CROSSRAIL

RAIL

FREE 32-page Special

SEE INSIDE FOR:

- Crossrail from the air
- Crossrail's uneasy birth
- Prospects for Crossrail 2
- Carillion's Christmas works
- New Aventra fleet introduced
- Behind-the-scenes at Abbey Wood
- Inside the integrated management team

CROSSRAIL.

ANTONY GUPPY.

Welcome

This 32-page special coincides with the passing of a significant milestone for the £14.8 billion Crossrail project, as the first of its 66-strong purpose-built fleet of Class 345 Aventras enters revenue-earning passenger service with TfL Rail, later in May.

For now, the Bombardier-built trains will be limited to running as seven-car formations on Crossrail's eastern section between Shenfield and Liverpool Street main line station. That will continue until the railway's 13-mile twin tunnelled central section opens in December 2018, when the full fleet will be in traffic and running as nine-car trains, each able to carry up to 1,500 passengers.

By then officially known as the Elizabeth Line, the final westernmost section of the route will be the last to open in December 2019, completing a network stretching for more than 70 miles between Shenfield and Abbey Wood in the east, and Heathrow and Reading in the west.

With 24 trains per hour running beneath central London, the finished Crossrail will then increase London's rail capacity by 10%, and is widely expected to serve more than 200 million passenger journeys per annum, between its 40 stations.

In this issue of *RAIL*, we track the progress of what is Europe's largest construction project to date, from its earliest beginnings through to its current status.

Looking all the way back to before the Crossrail Act received Royal Assent in 2008, or even the first ground was broken a year later, Ian Brown, one of the project's key architects, recalls his experiences on p48-51.

We also hear from both Bechtel (p58-59) and SYSTRA (p70-71) on their decade-long integrated roles as Project Development Partner, plus the Transcend Joint Venture (p62-63) about the significance of being appointed Crossrail's Programme Partner, and what that involved.

Construction is now more than 85% complete, and it's easy to forget the companies that are still hard at work completing the fit-out and commissioning of the tunnels, stations and surface sections, so Stefanie Browne catches up with one of the lead contractors Carillion (p52-53) to hear about what is being achieved to the west of Paddington.

RAIL also travels to Abbey Wood to see Network Rail's ongoing contribution to the project on its south-eastern section (p66-69), while Richard Clinnick focuses on what passengers can expect from the new Aventra trains (p44-47). There's also a look at specialist subterranean tracklaying, as *RAIL* is given a demonstration of the installation of floating track slab on p54-57.

Last but not least, Andrew Mourant analyses the current prospects for Crossrail 2 on p64-65.

PAUL STEPHEN
Assistant Features Editor, *RAIL*

CROSSRAIL

CONTENTS

EDITORIAL
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Aventras assemble

A new era begins at the start of the May timetable when TfL Rail introduces the first Aventra into service. **RICHARD CLINNICK** provides an update on plans for their introduction

Crossrail 345006 passes the Olympic Park near Stratford. This has fast become one of the busiest stations in Britain, and the opening of the Crossrail route will increase footfall further. ANTONY GUPPY.

The first tangible sign of Crossrail for most people will be when TfL Rail introduces the first Class 345 Aventras into traffic.

The electric multiple units will eventually be used across the full Elizabeth Line (as Crossrail will be known) from Shenfield/Abbey Wood to Heathrow Airport/Reading.

However, initially, the EMUs will be used exclusively on the eastern section between Shenfield and London Liverpool Street.

Transport for London awarded the Crossrail concession to MTR, and it operates TfL Rail. This covers the Metro service to Shenfield that was previously part of the Greater Anglia franchise. When it took over in May 2015, TfL Rail inherited 44 four-car Class 315s dating from 1980-81, and which were to be replaced.

Capacity-wise, whereas the Class 315s are fitted with 3+2 seating throughout, with 321 seats per train and a further seven wheelchair spaces, the Aventras have fewer seats and are fitted with longitudinal seats, as per Class 378s and S-Stock, and bays of four seats.

Like the S-Stock, Class 700 and Class 707 trains, the '345s' have been built with walk-through gangways for increased capacity. TfL claims that the trains can hold 1,500 people (450 seated). They will be driver-operated with on-train customer information systems delivering real-time travel information, allowing passengers to plan their onward journeys on the go. Free WiFi will be available on the trains, as well as on the platforms, and people will have access to 4G, says TfL.

Aventra is Bombardier's newest train design, replacing the Electrostar that has been on offer since 1999, and which has subsequently been bought in large numbers by Abellio for the GA franchise.

Bombardier won the contract in February 2014, and unveiled the design in November 2015. The first trains were showcased in July 2016. They have a higher top speed (90mph) than the 37-year-old EMUs they are replacing (75mph). Including the depot at Old Oak Common, the Class 345 deal was thought to be worth around £1 billion.

On April 25, Crossrail 345006 passes Goodmayes with the 1357 London Liverpool Street-Gidea Park test train. ANTONY GUPPY.

The first batch of trains to enter service will only have seven cars, while the remainder will all be built with nine. This is so they'll be able to stop at London Liverpool Street, until its suburban platforms can be re-modelled to accommodate the longer trains.

The rest of the fleet will be dispatched from the construction works at Derby Litchurch Lane. The first batch of Aventras will then move to Old Oak Common (the '345' fleet's maintenance depot) and be lengthened to nine-car trains.

