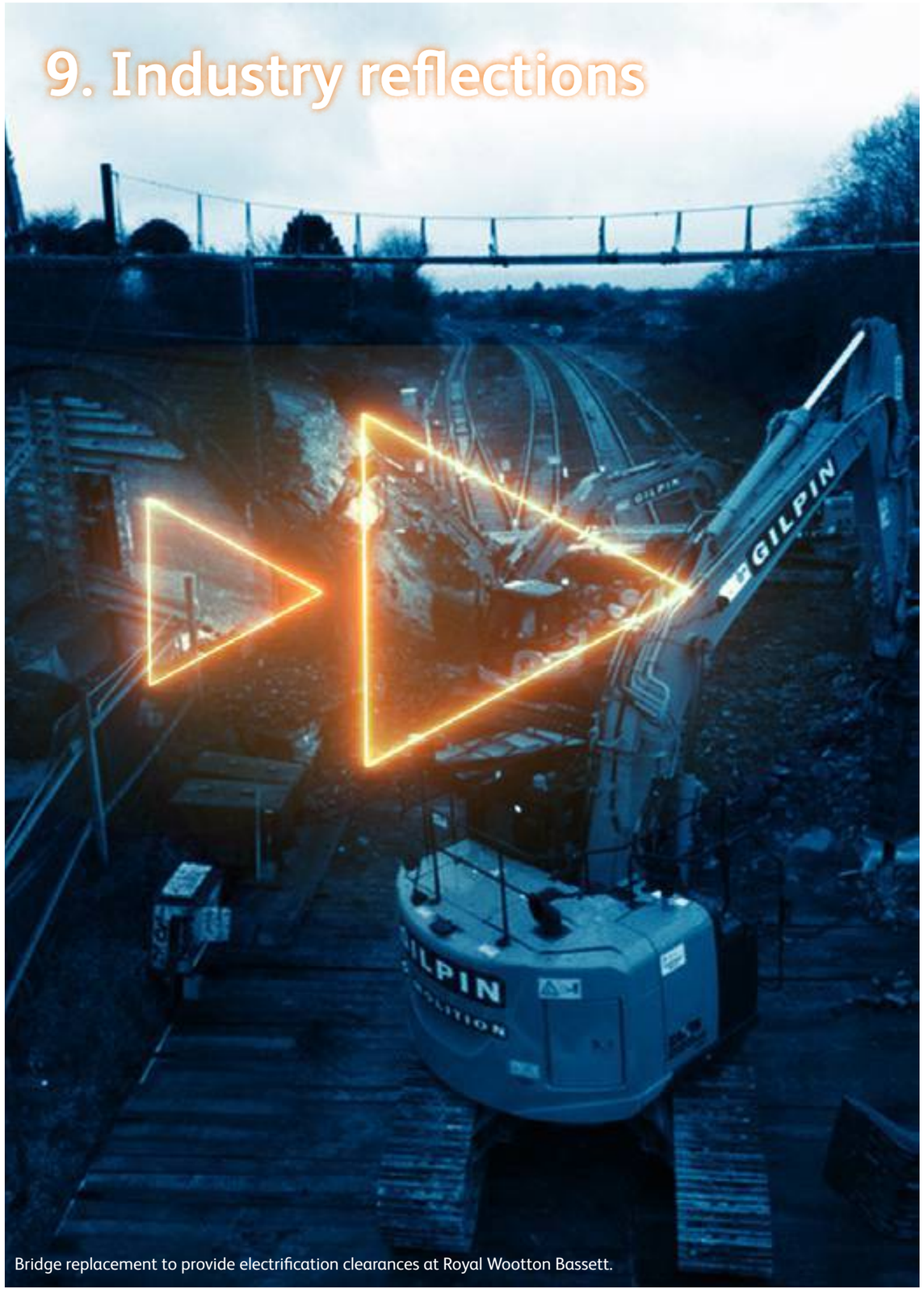


Photo: GWR

9. Industry reflections



Bridge replacement to provide electrification clearances at Royal Wootton Bassett.

Great Western Route Modernisation – Interim project completion report

9.1 Acknowledgement

The National Audit Office made it clear that both Network Rail and the Department fell short of what was required.

In 2016 the NAO reported[1] that: … *an increase in cost of £2.1bn since 2013 to £5.58bn, a delay to the electrification of the route of at least 18 to 36 months and recent changes to the new trains order means that the programme's value for money needs to be reassessed and the extent of electrification should be reconsidered.*

The NAO went on to say that: "*Network Rail's 2014 cost estimate was unrealistic and too optimistic about the productivity of new technology … Failings in Network Rail's approach to planning and delivering the infrastructure programme further increased costs.*"

Referring to the Department, the NAO said: "*before 2015, the DfT did not plan and manage all of the projects that now make up the Great Western Route Modernisation industry programme in a 'sufficiently joined up way" … the DfT did not produce a business case bringing together all elements of the programme until March 2015.*" [2]

Both organisations have learned, and changed, to avoid such problems happening in the future.

9.2 What went wrong?

In 2017 Mark Carne, Network Rail's CEO at the time, told the Public Accounts Committee: " … *if you start a big project really badly, it is really hard to get it back under control* … "

Efforts to improve the planning and delivery of rail enhancement had begun two years earlier, in 2015.

The Bowe review

In November 2015 Dame Colette Bowe reported against a background of enhancements 'costing more and taking longer' than forecast to deliver.[3] The report, which focused on planning rather than delivery, concluded that: "*there is no one overarching cause which explains the cost escalation and delays to projects and programmes … which if corrected would prevent it from recurring. Instead, a number of issues have combined … .*"

These issues were summarised as:

- planning processes … have been shown to be inadequate in the face of the scale and complexity of the CP5 programme…including … proposed electrification works on a scale not attempted before in the UK
- the definition of organisational responsibilities between the Department, Network Rail and the ORR. These were unclear, lacking the relentless focus and clarity required for … a major infrastructure programme
- the fact that the overall plans encompassed a complex portfolio of schemes, subject to poor scope definition from the outset and ongoing 'scope creep' which led to cost increases
- issues of effective internal programme and portfolio management, notably at Network Rail
- early costing errors, unanticipated interdependencies, lower than expected productivity and the failure to ensure agreed front end scope definition have also contributed.

The Hendy review

In November 2015 Sir Peter Hendy, Network Rail's Chairman, reported.[4] His review systematically examined every element of the enhancement programme reviewing costs and timescales, and establishing robust estimates of both, and resulted in improvements to projects plans and there are opportunities for further improvement as we move forward.

Sir Peter reported that the vast majority of projects were being delivered on time and on budget, but there were a small number of projects for which the forecast cost estimates were significantly higher than originally assumed, particularly electrification projects and several projects where the scope was poorly defined at the outset. His report identified two principal issues relating to the increased cost estimates:

1. inadequate planning and scope definition of a number of projects in their early phases
2. poor cost estimating, particularly on electrification projects.

1 Modernising the Great Western railway, National Audit Office (2016).
2 March 2015 was more than two years after ordering the trains and over a year after Network Rail began work to electrify the route.
3 Report of the Bowe Review into the planning of Network Rail's Enhancements Programme 2014-2019 (November 2015).
4 Report from Sir Peter Hendy to the Secretary of State for Transport on the replanning of Network Rail's Investment Programme (November 2015).

National Audit office review[5]

The Bowe and Hendy reviews were followed by a report from the National Audit Office (NAO), which offered a critical account of how the Great Western modernisation had been managed, highlighting both cost increases and delivery delays (see below). In summary:

- before 2015, the Department did not plan and manage all the projects which now make up the Great Western Route Modernisation industry programme 'in a sufficiently joined–up way'
- the Department entered into a contract to buy the intercity express trains, which created fixed deadlines for electrification when the infrastructure planning work was still at an early stage of development[6]
- the Department did not produce a business case bringing together all elements of the programme until March 2015, more than two years after ordering the trains and over a year after Network Rail began work to electrify the route
- Network Rail's 2014 cost estimate was unrealistic. It was too optimistic about the productivity of new technology. It underestimated how many bridges it would need to rebuild or modify and also the time and therefore costs needed to obtain planning permission and other consents for some works
- failings in Network Rail's approach to planning and delivering the infrastructure programme further increased costs
- Network Rail did not work out a 'critical path'—the minimum feasible schedule for the work, including dependencies between key stages before starting to deliver electrification
- it also did not conduct sufficiently detailed surveys of the locations for the structures, which meant that some design work had to be repeated.

The NAO found that delays to the electrification programme will cost the Department up to £330 million.[7] Some passengers in the north and west of England would have to wait longer, some nine months and up to two years respectively, to see improvements such as increased capacity in services because of the delays to the programme.

The NAO commented that Network Rail would have a challenging task to deliver the main benefits from the infrastructure programme within the current schedule and budget. It added that the value for money of the programme needs to be reassessed, and the extent of electrification reconsidered.

Public Accounts Committee review[8]

Network Rail told the Public Accounts Committee (PAC) that there had been many shortfalls in the design, planning and cost-estimating of the project and admitted that it had not fully understood the scale, complexity and difficulty involved until the end of 2015.

The Department told the PAC that the elements of the modernisation programme, particularly electrification and the interaction with investment decisions on new trains, were considered together but that no single business case was put forward. The infrastructure and new trains were seen as two linked projects[9], rather than 'one programme which needed to be managed as a whole.'

An integrated business case for the programme was produced in March 2015, but this was clearly too late to manage the cost pressures and risk to schedule delays the programme faced. In addition, the Department wrongly thought that an 18–month buffer between completion of electrification and introduction of new trains was sufficient. The Department acknowledged that this buffer was 'not enough' and it did not think of how the dependencies could be managed and risks reduced.

The Department told the PAC that a factor behind the lack of proper planning in the early stages of the programme had been the accountability arrangements. The Department specified its high–level requirements, whilst scrutiny of Network Rail's plans had been passed over to the Office of Rail and Road. The Department accepted this tripartite structure had been too complex and 'much weaker and less reliable than it thought'. The result was that the Department failed to challenge Network Rail and get the assurance it needed over Network Rail's ability to deliver the works to support the introduction of new trains in time and within budget.

5 Modernising the Great Western railway, National Audit Office (2016).
6 This, the NAO said, was exacerbated by the fact that Network Rail had only just identified that it would need to develop a new type of electrification equipment. The electrification timetable was not based on a bottom-up understanding of what the works would involve.
7 The Department would receive less income from the Great Western franchise between September 2015 and March 2019 because the train operator will bear the costs of providing extra trains and leasing depots, as well as higher running costs from operating diesel trains for longer, while also receiving less revenue from passengers than expected.
8 Modernising the Great Western Railway, Committee of Public Accounts, House of Commons, Forty-fourth Report of Session 2016–17 (2017).
9 This was particularly unacceptable, the PAC noted, since the contract for the new trains put the Department at risk of having to pay £400,000 to the company supplying the trains for every day the infrastructure was delayed.

As Mark Carne told the PAC: "*If I could have my time all over again and we were doing this project again, I would take even longer over the early phases of it, so that we could spend less time on the construction period … the early stages of this project were not carried out in an appropriate way. The initial design was incomplete. The cost estimating was not good enough … We started construction on this project before we had the permits and the consents because we had to in order to try to meet the schedule … Probably the no. 1 lesson that any project manager anywhere in the world will reiterate is, 'Get it right at the beginning and then you have a good chance of delivering it.'* "

The Public Accounts Committee made five recommendations:

1. **risk**—Network Rail must ensure that all risks to the project are identified, monitored and controlled and use this information to identify with the Department the critical path for the whole modernisation programme, setting out how the infrastructure, new trains and planned services will interact with each other by March 2017
2. **estimating**—Network Rail must improve its ability to produce realistic cost estimates, including making greater use of data from completed projects. Network Rail must make sure that robust and detailed plans, including a critical path, are in place for infrastructure projects before starting construction works and consider whether an Order under the Transport and Works Act would be preferable to multiple individual planning consents and other approvals
3. **assurance**—the Department must ensure that it has obtained suitable assurance over cost and deliverability before taking decisions on infrastructure investment and other major decisions which depend on infrastructure being available. It must set out how it will continue to develop its own programme management expertise, and how it will use this to monitor Network Rail's delivery
4. **planning**—the Department and Network Rail need to ensure that they plan major developments to rail services in a way which brings together trains, infrastructure work and the operation of services. As part of this, they should obtain independent assurance on the deliverability of their plans. We will expect to see this approach on forthcoming major programmes including the Midland Main Line and TransPennine upgrades
5. **business case**—the Department needs to reassess the case for electrification on a section by section basis and fund schemes only where worthwhile benefits for passengers could not be achieved otherwise at lower cost. In its new business case for the Great Western programme, which it expects to complete by the end of March 2017, it should reassess the extent of electrification, and it should also look again at its plans for the Midland Main Line and TransPennine routes.

9.3 Contributory factors

Approach to problem–solving

"*Whether you had summoned a plumber to fix a leak or invited an economist to advise on policy issues, you would hope that he or she would start with a diagnosis. You would then hope that the person has a box of tools from which it was possible to choose the right one or ones*." [10]

What was the diagnosis for Great Western? Principally, that journeys took too long. Journey time savings, monetised, were—it was assumed—a proxy for almost every other economic good thought likely to emerge. And the need for more seats to improve 'journey experience' (such as not being squashed into a crowded vestibule between Paddington and Reading). There would be benefits from reduced road congestion and lower greenhouse gas emissions—but those were consequences, not the primary aims.

But what wasn't diagnosed? The UK's deficit in agglomeration benefits was missed, which might have pointed to the value of expanding local rail by making use of the newly–electrified lines, added capacity–increasing measures where needed.[11]

The diagnosis failed to account for more trains terminating at Reading—both Elizabeth line services and, if Western Rail Link is funded, a new Heathrow service. And it missed the factors that caused GWR to experience the patchwork of ridership growth mentioned in chapter 5.

What about our tool box? It included new trains, of course, along with new depots and extended platforms. And electrification so that trains can accelerate better, which is how journey times are reduced. It included unblocking the critical 'pinch points' at Reading and Filton too, without which, little improvement would have been possible. Our new bi–mode trains for longer–distance services can run 'beyond the wires' on diesel power—a capability that has proven very helpful indeed.

10 Radical Uncertainty, John Kay and Mervyn King, p385 (2019).
11 But a need for greater connectivity *was* diagnosed in Cornwall—and was rewarded by ridership increases—showing the value of stakeholder input.

But it's interesting to look at what *wasn't* in the tool box. The programme, after all, was designed to deliver assets—electrification in specific places, and a new type of train—rather than outcomes.

The took box lacked an efficient rolling programme of electrification west from Maidenhead, which a full bi–mode fleet would have supported. It contained no simple off–the–shelf pure–electric train operating 'under the wires' all the way—a solution that worked in Scotland—offering lower capital (or lease) cost and greater reliability.[12]

It was presumed that a bespoke train with distributed traction would be best. And there was a presumption against locomotives[13], either as 'power cars' or in a more limited role hauling EMUs 'beyond the wires'.[14]

We had no long–term solution for the Didcot – Oxford corridor. Neither the proposed four–tracking between Radley and Oxford, nor a third phase to accommodate East West Rail at Oxford, sat in our 'tool box'.

Critically, we had no alternative 'programme architecture', which might have allowed us to consider other ways of achieving our aims—a Development Consent Order or Hybrid Bill, for example, as an alternative to over 1,800 separate consents. And we did not understand the role of complexity upon major programmes—information which might have counselled us to simplify development and delivery of Great Western electrification.

And, prior to the Investment Decision Framework, we lacked an industry programme paradigm that demanded cognizance of TRIFO (i.e. Timetable—Rolling stock—Infrastructure—Franchise—Operations).

The bi–mode train conundrum

"*Engineers would scorn any suggestion that, because generator sets are now more efficient, consumers can generate their own electricity at home and do away with ugly power transmission lines. No–one is making such a far–fetched proposal, but similar thinking has been used to justify halting railway electrification in England and Wales.*" [15]

Although electrification offers significant benefits, installation is inherently costly. Hence government has often been reluctant to invest in electrification which has been done on a boom–or–bust basis since the 1950s. Following cost increases, considerable elements of Great Western electrification were cancelled or deferred. But the government's announcement did not mention cost. Instead, the House of Commons was advised that "rail technology is advancing quickly" and that bi–mode train technology meant that journeys "could be improved without the need for electrification work".