There are five phases to the opening of Crossrail, and the introduction of the Class 345s is an element of Phase 1.

The first train (345002) was delivered to Ilford at the end of 2016, and began testing between the Essex depot and London Liverpool Street on January 13. By March, five more trains had been completed and were undergoing testing either at Derby, or at Old Dalby. This included 345018, which was the first nine-car train to be completed, but for testing only.

> "The first batch of trains to enter service will only have seven cars, while the remainder will all be built with nine."

By early April, Ilford had also received 345005 and 345006.

TfL says that a critical element of the construction and introduction of the Aventras is the multiple on-board systems and the complex software being installed. It highlights the Train Control and ➤

➢ Management Systems, and the software needed to integrate them. TfL says successive software releases are tested at Derby prior to installation on the test units before trains on the national network receive the updates. And after all that, only once they have passed an Independent Safety Assessment by the Office of Rail and Road (ORR) can they enter traffic.

TfL says the first Aventra in public service will be 345005, and this is undergoing testing. Meanwhile, also at Ilford, drivers are in training, with the help of two simulators.

Phase 2 of Crossrail features the introduction of trains between London Paddington and Heathrow Airport, in May 2018. Four trains per hour (4tph) will replace the current 2tph Heathrow Connect service.

To enable these trains to run so frequently, '345s' will be fitted with European Train Control System (ETCS) signalling, to be compatible with the ECTS-fitted route between Heathrow and Airport Junction (Stockley). Alstom is providing the signalling and the testing is expected to commence in the second half of 2017.

Phase 3 comes in December 2018, when services start running through the Crossrail central tunnel. These will run from Paddington (serving the new underground platforms as opposed to the ground-level station served from May next year) to Abbey Wood, via Canary Wharf. At this point, the route will be officially referred to as the Elizabeth Line.

Phase 4 will feature the Shenfield to Liverpool Street services being connected to the central tunnels and running through to Paddington; this is scheduled for May 2019.

Finally, Phase 5 comes in December 2019, when services from the west are connected to the central tunnel and trains start running to Maidenhead and Reading.

But even at this early stage, TfL is looking at increasing the service frequency - and ordering more Aventras.

It is proposing to run a higher frequency service during Off-Peak and an enhanced Peak service west of London. This would come into force in Phase Five.

The proposals for the service increase include a rise from 16tph in the Central Core to 20tph, with additional trains running from Paddington to Shenfield and Abbey Wood. There would be an increase in Peak and Off-Peak services west of Paddington and a revision of the Peak services operating across the network to provide a regular interval of trains, including a train approximately every five minutes westbound from Paddington.

TfL believes that the more regular service pattern could have a positive effect on operational reliability. Precise performance and reliability of the proposed timetable is being validated in a joint modelling plan with NR, as the timetable for Crossrail is developed. TfL says the initial analysis, however, does look favourable.

All these proposals would require four additional Aventras, but TfL says that no additional stabling facilities would be required.

So, on March 8, TfL recommended that the Programmes and Investment Committee increase the order for 66 nine-car Class 345s to 70. This would also give the option of taking the eventual fleet to 84 trains, if the need were to arise.

Additional track access rights are required for the proposals and, if granted, would affect franchised Great Western Railway services. West of Paddington, to cater for the enhanced Elizabeth Line services, five GWR trains in both the morning and evening peaks would need to be removed. It is then proposed to run these on the relief lines between Paddington and Reading using a semi-fast stopping pattern. TfL says that the GWR trains to Maidenhead, Twyford, Reading and the Thames Valley would continue to be provided during Peak by "other trains which operate over the main lines between Paddington and Maidenhead". TfL claims that these changes would mean "there is no material impact on maintenance activities in the Central Section or NR sections of the route".

It also states that any equalities implications from the removal of GWR Peak trains are being considered in the context of the proposed Elizabeth Line services, and will be reported to the TfL Board when approval is sought.

Before the first new trains are in traffic, and before the first section of new railway is even open, capacity concerns are already forcing TfL to think ahead, which can only be a good thing. And a deal for more trains in the offing before the first '345s' have even entered traffic bodes well for the success of the Aventras. ■

> "Even at this early stage, TfL is looking at increasing the service frequency - and ordering more Aventras."

On August 4 2015, TfL Rail 315836 leaves Stratford with the 1749 London Liverpool Street-Shenfield. These veteran electric multiple units were introduced in 1980/1981 and will be replaced, from May, by the Aventra fleet. ANTONY GUPPY.

HOW IS THE CROSSRAIL PROJECT DOING OVERALL?

Board meeting papers from a recent Programmes and Investment Committee meeting showed that construction of Crossrail was 82% complete, with 76% of track-laying complete by early March.

It said that the major physical activities currently under way were the fitting out of stations, installation of mechanical and electrical systems such as the ventilation, lifts and escalators, and also the installation of cabling, communications, power and signalling systems.

Operationally, the meeting discovered, TfL Rail remains one of the most reliable of the national train operators, with a 96.0% Public Performance Measure (PPM) during the most recently recorded period; this was the second best in the UK. For TfL Rail, 87.9% of trains arrived within a minute's scheduled time, which was the highest of any UK operator.

INFRASTRUCTURE

Introducing new trains also requires changes to infrastructure. On March 8, Transport for London highlighted how Network Rail was adjusting platform edges along the Metro route between London Liverpool Street and Shenfield ahead of the introduction of the Aventra fleet. It noted that much of this was carried out during a blockade over Christmas last year, but that additional work was completed during weekday night possessions and at weekends.

Ilford depot is changing, too. The test trains are currently accommodated in existing sidings, but new sidings are being built, will be ready for the introduction of the Class 345s from the May timetable. These are adjacent to the Great Eastern Main Line, on the site of former repair buildings.

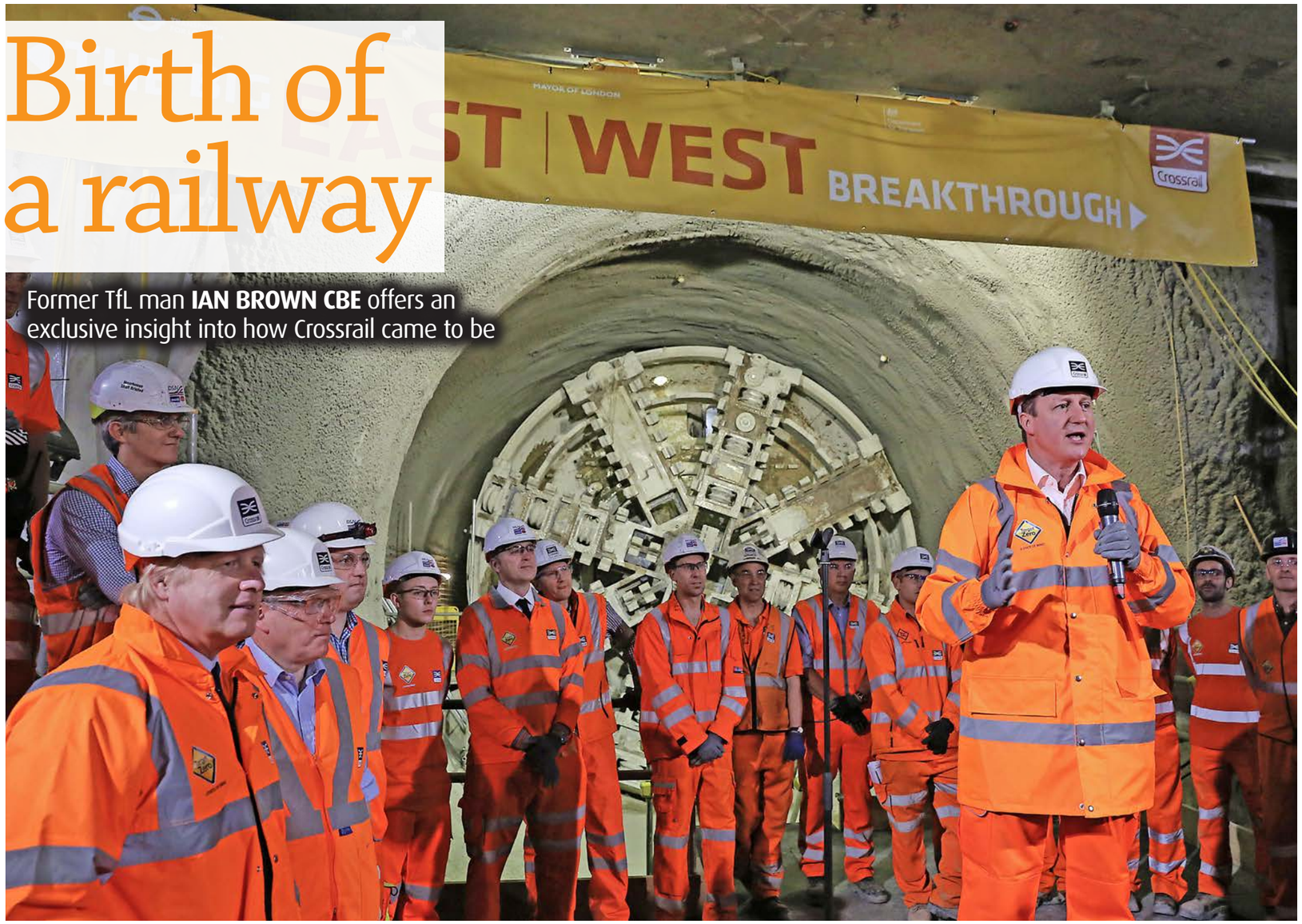
On the Western route from Paddington, Transport for London says that many platforms require significant work, including height adjustment to enable the '345s' to use the stations.

Additionally, the main depot will be at Old Oak Common. The maintenance building is structurally complete and electrification was under way in mid-April. The first section of the site should be ready in the autumn.

During a mileage accumulation trip to Southend, 345002 passes Hockley with the 1335 from Shenfield on April 6. The Class 345s will not run north of Shenfield. ANTONY GUPPY.

Birth of a railway

Former TfL man **IAN BROWN CBE** offers an exclusive insight into how Crossrail came to be



In recognition of Crossrail's national significance, the project's £14.8 billion price tag was split three ways between central government, local government and London businesses. The completion of both the tunnelling and the main construction phase on June 4 2015 was marked with a visit by then-Prime Minister David Cameron and Mayor of London Boris Johnson. CROSSRAIL.