The Department maintained that the decision to defer electrification will have "little, if any, impact on the benefits of this programme to passengers" as many of the benefits, including more trains per hour, journey time savings and more seats, "do not depend on electrification".[16] As the National Audit Office commented, the Department's claim that nearly all the benefits for passengers can be achieved without full electrification of the route cast doubt on the value for money of Great Western and other electrification schemes.[17]

The Department stated that wider benefits, such as reduced operating costs and environmental benefits, would only be marginally impacted by the decision. But this excluded several factors, amongst them air quality in places like Bath, Bristol and Oxford, and the inherently lower reliability of bi–mode trains compared to pure electric trains. It also failed to recognise the growing imperative of addressing the UK's climate change commitments.

This raises the question, as noted by the NAO: why electrify at all? Were passenger benefits the only criteria, electrification might only be justified where it would enable busy trains running several times an hour to make significantly faster journeys. In that case, the scope for further electrification would be limited. But running costs do matter, especially where pure electric traction is possible. The greater reliability of pure electric trains is significant. And the UK has signed up to a legally–binding commitment to achieve net zero emissions by 2050.

Bi–mode trains usefully provide through journeys to locations beyond the electrified network where it is difficult to justify electrification, or there has not been time or funding to electrify. But it is wrong to use these trains as an

12 Southeastern's Class 395 high–speed EMUs have achieved an MTIN MAA of 50,000 miles compared to the IETs 8,500 to 14,400 miles. Modern Railways (January 2020).
13 Amtrak and Long Island Railroad operate bi–mode locomotives with high power output in both modes, and Talgo offers a bi–mode fixed formation train with power cars.
14 Global best practice suggests that distributed traction is the superior choice for electric passenger trains, offering greater flexibility, lower weight (hence energy usage) per seat, and superior regenerative braking performance. The situation for diesel traction is more complicated, and it has been suggested that locomotive–hauled diesel trains are more cost–effective than DMU consists longer than around five cars, placing longer IET consists around the transition point. Arguably, a case may have existed for diesel locomotive haulage of EMUs 'beyond the wires' for shorter distances (e.g. Swansea to Carmarthen), but not for diesel or bi–mode 'power cars'. There may also have been an argument for electrification to, say, Cheltenham and Weston–super–Mare to take advantage of the lower cost and greater performance of EMUs.
15 Why does the government keep halting rail electrification schemes? IMechE (2019).
16 It was even claimed that passengers would not notice the transition from electric to diesel power, which presumes that most people are not particularly observant. Although well–insulated, the 560kW engines below the floors of most IET carriages do generate noticeable noise and vibration.
17 Modernising the Great Western railway, National Audit Office (2016).

excuse not to electrify. In diesel mode they suffer from the same cost and carbon disadvantages as diesel–only trains. And, in diesel mode, their lower acceleration limits their ability to reduce journey times (as Figure 19 shows).[18]

In 2018 the government told the rail industry to reduce emissions by developing new traction technologies to enable all diesel–only trains to be off the tracks by 2040.[19] With electric traction powering 72 % of the UK passenger fleet, this is already the case on many routes. Hydrogen trains are a solution for non–electrified lines, but are unsuitable for routes that require high speed and acceleration. Battery trains are suitable for shorter journeys that allow frequent recharging at termini. But there is no alternative to electrification for services fast services on busy main lines.

We must recognise the value of using the partly–electrified intermediate state enabled by bi–mode trains to establish an efficient approach to electrification. Electrification takes time. There will be a significant interim phase where longer journeys will benefit from bi–mode trains, which are a stepping stone towards full electrification of major routes, supporting an efficient rolling programme of electrification that will help take the UK towards its commitment to achieve net zero emissions by 2050. Completion of GWEP is not the 'end of history' for the route.

And we should seek to understand the implications of uncertainty (which is different to risk) as we develop programmes. We need flexible, scalable solutions which can provide an agile response to changing circumstances.

9.4 What we're doing differently

Memorandum of Understanding

In March 2016 the joint Department for Transport – Network Rail Memorandum of Understanding (MoU) responded to the recommendations of the Bowe Review by clarifying the roles and responsibilities of the Department and Network Rail in the delivery of Government–funded rail enhancement projects. It brought changes in six areas:

1. **roles**—establishing the Department is the principal client and funder of enhancements, defining the outcomes that the investment is expected to achieve, and the requirement for an appropriate business case in line with Treasury guidance. Network Rail is the railway system operator and infrastructure manager and a significant deliverer of railway infrastructure upgrades
2. **planning and delivery: lifecycle and joint decision gateways**—establishing a shared lifecycle for enhancements covering development, design and delivery. This supports a continuous planning approach and moves away from an overly rigid 5-year cycle for enhancement planning linked to Railway Control Periods. Three gateways are introduced (Strategic Business Case, Outline Business Case, Full Business Case) subject to which, if funding is available, the Department will commit funds to scheme development, design and delivery
3. **joint governance**—establishing new arrangements to govern the enhancements lifecycle at portfolio, programme and project levels, including programme boards to make decisions at the lowest possible level of governance
4. **baseline and change control**—in the light of the 2015 Hendy Review, a detailed baseline would be agreed and then be subject to change control
5. **management information**—the Department and Network Rail will work with a single version of the portfolio, programme and project management information. Network Rail will ensure this information is appropriate, timely and accurate
6. **assurance**—will be provided by robust challenge of data in management and programme boards, ensuring that governance groups are provided with accurate data, which all parties can be confident in. This will include assurance from independent, competent, bodies Network Rail will share with the Department the results of any internal assurance, including audit reports, of its scrutiny of costs and output delivery.

Investment Decision Framework and Programme Delivery Lifecycle [20]

Network Rail has introduced the Investment Decision Framework (IDF) for the delivery of railway enhancements from long term planning through to the initiation, development, and delivery of the programme including the Programme Delivery Lifecycle (previously known as GRIP for Programmes).

The IDF allows Network Rail to work across the industry with its funders and investors to make joint investment decisions for interventions that enhance the railway. It positions investment in the context of railway outputs and service change delivered through timetable, rolling stock, infrastructure, franchise, and operational changes.

18 Under diesel mode, IETs only have about 60 % of the traction power available in electric mode, and their top speed is lower.
19 The announcement was made by the transport minister,at the time, Jo Johnson.
20 Investment Decision Framework and Programme Delivery Lifecycle, Level 2 Business Process, Network Rail (2019).

The IDF describes an approach that relies on having the right information at the right time guided by the requirements of Treasury Green Book which describes the three stages of business case maturity.[21] It provides the governance arrangements for undertaking three incremental investment decisions that can be made in a transparent way recognising the needs of funders and investors.

Network Rail has also improved its approach to managing programmes—the Programme Delivery Lifecycle—helping to minimise and mitigate the risks associated with delivering programmes that enhance the operational railway. This replaces the previous GRIP for Programmes lifecycle.

Rail Method of Measurement

Since 2015, based upon practical experience gained on Great Western, and in Northern England and Scotland, Network Rail has devoted much effort into understanding the cost of electrification. The Rail Method of Measurement, Network Rail's cost planning tool, has been updated. Section 10.2 gives further information.[22]

Enhancements Framework[23]

The Enhancements Framework reflects a joint endeavour between the Department and Network Rail to address challenges identified with the current approach to enhancing the Railway. The Framework focuses on describing two aspects of Railway Enhancements:

1. achieving change / enhancing the Railway in an integrated way
2. the role of Infrastructure, as one aspect of enhancing the Railway.

It is an evolution of previous work, which related specifically to Infrastructure Enhancements and was captured in the Enhancements Memorandum of Understanding.

The Enhancements Framework covers:

- how the Industry comes together to integrate Timetable, Rolling Stock, Infrastructure, and Franchising and (train) Operations (TRIFO) to achieve railway outputs[24]
- infrastructure enhancement programme and requirement integration
- infrastructure integration with operational (train services and infrastructure) activity.

The Infrastructure Enhancements Framework specifically aims to address the three challenges to identifying, developing and delivering infrastructure enhancements:

1. **unclear accountabilities and responsibilities across the enhancement lifecycle**—the framework provides simplified, single line of accountability for enhancement; roles have distinct responsibilities; there is flexibility to adapt to different scenarios (e.g. for different funders & delivery models), there is a requirement to consciously select organisations to perform identified roles; and changes to terminology to clarify organisation boundaries
2. **Network Rail is not joined–up with the Department's decisions around rolling stock and franchising at which impact whole system outcomes**— the framework provides clear articulation of where infrastructure contributes to whole railway activity, and the boundaries and limitations of this; and this becomes the agreed model for achieving a VfM outcome for the Accounting Officer
3. **a lack of trust and transparency**—the framework provides the basis for clarity between parties, creating a foundation for trust and transparency.

Putting Passengers First

Network Rail is changing to be more responsive to the needs of passengers and freight users. The Putting Passengers First (PPF) programme is supporting Network Rail's ambition to have the skills, culture and focus to put passengers and freight users at the core of everything it does.

As part of the programme, capabilities and teams are moving to the right part of the organisation to be closer to the customer, bringing track and train closer together. These organisation changes are been implemented in phases and the new operating model is expected to be in place by the end of 2020.

21 The Strategic Outline Business Case (SOBC), Outline Business Case (OBC), and Final Business Case (FBC).
22 Sir Peter commented that Network Rail has not carried out any electrification of significance for 20 years, so there was limited information to support cost estimates, adding that is was clear that some of Network Rail's early cost estimates, particularly for electrification schemes, were inadequate.
23 Enhancements Framework Version 1.01, Capital Delivery Improvement Programme: DfT & NR Joint Workstream 1 (2018).
24 It does not address in detail the roles of timetabling, rolling stock, franchising or operations in achieving change on the railway—it covers simply how these elements are integrated with infrastructure change.

The operating model aligns the whole of Network Rail to support customer outcomes with 14 routes supported by five regions, two service functions and six network functions. The regions and functions each have a clearly defined purpose. Information about the organisation changes delivered so far is available in Briefing packs.

The regions, services and functions are now preparing for further locally–led changes in the Summer and Autumn of 2020 to achieve their target operating models to drive up performance and deliver for their customers.

Complexity

Complexity is a measure of the delivery environment of an infrastructure programme, and is one of the two key variables driving the cost of development.[25] Sponsors, working with funders, delivery agents and others, have the opportunity to influence the benefit realisation, cost, schedule and inherent 'riskiness' of infrastructure programmes through optimising their delivery environments. This depends upon early assessment of complexity—the Investment Decision Framework makes programme sponsors accountable for this assessment.

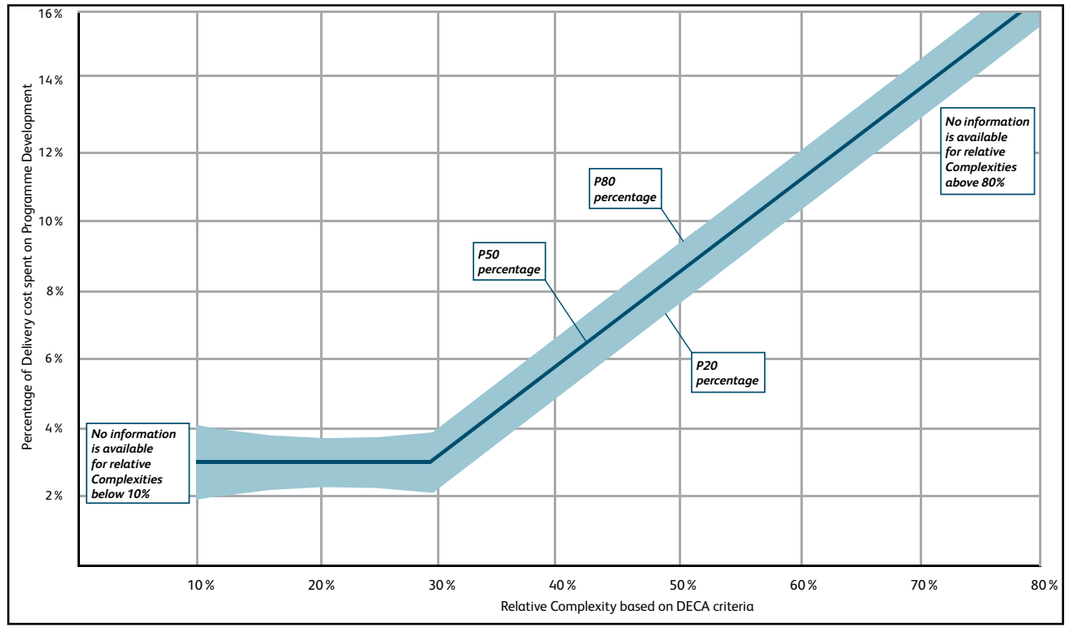
The terms 'complicated' and 'complex' are not interchangeable. Complication is a measure of the technical difficulty and scale of a programme. Complexity, in contrast, is a consequence of relationships and their organisation, diverse requirements, interconnection, and evolution. Research has shown that complex systems cannot be understood solely by simple of complicated approaches to evidence, policy, planning and management.

Complexity is assessed by considering a combination of contributory factors that are defined by the Delivery Environment Complexity Analysis (DECA) methodology.[26] The DECA is owned by the UK Infrastructure and Projects Authority (IPA), and is endorsed by Network Rail.

Complexity has been observed to vary considerably, leading to programme development costs ranging from less than 2 % of Delivery cost to over 15 % of delivery cost.

Figure 29 illustrates the results of a Network Rail study[27], and shows how the cost of development of a programme responds to complexity. In this chart, 'relative complexity' is used to give a scale of 0 to 100 %. Development cost is compared to delivery cost, rather than Anticipated Final Cost (AFC), to avoid circularity.

Figure 29: Relationship between percentage of delivery cost spent on development and relative complexity



25 Development is taken as the total cost to reach a Final Investment Decision, excluding delivery costs brought forward (such as land purchase). Broadly it conforms to GRIP 1 to 4, plus pre-GRIP costs, although it must be emphasised that the IDF is independent of GRIP.
26 The DECA criteria are: Strategic importance: Financial impact; Stakeholders; Dependencies; Context; Extent of change; Organisational capability; Interconnectedness; Requirements and benefits; Technologies; Interfaces; and Disciplines and skills.
27 The cost of Programme Development: Guide to applying a benchmark, Julian Ross, Network Rail (2019).

Figure 29 shows how lower levels of complexity can achieve considerable savings in development cost. Whilst assessment of development cost versus delivery cost is greatly complicated by scope change, benchmarking by Network Rail suggests that Great Western electrification spent around 15 % of delivery cost on development, whereas rolling electrification in Scotland spent around 2 % to 3 %. Other 'complex' programmes have spent large sums on development[28], which suggests a 'premium' of around one tenth of programme cost for a 'big bang' approach over a rolling programme. Learning during a rolling programme will deliver further savings.

9.5 Rolling programmes—a lesson from Scotland

Devolution has brought progress to Scotland's railway.[29] One of the Scottish Government's objectives is to create a greener Scotland. Clearly, electrification enables the creation of a greener country hence the rolling programme. Having a technically capable and regionally aware client in Transport Scotland was a major contributor to the success of electrification in Scotland. A client who funds Network Rail Scotland separately and has two franchises to manage can be very focused. Localism, being close to the action, seeing what the railway does and the benefits that it creates, is arguably a good model.[30]

As with Great Western, electrification is transforming the railway by increasing the number of seats, reducing journey times and cutting emissions. Passengers have noticed the difference—people want to travel by electric train.[31] Airdrie – Bathgate started off in 2010 with six–car sets, for example, and now passengers can struggle to get a seat on some services because of the growth. Similarly, in busy times the Paisley Canal route is standing–room only now whereas before electrification there was plenty of room.[32]

Transport Scotland views its railway as a system. Not only must electrification be installed and electric trains bought, depots must be improved, rolling stock cascaded, crews trained, platforms lengthened, and so on. In Scotland the railway found that having a lower volume of consistent activity is better than having peaks and troughs. A core team has rolled from one project to the next, bringing deep knowledge with it, if not by design then certainly by default.

With a rolling programme of electrification since the mid–2000s, Scotland has benefited from Network Rail and its suppliers being responsive to change, such as alterations to technology or legislation. The Shotts scheme showed that, with scope firm before a contract is let, delivery can be efficient. And Network Rail Scotland now has a single electrification team, a one–team approach that improves programme management.

To grow a strong base of engineering talent, the supply chain needs a reliable flow of projects. With boom and bust comes frequent personnel changes, and this has often been a serious challenge for Network Rail projects south of the border. Scotland managed to attain a true rolling programme: after electrifying to Larkhall in 2005, suppliers moved onto West Coast Route modernisation, then Airdrie – Bathgate, after that Paisley Canal and then Rutherglen – Coatbridge. Edinburgh – Glasgow via the remaining three routes, Shotts, and Stirling – Dunblane – Alloa followed.