The concept of an east-to-west London railway had been around since 1945, although all we had to show for the first 55 years was a large, allegedly 100 metre-wide set of archived files kept in storage at Eastbourne Terrace, in London. Mercifully, nobody was injured when the archive burnt down, but the files were lost.

To get one of the largest rail projects in Europe funded, planned and, so far, successfully delivered required an auspicious alignment of the stars, and that happened around the year 2000. Although London Underground had delivered several Tube lines over the last 50 years, notably the Victoria Line and the Jubilee Line Extension to Stratford, there were few developments in the area of bringing together the Underground and National Rail networks in a strategic way.

I learned three key lessons while working with the Docklands Light Railway (DLR team). I would contend they are still fundamental to the rail industry in terms of delivering rail projects, both new extensions and capacity upgrades.

Lesson 1: DLR was initially managed through legal contracts. This did not work, but what did work was the establishment of a strong client team, with serious engineering and project skills, to oversee contracts. We had to convince certain bodies, particularly the Treasury, that we were capable of delivering projects on time, within budget and with the required outputs.

Lesson 2: Development of the DLR, as later with Crossrail, had to be for a purpose, and for a customer. In this case, the purpose was the economic regeneration of Docklands with the London Docklands Development Corporation and the Government as stakeholders.

> "To get one of the largest rail projects in Europe funded, planned and delivered required an auspicious alignment of the stars."

Lesson 3: The Government wanted to privatise the DLR. We came up with our own version of this - the Concession Model. This achieved the benefits of competition to operate the railway, but we undertook the projects (either directly or through concessions), bought the new trains and, critically, oversaw the signalling control system upgrades. We specified the train services and, under direction of the Mayor, set the fares. This was a hugely successful model in terms of delivering a very reliable railway with excellent customer satisfaction. The Concession Model was later applied to the London Overground, again hugely popular, and will be applied to Crossrail.

The Greater London Authority Act 1999 is the Act of Parliament that established the Greater London Authority, the London Assembly and the first Mayor of London, Ken Livingstone.

Two effects of this Act were necessary for the evolution of the Crossrail project. The first was the onus on the Mayor to plan transport development for the next 20 years. The previous annual funding approach had only hindered the development of infrastructure projects. But the long-term approach meant looking at the entire transport network, including main line services.

The strategic choice for Livingstone as newly elected mayor was to determine what sort of London to go for, in terms of population and economic growth. The choice was between a stable economy and no population growth, or a growth of population by over one million people in this new planning timeframe. It was not a difficult decision, but there was one big ramification: the need to provide more rail infrastructure to accommodate a 20% increase in demand over the entire transport network in London, including the already-crowded Underground network.

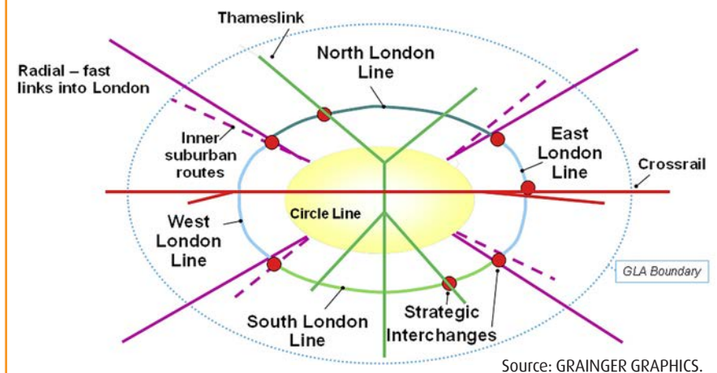
The second effect of the GLA Act was to set up Transport for London, with a rail and road planning capability to deliver an expanding and integrated transport system. TfL, in conjunction with the Mayor, went about this with a combination of road traffic restraint - the Congestion Charge, Underground upgrades, and the provision of a rational and complementary bus service. The big question was how to expand rail capacity overall by 20%

The first London Transport Commissioner, Bob Kiley, was imported by Livingstone from New York's Mass Transit Authority, initially to fight the Government's ill-fated 'Public Private Partnership'. As a concept it had some merit, but it failed because of a lack of understanding about the condition of the antiquated Tube system and what it would cost to bring it up to scratch.

In New York, Kiley had watched the catchment area of Manhattan expanding well beyond the extremities of the New York Subway system. In London, the Tube has done the same. The difference between these two cities is that in the US the national rail operators couldn't get rid of suburban rail operation quick enough, which led to transit agencies running suburban rail operations. In London, the Government franchises these operations, so rail providers can make profit. Furthermore, the Government was, and still is to some extent, very reluctant to give these rail operations over to a Labour mayor.

The integrated vision was the 'Electron Diagram' (see below). This required a new east-to-west railway (Crossrail), a north-to-south railway (Thameslink), and an orbital rail network, well beyond the Circle Line, with strategic interchanges, so that many services could avoid Central London.
The London Overground established TfL as capable of providing a modern, cost-effective rail service using the DLR Concession Model. It also established that TfL is capable of main line rail projects, as a result of the East London Line project. This was a combination of an Underground conversion, restoration of a former BR alignment (the Broad Street ➤

Crossrail as part of an integrated rail strategy for London... the 'Electron Diagram'



Source: GRAINGER GRAPHICS.

➢ Line), some new-build and, as later with Crossrail, integration with the main line rail network at both ends, north and south.

The orbital route was a cost-effective way of providing a new line, largely by using existing infrastructure round London. But the missing element was the east-to-west railway. Early ideas on Crossrail stations were modified to accommodate the 'Electron Diagram' integrated vision. In the east, Whitechapel was identified as a strategic interchange, now modelled to be one of the busiest Crossrail stations, while Old Oak Common in the west would be the big interchange, with its links to Overground and HS2.

The scene was set to promote Crossrail as an essential component of London's integrated transport plan. In strategic terms it was essential, but it had to be justified with a strong business case. This meant choosing the optimum route and maximising the benefits. Standard rail business cases (benefit:cost ratios, or BCRs) ensure that rail investment cases are difficult to justify.

The DfT will only consider a proposal if the benefits are twice the costs in strictly defined transport terms. Crossrail would relieve congestion on the Underground Central Line, which is a good thing. In these terms, however, it detracts from the Central Line, so is technically a 'bad thing'. But that's also a bit like saying that reducing road congestion reduces fuel tax revenue to the Treasury.

The breakthrough to surpass the valid business case threshold came from the GLA, not TfL. The proposal was to include Crossrail in the balance sheet for the city, as opposed to treating it as an isolated transport project. The principal business segment for London in terms of the generation of wealth is finance and business services. To be effective, and to develop, these businesses need to be concentrated into areas, namely the City and Canary Wharf.

This concentration and sharing of skills and business methods accelerates growth, and is referred to as the 'Agglomeration Effect'. A city such as London can only survive if good transport is in place, to bring all those people together every working day, at specific times. The Crossrail project was therefore justified against the background of serving both Liverpool Street and Canary Wharf.

DLR 131116 makes its way through east London with a service to Bank on November 13 2016. The concession-based operational model adopted and made successful by DLR was also applied to Crossrail. RON WESTWATER.

Although the central core between Paddington and Liverpool Street was well defined and partly safeguarded in terms of planning consents, what to do at each end was a matter of fierce debate between TfL and DfT. But it was all the better for this in thrashing out the optimum route solution. I would argue that Thameslink would also have been better, had it been subject to a similar approach.

In the east, there were three principal contenders for the route; the originally envisaged high-density, traditional corridor to Shenfield, a corridor north of the Thames through Barking Reach, and an extension of what was the North London Line under the river to Woolwich and Gravesend (and possibly Ebbsfleet.)

I recall arguing with Livingstone that he could not have all three, and that having two branches was preferable. He eventually went for Shenfield and Gravesend, although following a meeting with then Secretary of State Alistair Darling, this was cut back to Abbey Wood, where the Crossrail alignment joined the North Kent Line. I don't think Darling had ever been to Abbey Wood when he made that decision.

Barking Reach was to be served by a DLR Crossrail feeder to Custom House. TfL has since replaced this with a cheaper extension of the Gospel Oak to Barking Line to Barking Reach, and it's not related to Crossrail.

In the west, deciding on the route was much easier. We all agreed on the Great Western Main Line and also Heathrow (for economic reasons, to provide a direct connection to the City and Canary Wharf.) In terms of where a second branch could be built, Richmond was a serious contender due to its important interchange with the Central Line at Turnham Green. It also offered a range of options of connecting with the Chiltern Line and onto the West Coast Main Line, or the Watford DC Line.

There was much political resistance to Crossrail from Richmond, due to a marginal reduction in the number of District Line trains serving it. The favourite remains a connection onto the West Coast Main Line, to allow direct access onto Crossrail straight into Central London, the City and Canary Wharf. Although this got timed out of the first stage of Crossrail, it remains an aspiration. The effect of this in facilitating HS2 construction at Euston Station could be very positive.

Ken Livingstone's vociferous support for Crossrail as Mayor of London between 2000 and 2008 helped ensure the Crossrail Act was first introduced to Parliament in 2005, and then passed into law three years later. ALAMY.

There were many other aspirations from main line advocates to extend Crossrail to Stansted, to Colchester and to Basingstoke. In business case terms and, interestingly, the shortest proposal was a Tube service confined to Paddington to Stratford. It was the cheapest option, but it offered the lowest benefits and the worst BCR. The more extensive the Crossrail routes, the higher the income, but not the wider benefits described, and also the higher the cost and operational complexity.

DfT and TfL eventually agreed on Shenfield/Abbey Wood to Heathrow and Maidenhead (and indeed Reading, when the funding of reconstructing Reading station and the electrification beyond Maidenhead had been sorted out).

The Government recognised that Crossrail was key to London's development and would contribute to the UK economy, and as such treated Crossrail as a Project of National Significance, so treating the funding of the project as, what is described in theatrical terms, 'a three-way box office split'. Capital funding would come from central government, from London's government - including business rates, and the fare box, in roughly equal proportions. All this was on the proviso that we convince the Treasury we were capable of delivering the project on time and within budget, and with the specified results.

We did convince the Treasury that we could deliver Crossrail, using the three principles described. The Government stipulated additional measures to ensure they got what they were paying for - an enabling project to sustain the London economy.