Development was cheaper too. The rolling electrification schemes in Scotland typically spent around 3 % of their budget in development—the planning and design that precedes a Final Investment Decision—compared to as much as 15 % spent on developing Great Western electrification.[33]

9.6 Business case

The point of a business case is to guide decision–makers. But the value of a business case is constrained by a number of factors: ideology, uncertainty, completeness, knowledge, and assumptions.

Ideology

The owner of a business case has an ideology—whether acknowledged or tacit—concerning what the business case can tell them and how that information may validly be used.

28 Thameslink is estimated to have spent a sum equivalent to 13 % of delivery cost on development and the Crossrail On Network Works spent an estimated 10 %.
29 The sparks effect: remembering how and why railway electrification works Gareth Dennis, The Medium, 2019.
30 Alex Hynes, managing director of the ScotRail Alliance.
31 This isn't a new phenomenon. British Rail was well aware of the rapid growth in passenger numbers that followed the introduction of electric trains.
32 Iain McFarlane, Network Rail's delivery director for Stirling – Dunblane – Alloa electrification.
33 Benchmarking programme development study, Network Rail (2019). The actual cost of developing Great Western electrification is hard to assess because of the many changes to cost and scope, and development work carried out during delivery (such as some surveys). but 15 % is thought to be a reasonable assessment. For comparison, Thameslink spent around 13 % on development, and the Crossrail On Network Works spent around 10 %.

Gary Becker, successor to Milton Friedman at the Chicago school of economics[34], wrote: "*The combined assumptions of maximising behaviour, market equilibrium, and stable preferences, used relentlessly and unflinchingly, form the heart of the economic approach.*" This approach underpins much modern economic theory.

On this John Kay and Mervyn King comment that: " … *the assumptions of optimisation, equilibrium and stationarity[35] are useful as part of small-world approaches to constructing models that throw light on a problem … but such models provide only partial insight into human behaviour in large worlds.*" [36]

A business case, therefore, cannot represent 'the world as it really is', but is a tool for exploring ways in which a decision might or might not go wrong.[37]

But the Great Western business case—when it appeared, six years after electrification was announced— was assumed to fully represent all relevant information about the programme.

Uncertainty

We are used to solving 'puzzles', which can be analysed. The very assumption that a problem is soluble brings comfort. But there are also 'mysteries'—the 'unknown unknowns' which are fundamentally uncertain. Mysteries are not risks because we know too little to allocate statistical probabilities to them, let alone costs. Instead they are uncertain, in their nature and the outcomes that they bring—often radically so.

As a foundation to their treatise on radical uncertainty[38], John Kay and Mervyn King made three propositions:
1. economics, business and finance are 'non–stationary'—i.e. they are not governed by unchanging scientific laws
2. individuals cannot and do not optimise, and nor are they irrational[39]
3. communication plays an important part in decision–making.

Much is non–stationary. It is uncertain how people will travel in future, and how much, with Covid–19–induced home–working, 5G communication, cheap–to–run electric cars, mobility–as–a–service, the UK's economic situation, and so on in the mix. We do not know how travellers will perceive benefits in future (i.e. we don't know how to value their time[40]) or, indeed, whether new benefits will become evident. And how stakeholders along the route will perceive the value of investment is unclear. So any transport business case will, at best, represent an approximation—if based upon sound assumptions.

Cost is inherently uncertain early in a programme because we have limited knowledge and—if we are careless—there might be insufficient planning, poor organisation, and sheer optimism. But the Department and Network Rail can mitigate this, and are doing so, as described in Section 9.4. Engineering is, after all, essentially stationary. Uncertainty is arguably more of a threat to the benefits side of the business case and, more particularly, to the assumptions upon which projects are authorised or rejected.[41]

People are rational—they will take an electric train, or invest close by a station, if that appears advantageous to them. Advantages might mean quicker, quieter, ease of finding a seat, greater frequency, fewer cancellations, a greater range of jobs and employees within a comfortable commute, all of these, or something else. Where changes are transformational, beliefs change (train travel becomes a new option, for example), introducing non–stationarity.

And people talk—train operators advertise better services, passengers talk to friends, business leaders discuss where to invest. Decisions to travel by train or build a new office by a station do not result from people 'optimising utility'. Stakeholders and users behave differently because of the change—their behaviours are non–stationary—invalidating a key assumption underpinning neoclassical economic modelling.

34 The Chicago school of economics is a neoclassical school of economic thought associated with the work of the faculty at the University of Chicago. Neoclassical economics tends to be based upon three premises: 1) people have rational preferences between outcomes that can be identified and associated with values; 2) individuals maximize utility and firms maximize profits; and 3) people act independently on the basis of full and relevant information. This is in accordance with rational choice theory, which has come under considerable question in recent years (for example, it is challenged by behavioural economics).
35 Non–stationarity refers to the proposition that economics, business and finance are not governed by unchanging scientific laws. Instead, important challenges result from unique events that must be interpreted individually, leading to judgement about what should be done.
36 Radical Uncertainty, John Kay and Mervyn King, page 382 (2019)
37 Public investment in major projects is designed to generate large volumes of benefits, generally bought at a high capital cost. They do not generate the high rates of return that provide a measure of security to the sounder private sector investments. Hence the benefit to cost ratio will be dramatically affected by a major change to cost. One might have expected greater sensitivity testing of Great Western electrification's BCR.
38 Radical Uncertainty, John Kay and Mervyn King, page 382 (2019)
39 In other words they do not calculate how to obtain the greatest utility for their resources (and lack the 'perfect knowledge' to do so), and they are not victims of 'biases' that describe how they deviate from 'rational' behaviour.
40 Value of time, the keystone of rail project benefits, is an assumption. Moreover, it's an assumption that has changed and will, presumably, change again. Such changes—to artificially created assumptions—can (and do) greatly modify benefit to cost ratios.
41 The deferrals and cancellations of 2016 and 2017 were based upon a limited and temporary certainty—that Network Rail and the Department had made a mess of implementing Great Western modernisation. But a new rigour has emerged—as described in Section 9.3.

And, finally, what is net–zero worth? Can an existential threat like climate change even be allocated a financial cost? This goes well beyond such calculations as assessing the economic loss of the railway at Dawlish is washed away. There is a fundamental non–stationarity in the value of a net zero economy and, therefore, in the benefits attached to an electrified railway. But how will the value of electrification increase as the imperative of 2050 approaches?

Completeness

One thing has, until now, seemed certain at a qualitative level—rail ridership rarely fails to increase when significant improvements are made. Indeed, those increases often exceed expectations.[42] Why might this be?

The Department's business recognise 'welfare' benefits and wider economic impacts. Within welfare analysis, economic impacts are primarily captured by the estimation of user benefits, for example as a result of time savings.

Under a well–defined set of circumstances, user benefits will capture the entire welfare effects of a transport investment. However—the Department notes—if there are 'distortions' or market failures that mean the economy is not functioning efficiently, additional benefits (or disbenefits) will arise as the impact of transport improvements is transmitted into the wider economy. These are termed wider economic impacts.[43]

Distortions can mean that the full welfare impact of a transport investment may not be reflected in the transport market. Conversely, if a transport scheme reduces distortion, it can liberate wider benefits.

Bristol suffers considerable road congestion—a 'distortion' to the local economy. The Great Western business case includes road decongestion benefits. But what about agglomeration—the 'bringing closer together' that better train services could provide? With easier travel between Bristol, Bath, Reading and London (for example), productivity might be expect to improve. Construction of major office developments in the vicinity of Bristol Temple Meads station infers the importance attached to the connectivity that rail provides.

And what about Great Western Route Modernisation as an enabler of MetroWest?[44] In effect, a part of the capital cost needed to achieve the benefits of another transformative project—MetroWest promises a substantial improvement to connectivity—has already been incurred.

Economic growth forecasts differ along the route. Exeter, with a thriving local rail service, is forecast to achieve greater growth than Plymouth. To what degree do more frequent train services, giving more seats, support the economy of the arc between Exmouth, Exeter, Dawlish, Newton Abbot and Paignton? Does the improved train service make the area more attractive to holidaymakers—even those who drive there make local trips by train.

GWR reports significant growth in ridership, exceeding 20 % in some cases, implying that modernisation reduced 'distortion'. Crowded and infrequent trains had suppressed demand. We have already noted that people are 'rational', communicate, but do not 'optimise'—hence the impact of modernisation could be greater than simple demand elasticities predict. The patchwork of ridership increases (which are not uniform) also infers that we don't 'know what is going on here'.[45]

And, as mentioned in the preceding section, people are rational but not utility–maximising. And people communicate—one traveller to another, train operators to potential travellers, and the media to all. Their reactions to improvements, particularly those that are transformational, might not be defined by the neoclassical economist's tools of value of time and demand elasticity.

Knowledge

The Department's first overall business case for Great Western Route Modernisation was created in March 2015 to justify decisions already taken—to electrify Great Western and to buy IETs.[46] This was revised *ex post facto* in June 2017 to take into account changes to costs and benefits. The two iterations are summarised in Figure 30.

42 For example, British Rail was well aware of the 'sparks effect' which increased ridership following electrification—and so is ScotRail today. Traffic on Borders Rail dramatically exceeded demand forecasts. The few failures are insignificant: the brief reopening of Watford to Croxley Green and TfL's Epping to Ongar line to all–day train services, involved infrequent services on peripheral lines prior to the large rise in rail patronage that occurred from the early 1990s.

43 Wider Economic Impacts Appraisal, TAG UNIT A2.1, Department for Transport (2016).

44 Additional tracks installed between Bristol Temple Meads and Bristol Parkway are essential to projected new MetroWest services.

45 A more granular approach—rather than top–down economic modelling—might reveal why more people have started to travel by train, and how we could encourage even more people to do so.

46 It has not been possible to locate a copy of the detailed business case document.

Great Western Route Modernisation – Interim project completion report

Figure 30: Business case for the Great Western Route Modernisation industry programme[47]

Type of benefit / cost Value	March 2015 (£m 2010 prices)	June 2017 (£m 2010 prices)	Change (%)
Faster journey times	3,416	3,241	(-5.2)
Reduced crowding	510	507	(-0.6)
Enhanced journey quality	149	142	(-4.7)
Non–user benefits (reduced carbon emissions / road decongestion)	2,003	1,657	(-17.3)
Indirect tax	(-942)	(-821)	12.8
Present value of benefits	5,136	4,726	(-8)
Operating costs	(-4,221)	(-4,145)	1.8
Capital costs	(-2,636)	(-4,470)	69.6
Revenue	4,684	4,183	(-10.7)
Present value of costs	(-2,173)	(-4,432)	104
Benefit:cost ratio	2.4:1 (high VfM)	1.07:1 (low VfM)	

Lower benefits result from changes to assumptions about journey purpose, value of time, and inflation. Had these not changed, the June 2017 benefit:cost ratio would have been 1.16:1. Had costs been 20 % lower, or benefits 12 % higher, the BCR might have exceeded 1.3:1.[48]

TAG states that appraisal results can be shown under three different levels. Only Level 1 was shown in the GWEP business case[49], which originally showed high value for money without taking into account wider economic impact.[50]

Assumptions

Great Western electrification's well–publicised cost increase was not the only factor to negatively impact the business case. Indeed, whilst cost increased dramatically, modelled benefits fell—although passenger numbers remained buoyant.

When comparing these iterations of the business case, it must be remembered that five separate factors changed between 2015 and 2017, each with a significant negative effect:

- **the capital cost of Great Western electrification**— the programme AFC for Great Western electrification increased substantially , from £2,716m in October 2013 to £5,576m in August 2016[51]
- **the capital cost of the Intercity Express Programme**— the Department's decision to equip all IETs as bi–modes also added to the programme cost, albeit as a consequence of delay to Great Western electrification
- **value of time (VoT) assumptions**— the Department made changes to the VoT estimates in the TAG Databook (November 2016), as shown in Figure 31. There was a 9 % reduction in the 'rail business' category, a 46 % increase in the 'commuter' category, and a 25 % reduction in the other category. This had a significant effect on benefits because commuter trips account for only 30 % of all journeys across the Great Western route
- **journey purpose and ticket type assumptions**— the journey purpose and ticket type splits used in the 2015 appraisal were taken from the 2010 National Rail Transport Survey. Those used in the 2017 appraisal are based on updated information provided by the DfT from the Rail Demand Forecasting Estimates study. There are large differences, as shown in Figure 32, with commuting falling from 63 % to only 36 % of journeys
- **inflation assumptions**— downward revision to the RPI values in the 2016 TAG Databook has been lower than downward revision to the GDP deflator values, resulting in a lower uplift to benefits and revenues converted to nominal prices compared to benefits and revenues included in the 2015 appraisal.[52]

47 Prior to 2015, no business case existed for the GWRM industry programme. In the March 2015 business case, capital costs do not include the subsequent £1.2 billion increase in the estimated cost. In both cases, costs and benefits do not include the full costs of maintaining the infrastructure. All costs and benefits are discounted to a 2010 base, and are in 2010 prices (as measured by the Gross Domestic Product deflator). Department for Transport, Business case for the Great Western Route Modernisation programme

48 Benefits in the 2017 analysis would need to be 12 % (approximately £0.6bn) higher, or costs 22 % (approximately £0.8bn) lower for the programme to attain a 'pass mark' BCR of 1.3:1. Given that delays cost the Department £0.3bn and that rolling electrification in Scotland spent a sum equivalent to around 3 % of delivery cost on development versus Great Western electrification's 15 % (with 12 % of the AFC of Great Western electrification at almost £0.4bn), it might be concluded that GWRM might have attained a BCR exceeding 1.3:1 even without the benefits of wider economic impact and the cost savings driven by learning within a rolling programme.

49 Wider economic impact is excluded from the Department's standard Analysis of Monetised Costs and Benefits (AMCB) format, which is the basis for the table above. Cost–Benefit Analysis, TAG Unit A1.1, Department for Transport (2018).

50 Network Rail now uses the Department's WITA software to calculate Level 2 benefits for projects where we can prove a market failure exists and there is no displacement of benefits from elsewhere.

51 Modernising the Great Western railway, National Audit Office (October 2016).

52 Great Western electrification project business case: phase 1 report, CH2M. (June 2017). The degree of impact is not quantified.

Together, the changes to VoT and journey purpose resulted in an overall fall in the estimated overall journey time benefit—journey time savings are the largest single component of the industry programme's benefits.

Figure 31: Values of time in 2014 TAG and 2016 TAG versions (£/hour, 2010 prices)

	Rail business	Commute	Other
TAG 2014	31.96	6.81	6.04
TAG 2016	29.18	9.95	4.54
% change	-9 %	+46 %	-25 %

Figure 32: Journey purpose in the 2015 and 2017 appraisals

	Work	Commuting	Other
2015 appraisal	13 %	63 %	25 %
2017 appraisal	15 %	36 %	50 %

The assumptions to adopt a 'big–bang' approach rather than a rolling programme, and to exclude wider economic impacts, have already been discussed.

Implications

The point of a business case is to guide decision–makers. But the Great Western business didn't consider some useful choices, limiting the options available to decision–makers, and assumptions around market efficiency and stationarity might have resulted in the omission of valuable benefits.[53]

There was no comparison between a 'big–bang' approach and a rolling programme of electrification enabled by bi–mode trains. Nor was the option of an electric railway operating captive pure–electric trains presented. Either might have saved the taxpayer money.

Wider economic benefits weren't included, despite the existence market failures which include congestion in the West of England and poor roads in the South West. Indeed, recognition of agglomeration benefits might have led to modification of the scope of modernisation.

Non–stationarity wasn't taken into account. Given more capacity, train operators will seek to fill it with fare–paying passengers. Parking at stations could be increased (as GWR has done at Didcot Parkway, amongst other stations) and bus connections improved, supporting more people travelling by train.[54] Businesses might invest, and people relocate, as a result of transformational change. All point towards greater benefits.

Independent advice to decision takers, akin to that provided to the MoD by the Cost Assurance and Analysis Service (CAAS), might have led to the original proposals being challenged.[55]

UK national policy is tilting towards net zero and economic rebalancing, and the UK's regions seek to grow. Railway assets last a very long time—we're still running trains along Brunel's route—and investment today will influence many generations to come. If the UK's response to global warming requires a new equilibrium, such as shifting from car to train, we will be grateful for the advice that electrification 'is a good thing'—and perhaps wish that we'd done more of it, irrespective of the numbers in a 2017 business case.

And if the UK is serious about rebalancing its economy, a core of electrification (and associated power supplies) in Bristol and Cardiff will be found very helpful indeed when it's time to expand local rail services.

53 Decisions can only be as good as the information available at the time. One might add 'informed by experience', but the paucity of electrification in the two decades prior to the Great Western decision left the UK short on experience.

54 Multi–modal improvements would require a more extensive business case taking into account the costs and revenue associated with (for example) operating more buses.