The three most significant requirements were:

- To set up a separate company - Cross London Rail Links Ltd, to define a detailed route and to obtain the necessary powers. The Crossrail Act would be passed (in 2008) to make provision for the new railway. Operation using the model described was to be through TfL, but embedded in the Crossrail project.
- The imposition of 'intervention points', whereby if the project exceeded planned costs at a series of defined stages, the Government could reclaim the project and either run it itself or cancel it. This is not a particularly practicable approach, but it has conditioned Crossrail to keep rigidly to the budget, unlike so many other rail projects
- The appointment of 'independent engineers'. This would be a small independent team physically making investigations around the project and providing the sponsors with independent advice about delivery, both physical and financial. This gives the Treasury confidence that the project is running to plan and has proved to be a good investment.

It was originally intended for the Crossrail route to join the North Kent Line at Gravesend, before the decision was made to cut its southeastern arm back to Abbey Wood. DB 59203 passes through Gravesend with a train of empties on August 23 2013. DAVID ANDREWS.

> "The model is demonstrating that Britain can do huge rail projects, and leading to increased Government focus on building more infrastructure."

TfL had requirements too, particularly in the area of 'on network' costs; for example the Network Rail work. As Network Rail is regulated by the Government (although delivery of these significant works responds to Crossrail) the DfT carries the cost risk here if there are any overruns. Many of these works will be of benefit to multiple users, such as with the electrification to Maidenhead/Reading, the second flyover at Airport Junction, the Acton freight dive-under on the Western section and the refurbishment of the Great Eastern lines from Liverpool Street to Shenfield.

The Crossrail team, led by Keith Berry, was successful in getting the powers. The project has a clear purpose, is well defined and although undergoing the full rigours of the Parliamentary Bill procedure, has consistently enjoyed huge support from its stakeholders. Obtaining powers for such a huge project would be impossible through the Transport and Works Act procedure, although this process is adequate for relatively small schemes, such as DLR extensions. But for Crossrail, a full Act of Parliament was necessary.

The Parliamentary process gave Crossrail Ltd time to set up its delivery phase. The single focus approach has worked. Some may consider the caution and the control methods as rather heavy-handed, but the model is demonstrating that Britain can do huge rail projects, and leading to increased Government focus on building more infrastructure.

The last stage is a tricky one - turning the project into a live railway. TfL has a good model and the management skills to achieve this, having served its apprenticeship with the DLR and London Overground. ■

ABOUT IAN BROWN

Ian Brown CBE FCILT joined DLR Ltd as Chief Executive in 1996 and then served as MD of London Rail at TfL from 2001 to 2011. He was a Crossrail board member from 2011 to 2014, and is currently Director of Policy at Railfuture. Ian was awarded a CBE for Services to the Rail Industry in the 2011 New Year's Honours, and is a judge for *RAIL*'s National Rail Awards.

THE MAN WHO DELIVERS ON A PLAN

With military-style planning and a workforce of nearly 1,000 people, Carillion pulled off some epic feats over Christmas 2016. STEFANIE BROWNE talks to WAYNE BRIGDEN, the man who made it all come together

Once upon a time (last April to be exact) a man described through these pages how his team was preparing to deliver the largest ever single programme of works Carillion had undertaken for Network Rail. That man was Crossrail Director Wayne Brigden - the man with the plan. A year on, he's invited *RAIL* back to find out whether his plan worked.

When we last met, Brigden was well under way, preparing for a major ten-day blockade for Christmas 2016 across two separate contracts of work: Old Oak Common to Paddington Approaches (OOCPA) and West Inner Track Infrastructure (WITI).

Now, with Christmas long behind us, and the benefit of hindsight, how hard was that challenge?

Says Brigden: "We had the main lines up to Ealing Broadway for two days under possession, the airport lines and the main lines into Paddington from Old Oak Common blocked for six days and the relief lines blocked for ten days. It represented 14,500 shifts, which equates to 142,000 hours worked."


carillion SPECIAL REPORT

THE MAN WITH THE PLAN

On the most congested section of the Crossrail route, meticulous planning and unfettered collaboration are key to success, says Carillion's Crossrail West Director WAYNE BRIGDEN

That was the best part of 1,000 Carillion people working on the project, and those figures don't include hours done by people working for the other contractors.

But where did Brigden draw all these people from? When *RAIL* met with him during his planning phase, he mentioned that one of Carillion's key advantages was the firm's ability to bring people in from across the business to ensure successful delivery of a major project. He said at the time: "At a very early stage, when I identify what are our very busy periods, Carillion's rail business as a whole comes together to support us… Not only do we integrate and collaborate at contract level, but it's common practice throughout Carillion too; from the managing director down, everyone supports the successful completion of Crossrail."

So was that applied here? Did they come to the aid?

"We brought people in from all over the country to support the works. One of the most fabulous things about our business is that everybody stepped up to the challenge. I requested support from the wider business and, right from our managing director downwards, they were all on this project over Christmas, making sure that we were successful, which was a massive achievement. Lots of other project directors from other parts of the business came to assist me with the safe and professional delivery."

A big tick for the first part of the plan then - getting the right people for the job. What did they achieve over that blockade?

"The Stockley flyover link into Heathrow was successfully commissioned, we remodelled the layout of the track up on the airport lines, fully commissioned the new ramp that has been built by the Stockley Main Civils team and we removed a temporary crossover. We also completed all the associated overhead line (OLE) works to facilitate that during the ten-day blockade over Christmas."