55 The Cost Assurance and Analysis Service (CAAS) is the MOD's centre of excellence for pricing and costing support to the Acquisition Community, enabling continuous improvement of the acquisition process, risk reduction, and ensuring best value for money for Defence.

Great Western Route Modernisation – Interim project completion report

9.7 The UK industry's view

In February 2020 the Railway Industry Association (RIA) wrote to Transport Secretary Grant Shapps, saying that: "*[Taking] diesel trains off the network*[56] *… will require a rolling programme of electrification for intensively used lines, and for regional and rural lines the development of new technologies such as hydrogen, battery and the use of clean bimode and trimode trains, which the industry is ready to deliver.*"

After pointing out the key advantages of electrified railways—they are better for the environment, non–polluting at point of use, quieter, cheaper to run, reduce journey times, and more reliable—the RIA pointed out that the UK is at a critical time for rail electrification, saying: "*The industry recently finished electrifying the Great Western Mainline up to Cardiff and will soon complete the Midlands Mainline up to Market Harborough. Once these schemes are complete, there will be no electrification schemes taking place in the UK and, with no construction-ready schemes in the pipeline, there will likely be a significant hiatus before new projects are ready for construction. This could lead to a loss of capability and skills in the supply chain.*"

The RIA went on to say that, as its Electrification Cost Challenge Report shows, "*the stop-start nature of electrification is one of the key factors in cost increases. With a long–term rolling programme, that provides visibility and consistency to rail suppliers so they can build up and retain expertise, electrification could be delivered at up to half the cost of past projects. We believe delivery of electrification cannot wait until the next rail funding cycle 'Control Period 7', which starts in 2024, and that a ringfenced fund for an electrification programme should be provided immediately to allow work to continue.*"

Darren Caplan, Chief Executive of the Railway Industry Association (RIA), said: "*Kick-starting a programme of electrification on intensively-used rail is essential if the Government is serious about delivering on its goal to decarbonise UK rail by 2040 … Research conducted by RIA has shown that the costs of electrification schemes can be lowered by up to 50% compared to some past projects, particularly if supported by a 'rolling programme' of work to avoid the expensive and inefficient 'feast and famine' approach to investment in the past.*"

56 In February 2018, the Government set a challenge to industry to see how it could take diesel-only trains off the railways.

10. Rail industry legacy

Electrification work underway in the Severn tunnel, showing the novel new conductor beam installation.

10.1 Engineering innovation

Technology

Through Great Western electrification, Network Rail updated UK electrification technology, which was three decades old. A whole new system was developed[1], including Overhead Line Equipment (OLE), power distribution and control, to give excellent reliability. New projects will not need to go through the same developmental effort.[2]

Network Rail's in–house engineers reviewed the prospect of delivering electrification in a new, intensely–used, railway environment, with modern standards of safety for staff working at height. They reviewed existing overhead line systems, in the UK and abroad, to give a list of the known common failure modes, built up over decades of operational and maintenance experience. Approximately 80 common types of failure were identified, and these were systematically designed out. Network Rail then worked in partnership with suppliers to develop a new system, termed Series 1, specifically designed for better reliability, and compatible with high output construction.[3]

Through gaining experience, Network Rail's engineers reached the position of making complicated decisions expeditiously, without needing consultants. The programme became an educated client, agile and decisive – 'engineers buying engineering'.

Innovative technical development has created a 25kV electrification system that offers superior reliability[4], whilst generating savings. Key features include:

- the considerable power supply capacity of an autotransformer system—which can, for example, feed 200 route km from one transformer at Melksham in the event that the Didcot supply is not available—provides enormous resilience[5]
- the rationalised autotransformer system (RATS), which uses a new architecture and digital fibre–optic communication to deliver greater resilience. This innovation was developed within Network Rail and is now a part of European standards[6]
- GWEP was the first project to consider differential heating (e.g. greater heating from the higher load around the Didcot supply point) leading to improved resilience during hot weather
- a new spring tensioning system avoids the risk of balance weights striking trains in the event of a derailment, addressing a recommendation from the Potters Bar accident investigation as well as increasing resilience;
- elimination of tangential wiring—OLE from one line don't cross another line—provides full mechanical independence on all lines, considerably reducing damage in the event of a pantograph fault
- a risk–based approach to bridge clearances has reduced the scale, and therefore cost, of gauge clearance work. Significant savings were obtained at Cardiff Intersection and Steventon bridges, for example
- there are no traditional neutral sections on tracks where trains run at over 40mph—new carrier wire neutral sections were developed—removing a large mass insulator at each neutral section which was historically a major cause of failures
- improved foundation design, based upon new standards developed by GWEP, tailors the work required at each location due actual ground conditions.

During the 2019 heatwave, the exceptionally robust electrification system installed by GWEP continued to operate reliably, unlike traditional systems installed on other routes.

The new Series 1 Overhead Line Equipment has been criticised as visually intrusive. An important lesson concerns taking account of aesthetic considerations, especially where the railway passes through Areas of Outstanding Natural Beauty (AONBs).[7]

1 As noted in the following paragraph, a new system was developed to eliminate the known problems with existing systems.

2 For example, the GWML is unique in having a clear long–term traction power strategy, with resilience designed-in, yet having developed a fully rationalised approach to traction substations, using world–leading digital substation technology. This can be now used for future schemes to improve capacity at lower cost than previous approaches.

3 Series 1 is the overhead line design range, whilst the electrification consists of much more than overhead line. It is the latest development of the GB overhead line design range. Development was led by Network Rail engineers on the basis of their experience of previous reliability problems, and also with a view to high–output overhead line construction. Series 1 has proven itself already with high reliability, including increased resilience to high temperatures during July 2019.

4 Critically, the whole system has been designed for reliability, including power supply and tensioning as well as the geometry of the overhead wiring.

5 The system is noticeably stronger than the previous 25 kV systems. This has provided sufficient capacity for the future of the network, and importantly with grid supply installation costs at the lowest per installed megawatt of power of any UK system, and sets a new standard for long–distance, highly reliable, traction power using only a few well-positioned traction supply points.

6 The RATS scheme achieves fault clearance times of as little as 50ms, significantly lower than previously, and reduces damage to equipment due to faults. RATS won an innovation award, has led to European standards on modern traction substations using it as a first–of–its–type example of wide–area fault protection.

7 The Chilterns and North Wessex Downs AONBs were particularly affected. To mitigate the impact, Network Rail funded line–side tree planting costing £0.75m to help screen the steel gantries and other electrical equipment along a 20km stretch of line between the outskirts of Reading and Didcot. Network Rail also funded a further £3 million of landscape enhancement projects within the wider corridor of the electrification works along this part of the line.

Several historic tunnels have been electrified. Some were electrified with conventional Series 1 OLE, but the longer and more spatially–constrained tunnels benefited from the novel Rigid Overhead Contact System (ROCS).[8] The experience gained includes:

- design changes including water management to accommodate the challenging environment in the Severn tunnel
- access using blockades to allow for efficient installation
- use of a Track Reference Design (TRD) to help integration between OLE and track geometry
- managing the risk of damage to OLE systems in constrained spaces.

Information management

Three–dimensional design using Building Information Management (BIM) systems simplifies signal sighting (ordinarily a complicated and iterative process that carried the risk of costly re–work) and provided valuable digital information to maintainers.

10.2 Understanding cost

GWEP developed expertise in construction methodology—how best to build OLE based upon experience and innovation. The main cost drivers—access and use of labour, rather than volume of materials—are well understood and development takes this into account. Cost planners are now familiar with OLE, with a better knowledge of construction methodology.

The Rail Method of Measurement (RMM) cost planning tool was updated to include three levels of OLE complication—low normal, nigh normal, and abnormal—which cover the range of conditions found on UK railways. Factors driving classification include track geometry, accessibility of work sites, environmental constraints, volume of clearance works needed, topography, and the presence of tunnels and viaducts.[9] Figure 33 shows how cost can vary by category.

10.3 Managing programmes

Accountability

Each managing director of a devolved Network Rail region is fully accountable for their programmes and projects delivering the remitted benefits in full, safely, within budget, and to schedule.

Commercial

Great Western electrification demonstrated the need for an approach which generates realistic initial estimates of cost and time, and which enables better control of the actual cost of implementation:

- key elements of the programme must be as fully developed as practicable prior to entering into contractual arrangements—design and development, schedule and key milestones, and access to the railway
- high output plant is not able to deliver significant efficiencies unless greatly enhanced access is available[10]
- cost monitoring and analysis are simpler if a limited number of cost categories is set up and adhered to.[11]

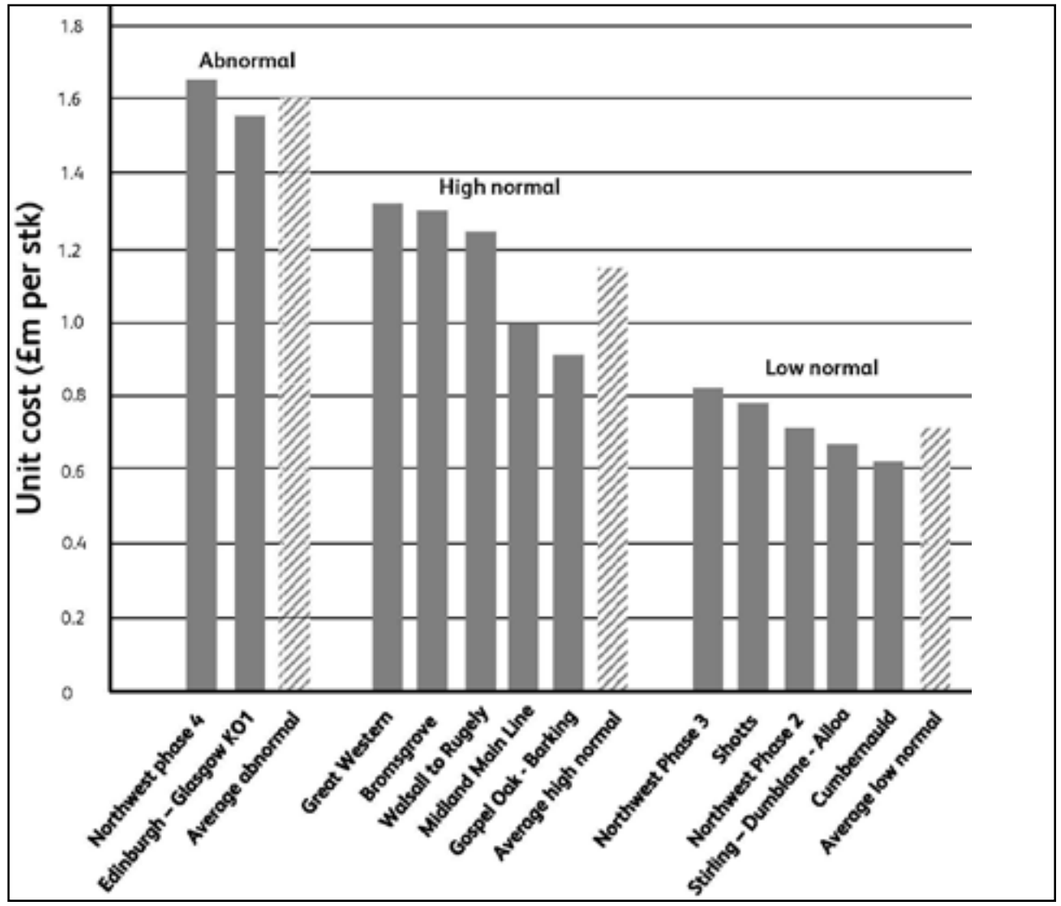
Consents and planning

GWEP did not gain statutory powers at the start of the work without which the programme became immersed in on third party negotiations. The need to consider obtaining statutory powers (for example, a Development Consent Order or a Hybrid Bill might be considered) is a key lesson from Great Western electrification.

As a result of having to obtain more than 1,800 separate consents[12], GWEP revised its assumptions about the time and cost needed to obtain consents, including those for highway closures (which were often contentious)[13], listed buildings, and protected species.

8 These include Chipping Sodbury tunnel, Patchway New, Old & Short tunnels, Severn tunnel and Newport Old tunnel.
9 GWEP was classified as high normal, with a cost per single track kilometre at the upper end of the associated range. This relatively high cost has been attributed to a combination of poor asset knowledge, productivity issues, need for rework, and poor access. This was exacerbated by installation having commenced before design work had been completed and by the programme having commenced before the supply chain developed the necessary capability.
10 The impact of changing assumptions about high output plant is noticeable when comparing the early cost plans of £1.2bn and £1.8bn.
11 The cost structure of Thameslink Key Output 2, which was of a similar cost out–turn, was set up in this way.
12 Modernising the Great Western railway, National Audit Office (2016).
13 In some cases, such as Steventon bridge, engineering solutions avoided the need for highway closures. This provided a useful lesson.

Figure 33: Cost per single track kilometre (stk) of various electrification schemes[14]



Programme development

A new 'industry programme' approach, pioneered by the Thameslink programme, facilitates open and realistic discussion of scope, schedule and cost of future schemes. Collaboration between Network Rail, GWR and the Department in the December 2019 timetable process showed how effective this can be. This approach helps avoid situations where a party might be reluctant to report 'bad news', which might be mitigated through collaboration. Transparent discussion with intelligent partners, who are open to challenge, also helps avoid 'group–think'.

Efficient delivery of electrification needs long wire runs, and these are disrupted when individual support structures are missing. Hence difficulty installing foundations for OLE structures, due to localised poor ground conditions or obstructions, is a major cause of excess cost and delay. Separating the contracts for design and installation of foundations from the contracts for OLE design and installation, and allowing a buffer of time between them, was a key lesson from North West electrification.[15] This shows how effective programme architecture can reduce cost risk.[16]

Project and programme management

GWEP enhanced the processes and practices employed within the Region. Highlights include:

- collaboration with sponsors leading to better decisions supported by a clearer understanding of risks
- clear and unambiguous contract requirements leading to delivery of fit–for–purpose assets
- a Budget Management Plan (BMP) showing authority, project budget, contingency, reserve and annual phasing by Oracle project provides key information, and supports the investment and audit processes

14 Redrawn from a chart provided by the Commercial director, Wales and Western.
15 Direct employment of specialist contractors, rather than generalists (who might subcontract to specialists at a premium), is a further advantage.
16 This approach would increase Network Rail's project management and commercial effort, and the time buffer would increase project duration—but these would increase more, and in an uncontrolled way, if problems with foundations was allowed to disrupt OLE installation.

- a growing focus on KPIs, via dashboards, automates the reporting process, using metrics extracted from core systems to provide a 'single source of truth'
- a well–defined and enforced change control process manages the integrity of cost positions
- good use was made of blockades, also called Temporary Periods of Disruption (TPOD) These are disruptive to passengers and freight customers, and expensive to implement, but extremely valuable where intense production is more efficient and safer. Through its extensive experience, GWEP produced a good practice guide for delivery of blockades.

Procurement

GWEP developed approaches that improved quality and reduced cost:

- collaboration yielded savings where working with intelligent suppliers. GWEP's work with National Grid resulted in savings—bulk supply points cost £90m vs. the £300m originally forecast
- where appropriate, contracting directly with Tier 2 suppliers simplifies procurement
- creation of a market for OLE components drives better solutions, enhanced by effective supply chain engagement.

Risk and value

The programme evolved to take ownership of risk (such as the risk of OLE foundations moving), promoting the adoption of cost–effective design solutions. This overcame the inherent risk–averseness of design organisations, which are constrained by professional indemnity issues.[17]

The programme developed a risk–based approach, for example deciding which bridges to replace. GWEP learned to design the OLE first so that less work would be needed to reconstruct bridges. Challenge to parameters and standards saved money—for example, at Steventon bridge.[18]

A change of philosophy embedded a search for better and cheaper solutions. For example, surge arrestors—which weren't previously approved—are now installed.

Stakeholders

Network Rail's fully devolved regions are closer than ever before to their stakeholders, who include train operators, local authorities, local enterprise partnerships, community groups, and developers.

The nature of the UK railway industry requires close collaboration between Network Rail and train operators. This helps to reduce impact of disruptive access on passengers and freight customers, in turn reducing the cost of Schedule 4 compensation that Network Rail is obliged to pay to train operators.[19] The Alliance between Network Rail and GWR helped with the associated access planning.

The programme also developed relationships with local authorities, whose consent was required for highway closures. Many of these closures were disruptive to the public, and effort was needed to minimise their impact. At Steventon, an alternative was found to an unpopular proposed closure of a busy local road.

Community engagement was developed throughout the duration of the programme to inform passengers and line–side neighbours. Western Route invested in a central communication team to manage stakeholder relations consistently across the route. The programme spanned a large geographical area with high volumes of delivery, change and disruption with minimal complaints from the public.[20]

Sustainability

Biodiversity No Net Loss was introduced as a guiding principle to halt the loss of biodiversity within the railway landscape. GWEP measured its impact using the DEFRA metric, applying the mitigation hierarchy and delivering biodiversity projects off site as a last resort.

Sustainability work streams showed how targeted value can be delivered, for example:

17 Hence, for example, a single OLE foundation shifting under load would represent less of a problem to Network Rail (which might take a statistical view) than to a design organisation (which would be liable for any 'mistake' that led to an insufficient foundation, hence would tend to over–specify parameters such as pile depth).

18 A new risk–based approach to bridge clearances has reduced the scale, and therefore the cost, of gauge clearance work, particularly at Steventon. Additionally, the opportunity was taken in the later parts of the scheme to trial a new approach to using insulated coatings on bridges, with surge arrestor technology to limit line voltages. This has allowed the system at Cardiff Intersection Bridge to operate safely with less than 100 mm of clearance, with additionally no adverse effect on reliability.

19 For financial reasons, and out of public duty, Network Rail must avoid the railway equivalent to motorway lanes 'coned off' without work taking place. Schedule 4, it may be argued, can provide a contrary incentive to train operators.

20 Objections to visually intrusive OLE structures were an aspect that Network Rail might have handled better.

- where practicable, Circular Hollow Steel (CWS) piles replaced concrete piles, reducing embodied carbon
- GWEP undertook Japanese Knotweed incineration, diverting spoil from landfill and reducing associated haulage.

10.4 Authorisation

GWEP pioneered progressive assurance in accordance with the ORR guidance on authorisations, removing the need to authorise each entry into service and having one system authorisation at the end of the project.

The programme developed an understanding of the intricacies and complication of testing and commissioning a modern OLE system. The programme introduced Entry into Service Verification and added CSM / Interoperability to Level 3 standards, developments that will materially assist future electrification schemes.

As a result of the programme's efforts, the safe status of OLE reference designs has been assured. GWEP's approach—for example, treatment of reduced clearances—has helped Network Rail to better understand how standards can be applied.

10.5 People

Network Rail and its suppliers built a strong team of experienced design and construction engineers. Through their skill and ingenuity, complicated design challenges were solved, and state–of–the–art solutions developed.

Vocational skills involved in installation and maintenance have been strengthened too. Network Rail's Electrification Training School continues to provide training for maintenance staff.

Through the large volume of work delivered over several years, the UK supply chain has been up–skilled, providing network Rail with strong Tier 2 suppliers to contract with.

These human capabilities are, of course, time–limited: without further work, skilled people have left to find new opportunities.

Track lowering at Steventon bridge

11. Towards decarbonisation

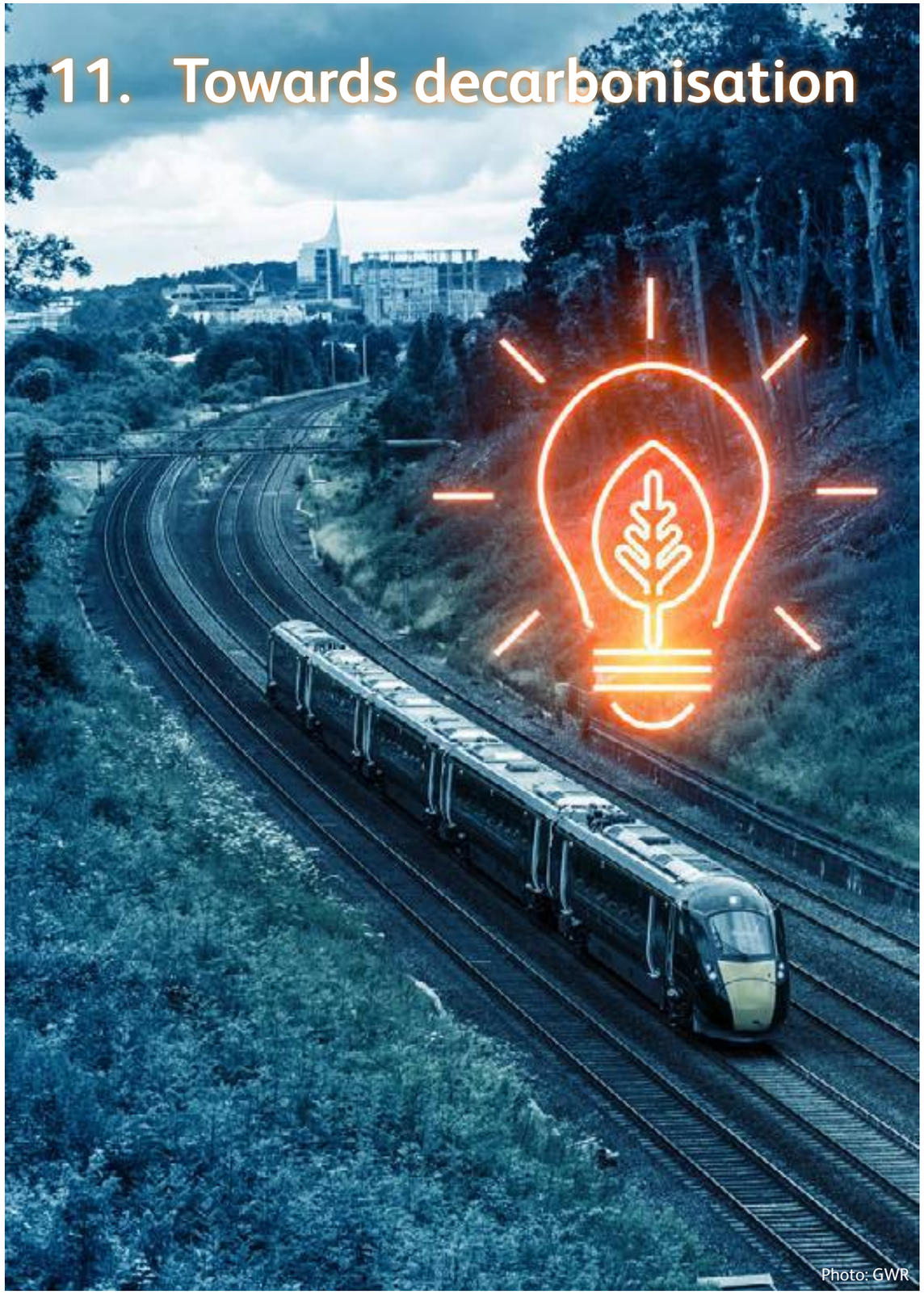


Photo: GWR

11.1 Better national capability

Great Western electrification has left the UK better placed to increase the proportion of its railways that are electrified, helping to decarbonise the nation's economic activity.

11.2 Supporting decarbonisation

A model to decarbonise our railway

Great Western electrification showcases the Great Western route as a model for expanding decarbonisation, employing a mix of new fixed assets and innovative bi–mode trains to enable the progressive capture of reduced emissions. This will enable electrification to be employed where cost–effective, potentially backed up by carbon offsetting where it is uneconomic to electrify and where alternative technologies (such as battery or hydrogen trains) do not offer the capability needed.

Electrification also enables traction power to be generated using an enhanced grid mix including a rising proportion of energy from renewable sources.

Supporting an efficient electrification strategy

Network Rail's renewed capability to deliver large volumes of electrification, together with an emerging delivery pipeline approach, enables the UK to efficiently employ electric railways as a decarbonisation tool.

A fresh understanding has been gained of the value of an electrification 'pipeline', which would maintain the UK's capability, increasing certainty of delivery to cost and schedule, with potential to reduce the unit cost of installation. Figure 34 illustrates the disparity between rates of electrification in the UK and Germany.

Network Rail's benchmarking of programme development work supports a 'pipeline' approach. For example, rolling electrification in Scotland achieved appreciably lower development costs than large unitary 'major projects' such as GWEP, as well as allowing learning to be gathered and embedded before moving on to the next element.[1]

Network Rail's Traction Decarbonisation Network Study presents the case for deployment of electric, hydrogen and battery trains in the UK, and provide a map of the UK rail network identifying where each technology should be deployed, along with the strategic, technical and economic rationale.

Planning and governance

Arguably, the challenges provided by Great Western Electrification encouraged the development of better planning and governance for rail enhancements. The Investment Decision Framework (IDF), Capital Delivery Improvement Programme (CDIP) and the Rail National Enhancements Pipeline might be listed amongst the legacy of GWEP.

11.3 Delivering an electrified railway

A resilient system

The new electrification system developed by GWEP embodies exceptional resilience, allowing passengers and freight customers to trust the railway to provide reliable service. This resilience extends to extreme heat, wind and rail, the likelihood and severity of which are expected to increase as climate change worsens.

A capable industry

The UK rail industry, including Network Rail and its suppliers, and rolling stock providers, have demonstrated capability to deliver all components of a modern electrified railway. Planned use of this capability, via a pipeline of work, will maintain and enhance its ability to support decarbonisation of the UK.

Transferable technology

The new 25kV electrification system developed by GWEP is transferable to other routes, with specific technologies

(such as new standard designs for low–clearance electrification) and systems (such as the Rationalised Autotransformer System) ready for application elsewhere.
Bi–mode trains provide the means to capture many of the benefits associated with new trains whilst the network is electrified progressively as part of a long–term plan to decarbonise the UK economy. They are already being employed elsewhere in the UK to enable scaled capture of electrification benefits.

Managing change

The railway industry has demonstrated that it can efficiently and reliably introduce complicated new timetables that maximise capacity whilst reducing journey times. This will support the progressive expansion of benefits as electrification is progressively extended.[1]

Supported by customers

Decarbonisation of the UK economy requires more people and goods to travel by low and zero emission modes, with potential for a substantial shift to rail. Electrification helps make better use of network capacity for both passengers and freight, supporting sustainable growth along existing and emerging economic corridors (such as Bristol–Cardiff and Oxford–Cambridge). This can only happen if people want to travel by train.

The clean, efficient ethos presented by new electric trains operating on a state–of–the–art electrified railway can only enhance the image of rail travel in the UK, making it easier to achieve modal shift as an approach to support decarbonisation.

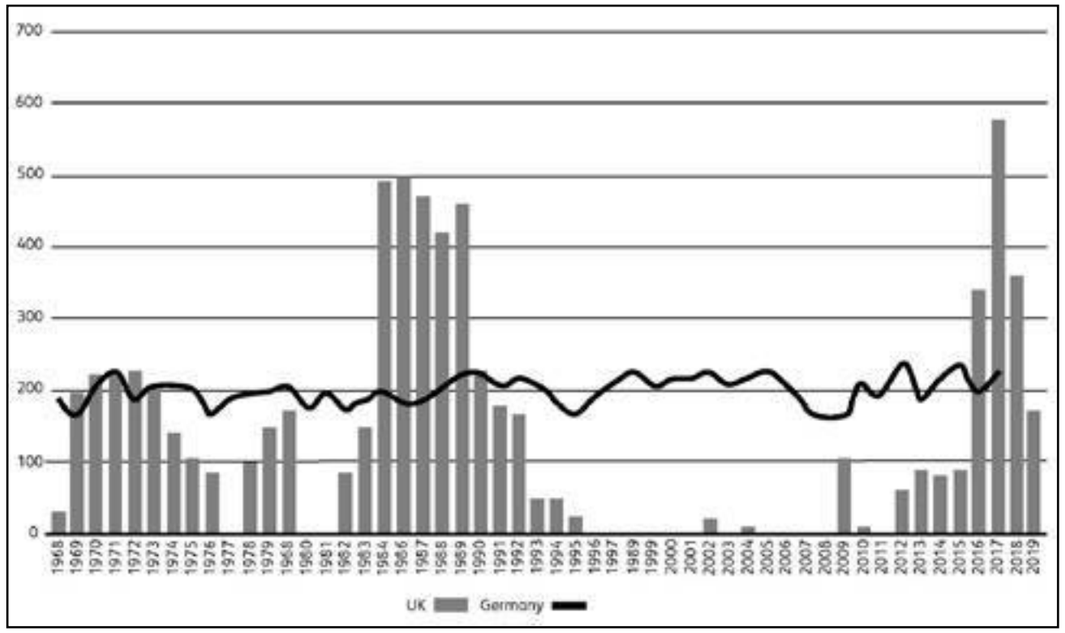
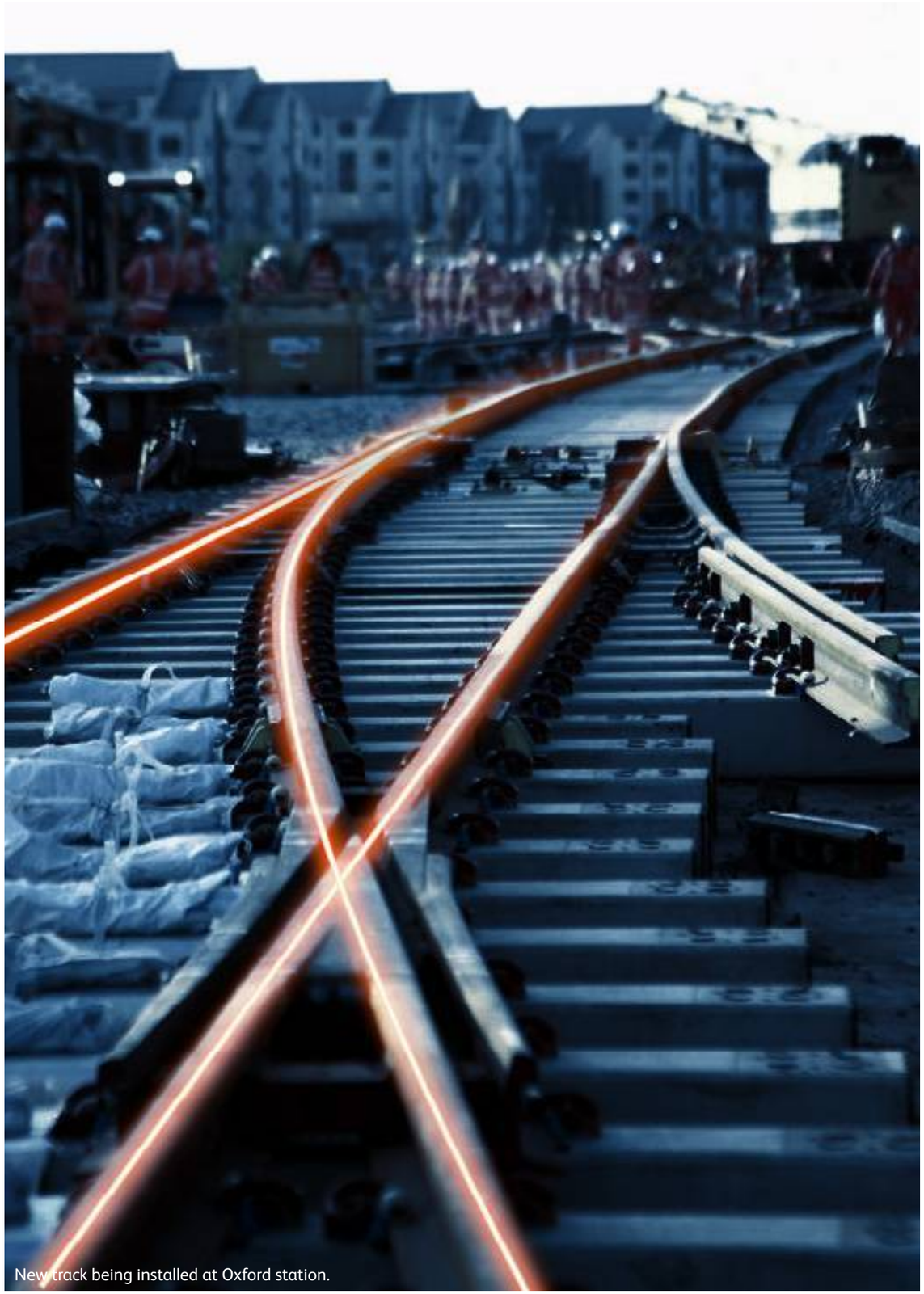


Figure 34: Comparative rates of rail electrification in the UK and Germany[2]

1 Arguably, Network Rail has learned from the débâcles of May 2018, when Northern Trains and Thameslink timetables proved inoperable. An integrated industry approach is now taken, including factors beyond infrastructure and rolling stock, such as numbers of train crew and their rostering, which caused problems in May 2018.
2 Re–drawn from a chart in Electrification Cost Challenge, Rail Industry Association (2019).



New track being installed at Oxford station.

12. Responding to priorities

Artist's impression of the new sea wall at Dawlish.