> "The plan worked. We made sure it was robust from the start and we stuck to it."

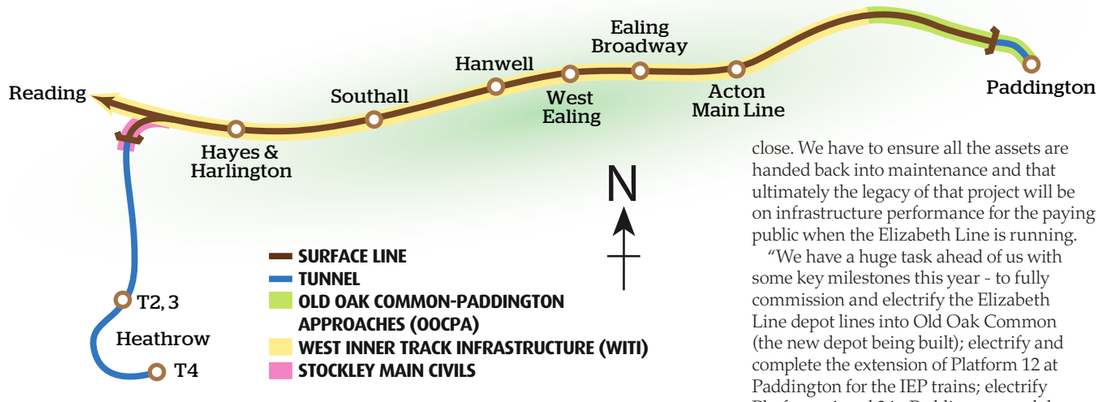
Inside that was a six-day blockade of the airport lines, which was previously unheard of. It was their only chance to do the work and was only possible because of the support of Heathrow Express, which understood that the work needed to be completed all in one go. It was worth it - the full functionality of the new track layout into Heathrow Airport has now been realised. Before, there were just Up and Down airport lines. Now there is an Up relief line and two other routes off the relief and main lines as well.

At Hayes & Harlington, they finished the layout requirements to allow the new turnback facility to be used and it is now fully commissioned. By commissioning the crossover with all the associated OLE works, it means that the new Great Western Railway Class 387s can run into the bay platform at Hayes, giving passengers new trains and more capacity from Hayes into Paddington.

Brigden continues: "In conjunction with Network Rail, we commissioned the Acton dive-under. Carillion has been responsible for all the track and overhead lines there."

This work was completed under a collaborative working arrangement with BAM Nuttall (who do the civils work) and Amey (who do the signalling). Brigden says this was a very successful joint effort and the dive-under is now fully operational. Elizabeth Line (Crossrail) trains will eventually use this when they come into service.

While much of the preparatory work was done for these projects in advance of the Christmas blockade, all the final connections and OLE adjustments were done over Christmas.



What did the Old Oak Common to Paddington Approaches works entail?

"We entered into service the Elizabeth Line depot lines as a secondary route into Old Oak Common, we installed switches and crossings at Westbourne Park and we did some unique headspan conversions, in which we removed the headspan wires and installed portal booms."

Still under the same contract but relating to IEP (Intercity Express Programme) works, Brigden's team also remodelled platforms 11 and 12 and installed a new footbridge on Platforms 1 and 2, while carrying out significant bridge strengthening works to Westbourne Terrace.

When you put the whole programme together, it suddenly becomes clear where those 142,000 man-hours went. Echoing the sentiments that Brigden made when we met last, he says the biggest achievement from all of that in his eyes is "there was no personal injury on site. We were accident-free. Everybody went home safe, every day".

> "Right from our managing director downwards, they were all on this project over Christmas."

Sounds like it all worked then?

"The plan worked. We made sure it was robust from the start and we stuck to it. And we had very robust contingency plans in place, should we have needed them."

While that was a huge undertaking over Christmas, these contracts are still in play - West Inner Track Infrastructure is due to finish in May this year and Old Oak Common to Paddington Approaches in March 2018. So what challenges is Brigden planning for now?

"The WITI contract is coming to a close. We have to ensure all the assets are handed back into maintenance and that ultimately the legacy of that project will be on infrastructure performance for the paying public when the Elizabeth Line is running.

"We have a huge task ahead of us with some key milestones this year - to fully commission and electrify the Elizabeth Line depot lines into Old Oak Common (the new depot being built); electrify and complete the extension of Platform 12 at Paddington for the IEP trains; electrify Platforms 1 and 2 in Paddington; and do significant infrastructure work at Royal Oak sidings and on the final connections into the Elizabeth Line tunnel lines at Westbourne Park."

Brigden says that the OOCPA contract is the true jewel in the crown for Carillion's Crossrail works.

"It is the last piece of the jigsaw for Carillion finishing its successful programme for the Network Rail surface works for Crossrail."

Are there any challenges Brigden is concerned by, or is he pretty confident?

"Access is definitely a challenge because of the sheer volume of services in and out of Paddington. But other than that, I'm confident. We've got the plan, the plan is on the wall, now it's just all about the professional execution of that plan!" ■

Work takes place to reinforce Westbourne Bridge on the approaches to Paddington station on December 26 2016. CARILLION.