12.1 UK priorities

Three priorities underpin debate about the UK's future:

1. **decarbonisation**—UK law enshrines the achievement of net–zero emissions by 2050
2. **prosperity**—economic growth to support the needs of the UK's population
3. **rebalancing**—making sure that the UK's regions share in that prosperity.

12.2 How rail may help

Investment in the UK's railways, including the Great Western routes, may help respond to these priorities.

Decarbonisation

Further electrification of our railway will reduce the emissions from trains. Combined with a shift from road transport, electrified railways can make a major impact on reducing the UK's greenhouse gas emissions. Electric trains are also cheaper to run, and offer faster journeys.

Prosperity

Fast, frequent trains offering sufficient capacity enable agglomeration, bringing people and businesses closer together in time. New and enhanced lines forming local and regional metro services, dovetailing into intercity services, will help make the UK's economy stronger and more productive.

Rebalancing

Through connecting regional towns and cities together, and linking them to a national network of fast, frequent trains, the Great Western route can help strengthen the economies of the West of England, South Wales and the South West. It will both enhance local agglomeration—helping the regions to function better as economic entities—and more effectively integrate them into the national rail network.

12.3 Envisioning the future

This chapter, of necessity, speculates. It is for funders to decide how to apply their investment to best effect. But, without seeing all the alternatives, some choices may be hidden from sight. Hence it is worthwhile to suggest some which might lead to investigation and hence informed choices.[1]

12.4 The Thames valley: new services and ideas?

Fast, frequent, modern trains serve the length of the Thames valley. The region's economy is growing, and there is ambition to grow it further. Rail has potential to boost that growth through increasing connectivity, which will enable quick, regular, convenient travel to an expanding range of destinations.

Soon the Elizabeth line will provide time–saving connections to stations across Central London and through to the Docklands, East Anglia and North Kent.

Reading Green Park station will soon provide local rail connections for businesses in south Reading.

Western Rail Link might—if funded—speed access to Heathrow for passengers and airport workers, eliminating the need for many trips by car.

East West Rail might provide regular trains, via Oxford, to Milton Keynes, Bedford and Cambridge—the prosperous 'OxCam arc' of science and business which complements the Thames valley's economy—saving much time currently wasted on congested roads.

The Thames valley's branch lines have potential for innovative battery-powered electric trains, which have zero emissions, are cheap to run, and reduce journey times. Application of tram–train technology might even allow some branch line trains to run beyond their historic termini via street running, or make calls at new stops.

1 The ideas presented within this chapter are, many cases, speculative. Further study would be needed to confirm feasibility and give an idea of benefits and costs.

12.5 Oxford: east – west opportunities?

Once a quiet part of the rail network, Oxford lies at the centre of a growing web of rail connections. With a fast GWR service to London taking only three–quarters of an hour, the new Chiltern Trains route to London Marylebone via High Wycombe, half–hourly CrossCountry Trains services to Birmingham, Northern England and the South Coast, and regular local service, Oxford is well connected.

East West Rail promises further fast, frequent rail links, to Milton Keynes, Bedford and Cambridge. With support from funders, these services might extend further afield—Reading, Bristol or South Wales, for example, putting Oxford at the heart of a growing prosperous knowledge, science and technology–based economy.

12.6 The West of England: regional metro opportunities?

As WECA acknowledges, the West of England is already well–connected. But no economy can stand still, as WECA acknowledges through its enthusiastic support for MetroWest. GWR too is keen to see more trains on key corridors such as Bath – Bristol – Cardiff.

Completion of the deferred electrification might, if funded, enable a step–change in train services upon the vital foundation of GWRM's Filton bank four–tracking. To provide 'turn–up–and–go' service, a service of four trains an hour is needed. The quick acceleration offered by electric trains, plus the high seating capacity of new trains such as the Class 387, allow more trains to run carrying many more people.

The vision of a metro–style service linking Bristol and Cardiff with Bath, Filton, Gloucester, Taunton, Westbury, Weston–super–Mare, Yatton and other places is exciting. It would enable the region to function as a well–connected entity, no longer car–dependent, with cleaner air and more plentiful, value–adding jobs.

12.7 South Wales: benefiting from core electrification?

Great Western electrification is the first step, and modernisation of the Valley lines has now commenced.

A great local network of suburban electric trains, plus buses and even trams, will be complemented by fast, frequent regional and intercity trains.

The extra capacity offered by electric trains will not only encourage green commuting to the growing commercial centre of Cardiff—it will support valuable events at the Principality stadium which depend upon good, high–capacity transport links.

Electrification between Cardiff and Swansea will help deliver a clean, fast, frequent regional metro service that brings people together for work, study and leisure.

Tilting trains: proven to reduce journey times in the UK

12.8 The South West: rebalancing through connectivity?

The South West faces the challenge of increasing its economic activity, bringing more and better-paying jobs. Better connectivity is vital, and rail has a key role to play—subject, of course, to support and funding. And greater connectivity helps commercial redevelopments attain viability—more workers and customers can gain easy access.

How might a step change in connectivity be achieved?

The electrification enabler

We think of electrification in terms of lower costs, faster trains and cleaner operation: and it delivers all of these. But it also allows more trains to be run on a mixed railway, because stopping trains accelerate faster, and so have a lesser impact upon non-stop services. And express trains can make additional station calls with less additional journey time.

The Exeter – Plymouth route provides an opportunity to add value through electrification. Express trains might not run much faster owing to the hilly terrain, though they will be cheaper to run, and cleaner. But more local trains would be able to run too, improving regional connectivity, and making it easier for people to reach jobs, education and leisure. And new local train services might provide opportunities for people living in places like Brent, Exminster, Ivybridge and Plymstock, creating a regional metro with cross–city trains boosting prosperity including both Exeter and Plymouth. Might discrete regional electrification to come on stream by the time that current diesel trains become life–expired?

Green hydrogen power

Services might expand: Barnstaple (and, it is to be hoped, Okehampton) to Cranbrook and Honiton, for example. On these longer journeys where the cost of electrification may be prohibitive, hydrogen fuel cell technology might one day provide clean transport.

Faster trains boost connectivity

Other new technologies might be applied: new, that is, to this part of the UK. Tilting trains have potential to reduce journey times for express trains—by up to 35 % in some cases. Investment in new signalling and replacing level crossings would add to the cost, however faster journeys between regional towns and cities, and quicker links to places like Bristol, Birmingham, Reading and London, will bring people, work and leisure closer together, helping make the South West more attractive to investors and skilled professional people.

Is there time to develop a project before CrossCountry Trains' Voyagers become life–expired: and even to electrify more of the network if a bi-mode tilting train isn't desired? Adding to the imperative, a new service might even run via HS2 to reach the Northeast, Northwest and Scotland more quickly.

Integration for easy travel

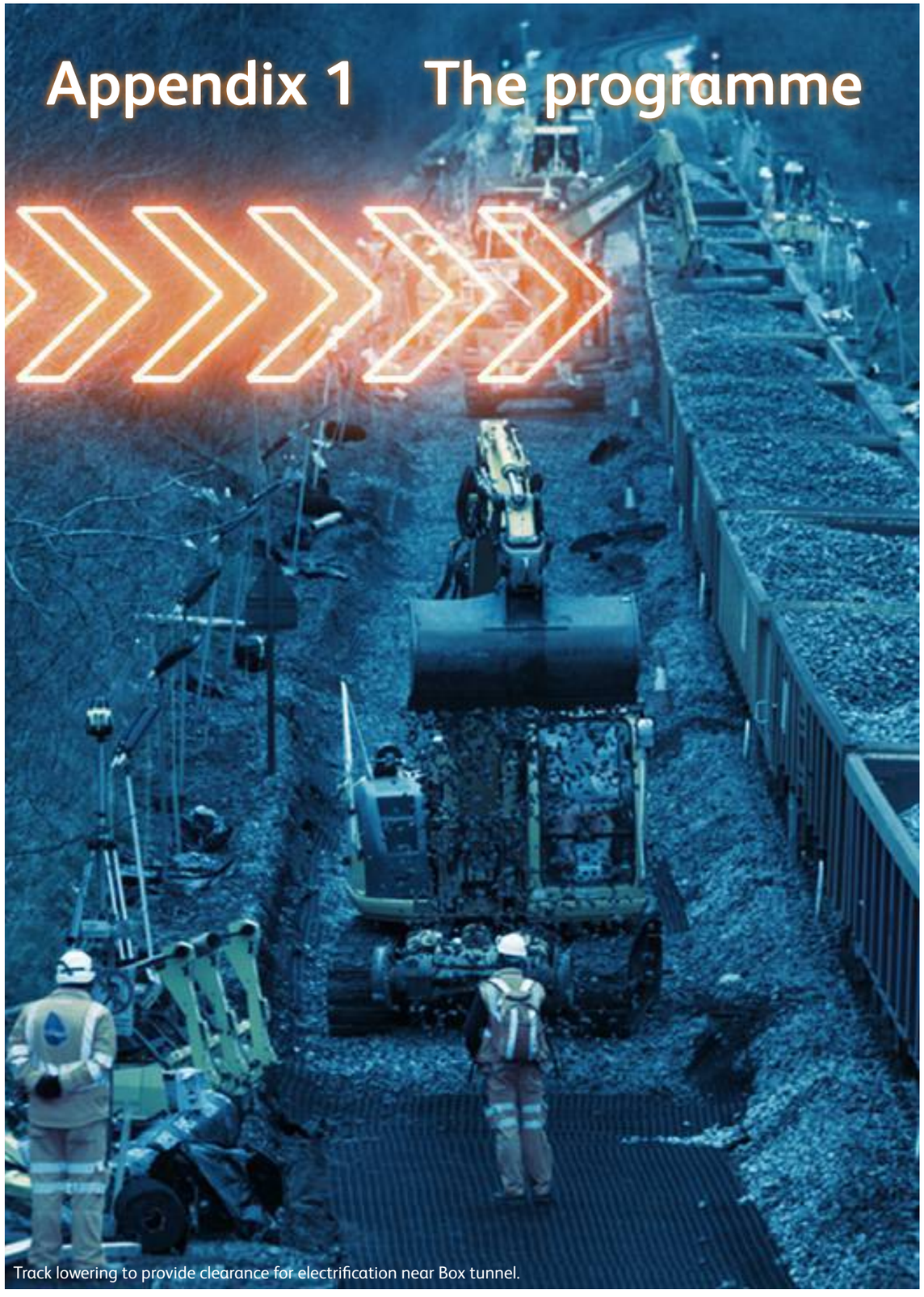
How can mobility–as–a–service be rolled out to extend the reach of a regional metro rail service? There is great potential to integrate rail, bus, taxi, car and bicycle via a new platform that allows easy booking of a whole, integrated journey: vital for people without cars, and helpful for those who want to leave their cars at home.

Extending connectivity

Reversing some of Beeching's cuts, old railways might be re-opened to expand agglomeration via new connectivity: an opportunity the UK government has acknowledged. The former route between Exeter and Plymouth via Okehampton and Tavistock is a much–discussed gap in the rail network. Lessons from Borders Rail not only infer a realistic order–of–magnitude cost, but suggest how new housing and employment can complement the re-opened railway. Ridership exceeded expectations, and Borders Rail is a great success.

Might other closed lines and stations also one day become candidates for re-opening? Perhaps these too might help spread the benefits of fast, frequent trains, alongside mobility–as–a–service where rail restoration isn't a realistic option.

Appendix 1 The programme



Track lowering to provide clearance for electrification near Box tunnel.

A1.1 The Great Western Main Line

The Great Western Main Line (GWML) creates main line links from London to the West of England and South Wales. Extending from this are radial routes to Oxford, the Cotswolds, Birmingham, the South Coast and the South West. Services also operate on branch lines into the inner and outer London suburbs, around Bristol, and to the Devon and Cornish coasts.

The GWML is amongst the busiest mixed traffic railways in the world, operating up to 20 trains per hour (tph) into Paddington, alongside frequent stopping trains and heavy freight flows. Prior to Great Western Route Modernisation (GWRM), the GWML hosted the fastest and most intense intercity diesel service in the world.

The GWML serves a variety of train operator customers:

- Great Western Railway (GWR) serves commuters into London, Reading, Oxford, Bristol, Cardiff and other economic centres, as well as business and leisure travellers, and holidaymakers
- TfL Rail operates Elizabeth line services into London, soon to use new cross–London tunnels
- Heathrow Express carries important airport traffic
- CrossCountry uses sections of the GWML to link places in the South, Southwest and Wales with the Midlands, Northwest, Northeast and Scotland
- Transport for Wales trains also use the western section of the GWML
- major north–south and east–west freight flows carry intermodal traffic, construction materials, chemicals, oil, vehicles, and other commodities.

A1.2 The case for modernisation

In 2007 the Department for Transport (the Department) planned to buy new high–speed diesel trains for the Great Western Main Line (GWML), the last major UK rail route to principally depend upon diesel power.[1] Two years later, electrification was announced, representing the first big rail electrification project in the UK for 20 years.

The Great Western route was, by the time that electrification was announced in 2009, beginning to enter a 'perfect storm' within which obsolescent trains offered insufficient capacity for commuters and leisure passengers, infrastructure constraints prevented more trains from operating, and diesel traction inflated operating costs.

The National Audit Office (NAO) concluded that a good case exists for increasing passenger capacity on the Great Western Main Line.[2] The NAO noted that, in autumn 2013, three of the ten most overcrowded services in England and Wales were Great Western services into Paddington. The Department forecast that passenger demand would grow by 81 % between 2013–14 and 2028–19.

The NAO summarised the strategic argument for investing in the route as:

- there is a need for greater capacity on the route. The Department forecasts that passenger demand on the route will grow by 81 % between 2013–14 and 2018–19. This means an extra 21,200 passengers arriving at London Paddington during the peak period, each day. The modernisation programme will allow two additional peak–time services per hour between Bristol and London, from December 2018
- the franchise had a history of unreliable service. For example, in 2013–14 and 2014 15, the proportion of trains arriving on time was below the target for the funding period
- passengers' experiences have been poor. In autumn 2013, three of the 10 most overcrowded train services in England and Wales were Great Western services into Paddington. National Rail Passenger Survey results for Great Western Railway, quoted in the business case, indicated that passenger satisfaction has been generally below the average for train operators
- the works were needed to provide the full benefits of investments that the Department had already made on the Great Western route, such as the Intercity Express Programme and the redevelopment of the Reading station area. The works also complement other investments such as upgrades to signalling (the European Rail Traffic Management System) and Crossrail.

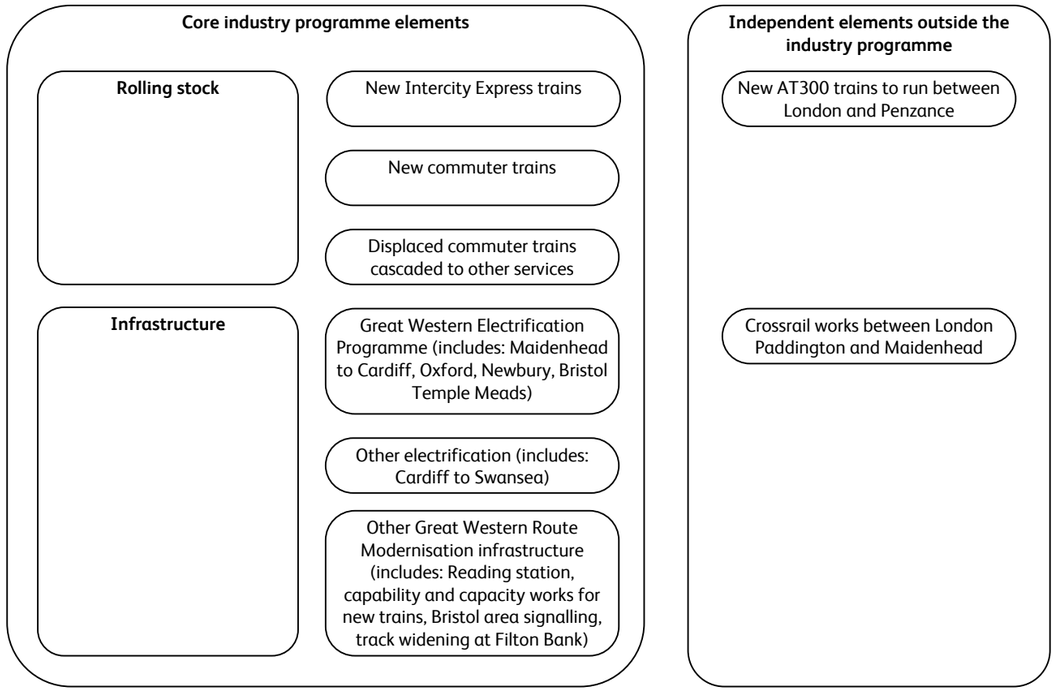
1 The Midland Main Line was largely diesel–powered, however electrified services ran to Bedford. Electrification was announced in 2012 and largely cancelled in 2017.
2 Modernising the Great Western Railway, National Audit Office (2019).

A1.3 Industry programme

By 2015, an 'industry programme' had been assembled. Figure 35 summarises the industry programme diagrammatically. Expressed according to the TRIFO paradigm—Timetable, Rolling stock, Infrastructure, Franchise and Operations—the elements are:

- **Timetable**—Network Rail devised a new timetable that sought to meet the Department's High Level Output Specification (HLOS) targets;
- **Rolling stock**—the Department commissioned new intercity and commuter trains
- **Infrastructure**—Network Rail's infrastructure programme included electrification between London, Cardiff, Bristol Temple Meads, Oxford and Newbury, and upgrades to signalling, tracks, stations, bridges and tunnels. The Department set high–level requirements for this work;
- **Franchise**—the Department awarded and managed the Great Western franchise, and made plans to redeploy displaced trains; and
- **Operations**—Network Rail, GWR and other train operators established optimal means of maintaining and operating the modernised railway.

Figure 35: The Great Western Route Modernisation industry programme[3]



Other programmes and projects complement GWRM:

- Network Rail's Crossrail On Network Works electrified the GWML from Airport Junction to Maidenhead, connecting the pre–existing electrification to that delivered by the Great Western programme;
- GWR acquired a fleet of Class 800 IETs to operate between Paddington and the South West; and
- GWR is acquiring a fleet of Class 769 tri–mode[4] units for Thames Valley and Reading–Gatwick services, which will allow further Class 16x units to be cascaded to the South West.

3 Adapted from a chart in Modernising the Great Western Railway, National Audit Office (2016).
4 Class 769 units are converted from dual–voltage Class 319 units, and can operate on 25kV overhead electrified lines, 750v DC third–rail electrified lines, and stand–alone on diesel power. This enables them to operate on the GWML (such as Oxford to Reading) using the new electrification and east to Gatwick Airport (using the DC electrification which exists along sections of that route).

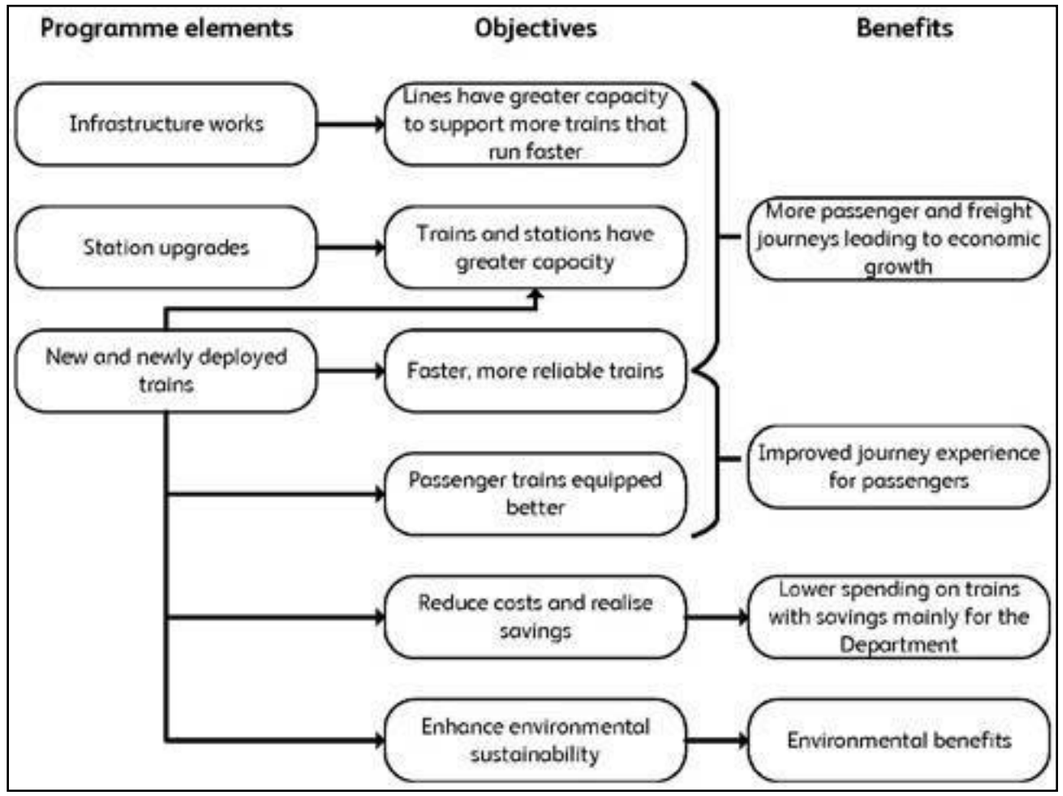
A1.4 High level objectives

The Department anticipated that the projects making up the Great Western Route Modernisation industry programme would together provide a range of benefits to passengers, including faster, more frequent services. These are summarised in Figure 36.

The Department's Benefits Map (see Figure 37) maps a variety of *Intermediate Benefits* to six *End Benefits*, against which the success of GWEP may be assessed. The End Benefits are:

- increased passenger capacity
- improved service reliability
- reduced journey times[5]
- improved passenger experience
- reduced operational costs
- improved environmental performance.

Figure 36: Great Western Route Modernisation benefits generation[6]



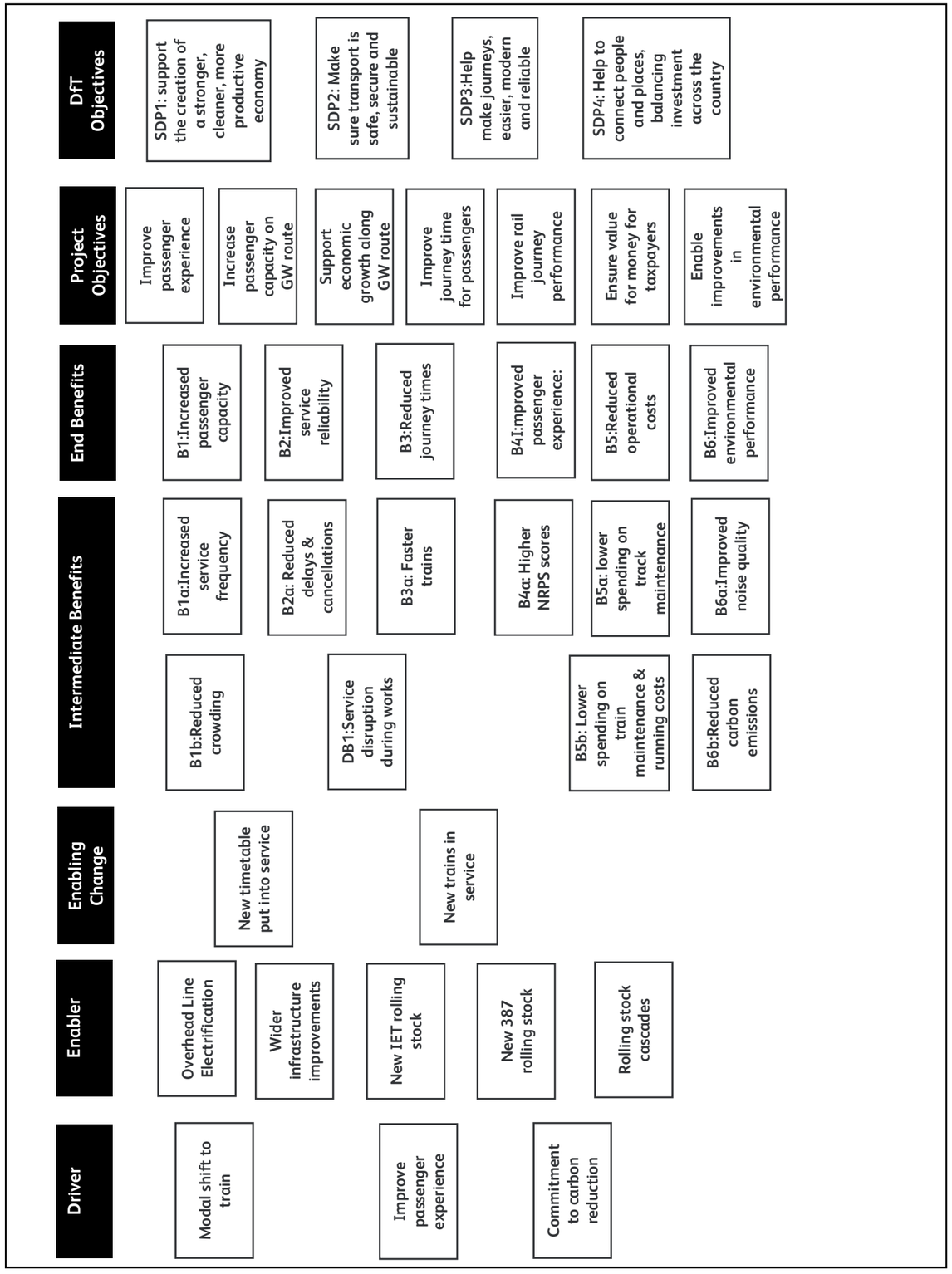
The Department's Benefits Map also sets out four *DfT Objectives*. These give four categories of value:

1. support the creation of a stronger, cleaner, more productive economy
2. help connect people and places, balancing investment across the country
3. help make journeys easier, modern and reliable
4. make sure that transport is safe, secure and sustainable.

The industry programme has delivered safety improvements (for example, through level crossing closures) and health improvements (such as toilet waste no longer being dumped onto the track). Various other incidental benefits have also been captured, such as additional gauge clearance for freight trains carrying 9'6" containers on diversionary routes.

5 At the time of writing, the full new half–hourly 'super–fast' service to Bristol has not been implemented due to owing to Covid–19.
6 Adapted from a chart in Modernising the Great Western Railway, National Audit Office (2016).

Figure 37: Department benefit mapping for Great Western Route Modernisation[1]

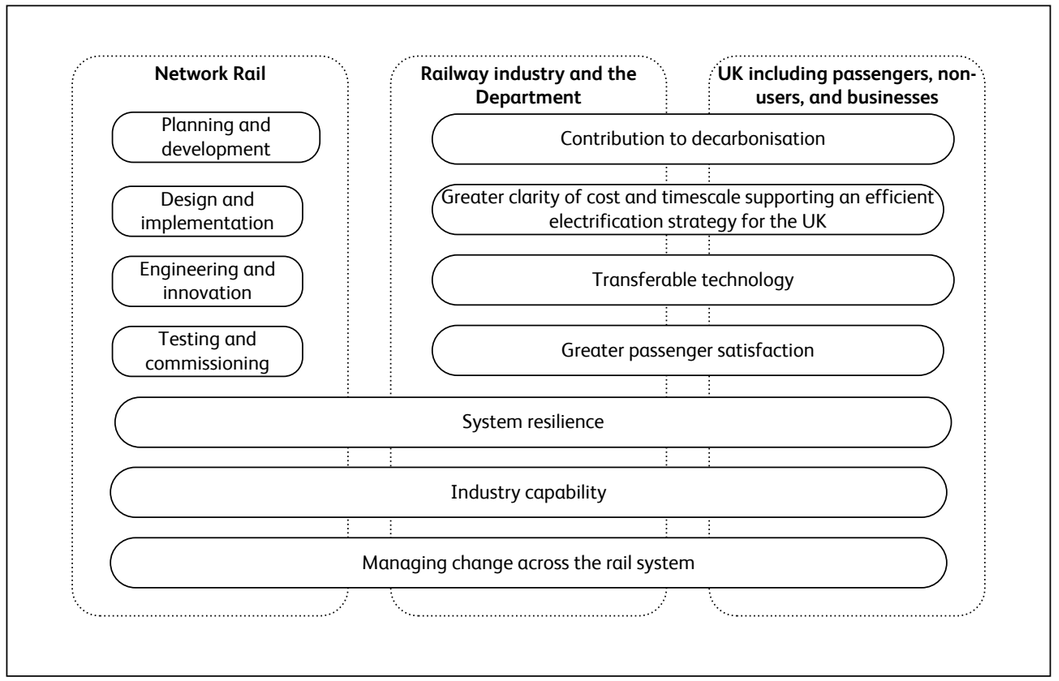


1 Redrawn from a chart published by the Department for Transport (2019).

A1.5 Legacy

Although not explicitly remitted, GWRM has delivered a legacy of added value, including a greater capability for Network Rail and its suppliers to deliver complicated new electrification schemes. Figure 38 summarises this legacy.

Figure 38: Legacy value from the Great Western Route Modernisation industry programme



A1.5 Challenges

By 2015, the forecast cost of Great Western electrification had tripled, with completion expected to be delayed by a year. A year later, Sir Peter Hendy's review stated that costs had risen from the £874m original estimate to £2.8bn, and was £1.2bn higher than the estimate made a year earlier. The NAO reported that Network Rail had been too optimistic about the productivity of new technology, had underestimated the time and cost associated with obtaining consents, and had commenced construction whilst product and development programme development were still underway.[7]

In November 2016, electrification work was indefinitely deferred from Didcot Parkway to Oxford, Bristol Parkway to Bristol Temple Meads, Thingley Junction to Bristol Temple Meads, and on the Henley and Windsor branches. In July 2017, electrification from Cardiff to Swansea was cancelled.

7 The NAO noted problems across the industry. Prior to 2015, the Department "did not plan and manage all the projects which make up Great Western Route Modernisation in a sufficiently joined up way". There was no business case for the 'industry programme' until 2015, more than two years after trains were ordered and a year after electrification work has begun.

A1.6 Deliverables

GWRM bought new trains and built new infrastructure, including new electrification. Originally the Department intended to procure a combination of bi–mode and electric trains, enabling new rolling stock to operate beyond the geographical extent of electrification. This represented a difference compared to 'traditional' electrification schemes where a captive fleet operates solely 'under the wires'.

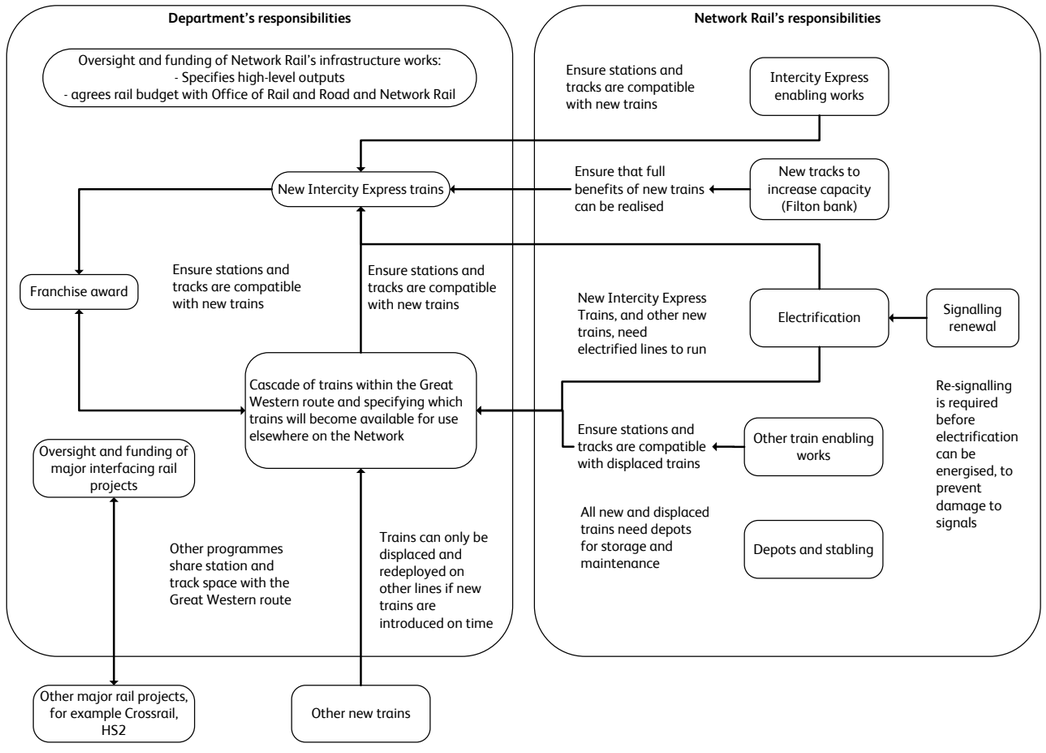
This innovation, which has been repeated on the Transpennine route, allows the performance benefits of electric traction to be obtained where most needed without electrifying a whole section of line. It also allows the progressive electrification of routes, which allows incremental capture of benefits, and promotes affordability.[8]

Figure 39 sets out the main infrastructure components of Great Western Route Modernisation.

A1.7 Responsibilities

The Department defined its responsibilities, and those of Network Rail, within the industry programme. These are set out in Figure 40.

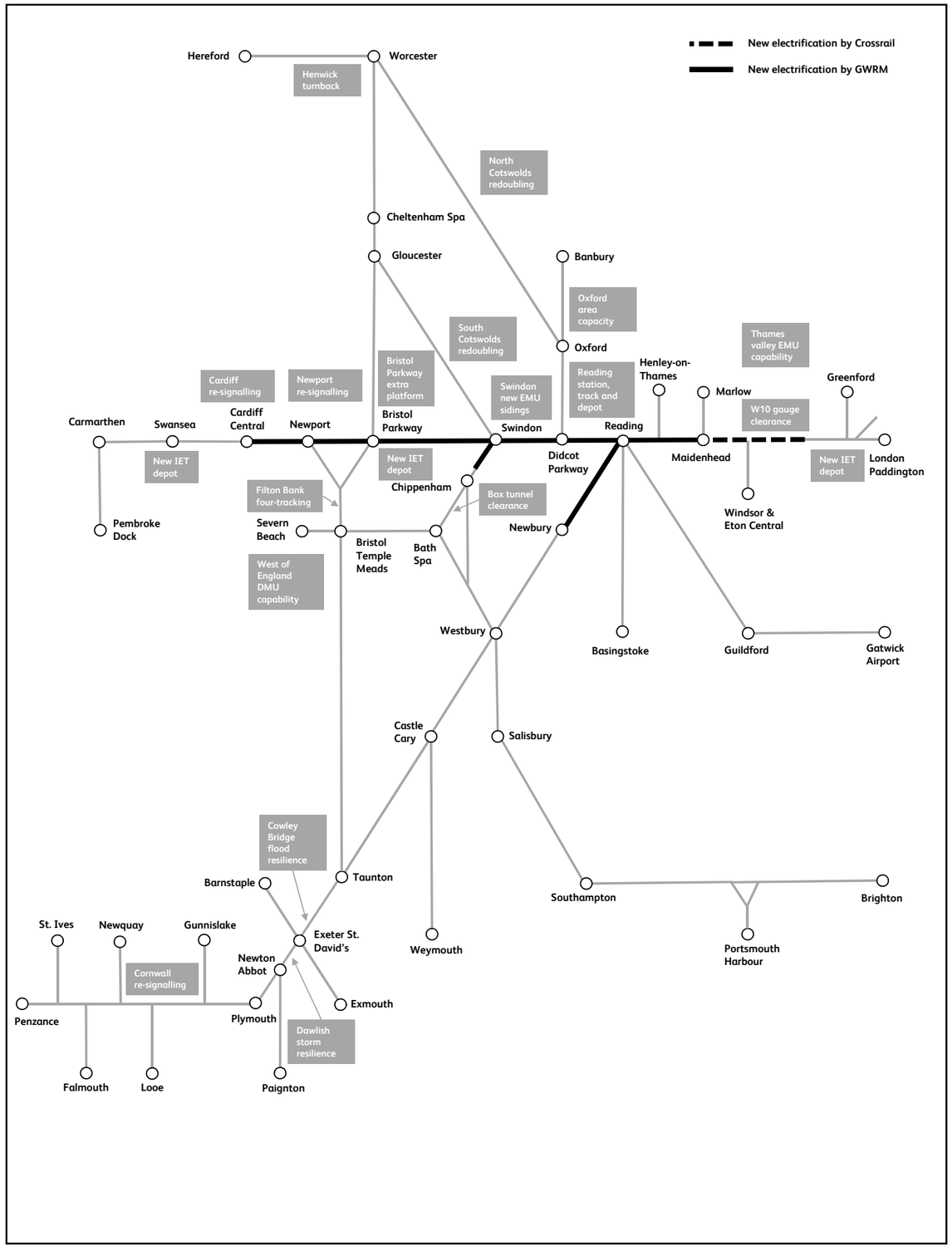
Figure 40: Great Western Route Modernisation industry programme responsibilities[9]



8 The expense of transporting diesel engines and fuel 'under the wires', and the inherently lower reliability of bi–mode trains (even under electric traction) compared to pure electric trains, needs to be taken into account.

9 Adapted from a chart in Modernising the Great Western Railway, National Audit Office (2016).

Figure 39: Infrastructure delivered by GWRM and associated projects[1]



1 This map shows key infrastructure built for Great Western Route Modernisation. For clarity, smaller elements (such as footbridges and platform extensions) are not shown.

A1.8 What Great Western Route Modernisation delivered

Timetable

The December 2019 timetable provided for substantial enhancement to long distance services, increasing frequencies and reducing journey times. This included the first GWR 'super–fast' services running non–stop between Paddington and Bristol Parkway.

Previous timetables had introduced IETs onto all of GWR's long distance services, and Class 387 electric trains onto services between Paddington, Reading and Didcot Parkway.

Future timetables, post–Covid–19, will expand the volume of GWR 'super–fast' services.

Rolling stock

The Depaertment procured two new fleets of trains:

- 57 Intercity Express Trains funded by the DfT via a £5.7bn Public Private Partnership agreement with Agility Trains to design, build and maintain high speed trains for the Great Western and East Coast
- 33 x 4 car new class 387 commuter trains for the Thames Valley.

GWR also procured a complementary additional fleet of 36 bi–mode Intercity Express Trains to operate to the Southwest. These trains use the new electrification between Paddington and Newbury.

A number of rolling stock cascades were made as a result of new train procurement. Transfers comprised:

- HSTs to the West of England (the 'Castle class')
- class 16x DMUs from the Thames valley to Bristol and the West of England
- HSTs to Scotland
- class 15x DMUs to the North of England.

Infrastructure

Great Western Route modernisation included the infrastructure shown in Figure 41. Great Western electrification represents the single largest element, followed by Reading Station Area Redevelopment. Adding capacity on Filton Bank, and between Swindon and Kemble, were also substantial projects.

Approximately one fifth of the electrification, measured by single track kilometre, was deferred. This is the subject of strategic advice by Network Rail.[10] Figure 41 shows the extent of electrification installed and deferred.

Complementary works across the region funded separately included:

- Crossrail infrastructure between Paddington and Maidenhead, which enabled a more intense suburban service to run alongside freight trains
- resignalling in Cornwall, which enabled an increased frequency of services to run between Plymouth and Penzance
- resignalling at Newport, which provided immunised signalling
- North Cotswold redoubling, which enabled an increased frequency of services to run between Paddington and Worcester
- weather resilience works at Chipping Sodbury, Cowley Bridge, and Dawlish—the lattermost also including major repairs to storm damage.

10 Western Electrification Deferrals, Strategic Advice, Network Rail (2020)

Figure 41: GWRM infrastructure scope

Infrastructure project	Purpose
Great Western electrification	Enables electric operation.
Reading Station Area Redevelopment	Substantially increases route capacity, relieving a major constraint to increasing service levels. Increases passenger circulation capacity.
Dr Days Junction to Filton Capacity ('Filton bank')	Increases route capacity, relieving a constraint to increasing service levels.
Swindon to Kemble Redoubling	Increases route capacity, relieving a constraint to increasing service levels. Provides a diversionary route avoiding the Severn tunnel.
Oxford Phase 1 improvements	Increases route capacity, relieving a constraint to increasing service levels.
Thames Valley EMU Capability	Lengthens platforms to accommodate EMUs. Adds step–free access at selected stations.
IEP Western Capability	Enhancements to enable IETs to run on the Network.
IEP GWML Capacity	Enhancement to specific infrastructure to enable operation of an enhanced timetable using IETs.
West of England DMU Capability	Lengthens platforms to accommodate cascaded DMUs.
North Cotswolds Platform Lengthening	Lengthens platforms to accommodate IETs.
West of England Platform Lengthening	Lengthens platforms to accommodate IETs.
Bristol Temple Meads Station Capacity	Increases passenger circulation capacity.
Reading Outer Resignalling & Immunisation (RORI)	Provides a signalling system immune from interference by 25kV electrification. Transfers control to Didcot signalling centre. Creates space for additional platforms at Reading station.
Swindon Area Resignalling	Provides a signalling system immune from interference by 25kV electrification. Transfers control to Didcot signalling centre.
Bristol Area Signalling Renewals (BASRE)	Provides a signalling system immune from interference by 25kV electrification. Transfers control to Didcot signalling centre.
Level Crossing Risk Reduction	Reduces risk associated with enhanced service levels by providing bridges and diversions.
Access To Assets	Provides enhanced maintenance access.

Franchise

The Department provided for the HLOS targets via its franchising arrangements with GWR.

Operations

Network Rail and GWR, collaborating via their Alliance, devised operational methodologies covering maintenance, access, management of disruption, and other issues.

Network Rail recruited additional staff to maintain the new electrification system, and constructed a new Electrification Training School at Swindon.

A1.9 Timeline

2020
- Electric services operate between Paddington and Cardiff
- OLE in the Severn tunnel is energised. marking the completion of GWEP's electrification.

2019
- A new enhanced GWR timetable starts to operate in December
- The Spring National Rail Passenger Survey shows a 6 % rise in overall satisfaction for Great Western Railway, which Transport Focus have partly attributed to new trains.
- GWR took delivery of its final IEP train.

2018
- First electric operation to Didcot Parkway and then to Swindon.

2017
- Intercity Express Trains launched after testing and commissioning
- HST Cascades to Scotland start
- Cardiff to Swansea electrification cancelled.

2016
- Hendy Review of portfolio affordability: four sections of electrification deferred; and other scope deferred into CP6 (2019–2024)
- The NAO reported that Network Rail had been too optimistic about the productivity of new technology, had underestimated the time and cost associated with obtaining consents, and had commenced construction whilst product and development programme development were still underway.

2015
- Second Direct Award to GWR
- The Department defines GWRM as an 'industry programme'
- Delay to electrification results in a decision to convert electric–only IETs to bi–mode operation
- The forecast cost of Great Western electrification had tripled, with completion expected to be delayed by a year.

2013
- First Direct Award to GWR.

2012
- IEP Contract signed, providing for 57 trains (consisting of a mixture of electric–only and bi–mode), three new depots (North Pole, Stoke Gifford and Swansea). It was assumed that new electrification would be used to test the trains
- 2012: the High–Level Output Specification (HLOS) confirmed requirements to reduce crowding, cut journey times, increase efficiency and improve the passenger experience.

2009
- Electrification of the Great Western route was announced.

2007
- The Intercity Express Programme was announced, initially to provide diesel trains for the Great Western route.

Great Western Route Modernisation – Interim project completion report

Appendix 2 Methodology

A2.1 Methodology

Benefits

Benefits are the outcome from a chain of events: *Project → Result → Use → Benefit*. An example is journey time improvement, which requires electrification of the railway, buying electric trains (which can accelerate more quickly than diesel trains), introducing a new timetable, at which point our passengers may use the faster trains and save their time.

Outputs

Outputs (or *results*) are measurable, even if the resulting *benefits* cannot yet be assessed.

The Department's Benefits Map (see Figure 39) maps a variety of *Intermediate Benefits* to six *End Benefits*:
1. increased passenger capacity
2. reduced journey times
3. improved service reliability
4. improved passenger experience
5. reduced operational costs
6. improved environmental performance.

This report collates measures that show how GWRM has performed. These include direct measures (such as numbers of seats (provided) and opinions (such as passenger satisfaction survey data).

Use

Investment generates benefits because passengers and freight customers use the railway. Business cases are based upon forecasts, and the validity of these will only become apparent over time. But the new trains and timetable have only just been delivered, forecast growth has not had an opportunity to appear, and passenger numbers have been severely impacted by the Covid-19 pandemic. This does not allow forecast benefits to be audited, but the soundness of the initial assumptions has been tested.

Value

Value reflects the *importance, worth, or usefulness of something*.[1] It relates to the perceptions of stakeholders and is intrinsically qualitative.[2] Examples include the perception by a Local Enterprise Partnership (LEP) that railway modernisation improves the economic prospects of an area, and the availability of better data on electrification costs.

The Department's Benefits Map also sets out four *DfT Objectives*. These give four categories of value:
1. support the creation of a stronger, cleaner, more productive economy
2. help connect people and places, balancing investment across the country
3. help make journeys easier, modern and reliable
4. make sure that transport is safe, secure and sustainable.

Safety performance, a core Network Rail value, is embodied in the fourth *DfT Objective*.

The four *DfT Objectives* represent *Value*. The impact of GWRM cannot yet be measured—benefits will be created over time, via complex processes of investment and relocation, and this will be influenced by performance of the wider UK and global economies. Where possible, they will be qualified.

Two further categories of value have been added, which are linked to the first *DfT Objective*:
5. better industry capability, which will lead to more efficient delivery of future electrification projects
6. better national capability, supporting the future delivery of decarbonisation via a reliable approach to electrification across the UK rail network.

These two categories represent value that was not explicitly remitted to Network Rail, but which might be expected after the 25 year near–hiatus in UK rail electrification.

1 Oxford English Dictionary.
2 A stakeholder is any party who expects to derive value or benefit from a change.

A2.2 Approach

Evidence for outputs and value was sought within three categories:

1. **outputs**—which may be measured
2. **value**—which may be described by stakeholders
3. **legacy**—which may be described by those who learned.

Numerical data was gathered from Network Rail's System Operator and Wales & Western financial team, Great Western Railway (GWR), publications by the Department, the Office for Rail and Road (ORR) and the National Audit office (NAO), from Hitachi Rail, and from Modern Railways magazine.

People in Network Rail and GWR were interviewed to obtain information. Other information came from Network Rail lessons learned reports and publications by the Department, the Office for Rail and Road (ORR) and the National Audit office.

Findings are presented starting with policy and strategy, then value to our economy, the places we serve, and our passengers in order to make the information easier to assimilate.

The author did not examined whether GWRM delivered value for money. The NAO has reported on how Network Rail and the Department performed[3], and the Department has updated its business case[4]. This report does show that GWRM has generated considerable value in all areas covered by the Department's business case. And Great Western electrification contributes to decarbonisation of the UK economy, a source of value that is becoming increasingly important.

3 Modernising the Great Western Railway, National Audit Office (2016).
4 Great Western electrification project business case: Phase 1 report, prepared by CH2M for the Department (2017).

A2.3 Outputs and value of Great Western Route Modernisation

Figure 42 summarises the structure of outputs and value which this report references.

Figure 42: Summary of outputs and value

Grouping	Category	Output or value	Possible measures
Department's End Benefits (Outputs)	Increased passenger capacity	Additional seats	Additional peak seats into London and other towns and cities.
	Reduced journey times	Journey time improvements	Reduced timetabled journey times between London and other cities.
	Reduced operational costs	Lower cost per train–kilometre	Combined figure including train charge and track access charge (including energy).
		Reduction in rolling stock requirements	Fewer trains needed because of higher reliability. More choice of routes for electric trains to operate on.
		Electric stabling capacity	Better choice of stabling for electric trains with lower operational impact.
	Improved service reliability	Improved reliability per train–kilometre	Train reliability data. Public Performance Measure (PPM). Cancelled and Significantly Late (CaSL) measure.
	Improved environmental performance	Reduced carbon emissions	Assessed reductions in emissions based upon modelling. Proportion of GWR train mileage on electric vs. diesel power.
		Reduced diesel fumes	Measured reductions at key stations.
		Reduced noise	Measured reductions at key stations and adjacent to railway lines
Department's Objectives (Value)	Support the creation of a stronger, cleaner, more productive economy	Value provided to London, Thames valley, and regional economies Value provided to the Department and its planning processes	Statements by local authorities, LEPs and others. Evidence of value generated by similar schemes.
	Make sure that transport is safe, secure and sustainable	Safety of passengers, staff and neighbours. Contribution to sustainability objectives. Non–user benefits.	Reduced maintenance risk. Reduced level crossing risk. Reduced trespass risk. Sustainability impact. Decarbonisation impact. Reduction in road accidents and congestion. Modal shift.
	Help make journeys easier, modern and reliable	Value provided to passengers	National Rail Passenger Survey (NRPS) data.
	Help connect people and places, balancing investment across the country	Capacity and connectivity to cities and regions away from London	Impact of rolling stock cascade.
Industry legacy	Value to the railway industry as it plans further electrification	Support for efficient delivery of future electrification projects	Technical and organisational legacy: summary of positive changes and learning
	Value to the UK as it plans to decarbonise	Support for future delivery of decarbonisation	Knowledge legacy: summary of positive changes and learning

NetworkRail

July 2020