Keeping track of Crossrail

Ventilation and access to the Liverpool Street construction site for heavy materials is via a 42-metre-deep temporary shaft in Finsbury Circus, located halfway between the station's eastern and western ticket halls. Eventually it will be covered up, and Finsbury Circus restored to its former use as a public park, once construction is complete.

RAIL continues to document the progress of Crossrail with a detailed look at the high-tech track underpinnings currently being installed

All *RAIL* photography: PAUL STEPHEN

Crossrail's surface sections hit a key milestone this month (May 2017) as the first TfL-operated services begin running from Shenfield-Liverpool Street, resulting in the first Bombardier-built Class 345 Aventras entering traffic.

Until December 2018 they will have to terminate at Liverpool Street main line station, however, while Crossrail's central tunnelled section is fitted out and commissioned. This will pave the way for the 66-strong Aventra fleet to serve destinations further west, and also in south-east London, on what will have by then become officially known as the Elizabeth Line.

Finally, the westernmost sections of the route from Paddington to Reading will open in December 2019, completing the 73-mile pan-capital railway.

To facilitate this phased introduction of services, Crossrail Ltd is currently focused on fitting out the tunnels, and stations within them. Track laying, electrification, communications and signalling works are all due for completion later this year by joint venture ATC (comprising Alstom, TSO and Costain), so that testing and commissioning of the operational railway can begin in early 2018.

80% of the track within the tunnels will be standard track slab (STS) secured directly to the tunnel floor. This is delivered on site as individual track panels by four giant multi-purpose gantries (MPGs), where they are clipped into place, welded together and then concreted into position by a 465-metre concreting factory train, stabled near the Plumstead tunnel portal in south-east London. More than 80% of the 25.6 miles of STS needed for the project had been laid at the time this issue of *RAIL* went to press.

The remaining 20% of the tunnelled section track comprises four distinct types. 2.6km of Direct Fixed Track has been laid within Connaught Tunnel in Docklands, due to clearance restrictions presented by its 1878-built bore, while the Crossrail Act (2008) legislated that high-attenuation sleepers and two different types of floating slab track were to be installed in order to mitigate the vibration of passing trains beneath several isolated and noise-sensitive areas of central London.

In June 2016, *RAIL* was invited to a tour, hosted by track engineer Juliet Murray, of the 1.97km section of the route between Tottenham Court Road and Bond Street, where lighter floating track slab was being laid due to the proliferation of hotels, recording studios and editing suites overhead (*RAIL* 803).

Nine months later, *RAIL* went to visit a 1.34km section of tunnel near Liverpool Street, where a heavier and more energy-absorptive variant of floating track slab (FTS) is being installed in Crossrail's two running tunnels, 40 metres beneath the Barbican Theatre.

The process for laying both light and heavy FTS is very different from STS, explains our guide, Crossrail track manager Adam Ersser.

FTS sits above the tunnel floor on a bed of rubber bearings and heavy duty springs. To start with, steel rebar is laid to provide reinforcement for 30-metre floating slabs, upon which the track will sit. Unusually heavy MagnaDense concrete is then poured to form the slabs, which are then jacked up, one by one, into position. Small holes are left within the concrete for the heavy-duty springs and bearings to be inserted beneath the slabs once they have set. These have to be flexible enough to absorb the energy of passing trains, yet sufficiently rigid to bear their weight and prevent the slabs from being forced out of position by the horizontal forces exerted by fast-moving traction.

During *RAIL*'s visit on March 3, work to lay a 500-metre stretch of heavy FTS between Liverpool Street and Farringdon was over 50% complete; 15 slabs had been fully concreted and jacked into position out of the required total of 25 in the western running tunnel, and 11 out of 25 in the eastern.

Having started laying the heavy FTS in January, this section was due for completion by the end of April (when this issue of *RAIL* went to press), with 200 staff deployed on eight-hour shifts, and three shifts per day.

RAIL presents a series of photos taken during its latest site visit, documenting the heavy FTS track laying process. ■

Looking west towards Farringdon in Crossrail's heavy FTS section, and steel rebar is in place ready for that night's Magnadense concrete pour. Up to two 30-metre slabs can be completed during a single shift, with each requiring 45 cubic metres of concrete delivered on site by the grey pipe on the right-hand side tunnel wall. The concrete is pumped up to 900 metres from a shaft on Hayne Street (near Barbican Tube station), as it is too dense for delivery by rail. Concrete pours begin at 1900; grout must first be pumped through the pipe for lubrication before the actual pour can commence. Pumping must be completed by no later than 0100, as Crossrail is limited by a Section 61 agreement with local councils that restricts noise disruption to local residents. The rails on top of the rebar are only temporary, and act as markers for the positioning of steel plates, and the holes needed to insert springs and bearings.

Looking east and back towards Liverpool Street's westbound platform where STS track panels have been stacked, ready to be laid and clipped into position by an MPG. They will then be welded together and concreted into place. Some 70,000 STS sleepers are being used for Crossrail.

Heavy-duty springs await insertion beneath the freshly set floating track slabs. Each will require 24 hours to settle, and will compress by 10mm under the weight of the slabs.

1. The westbound platform at Liverpool Street. The hoardings will stay in place here for another few months to protect the new cladding and other interior station fittings from the diesel emissions of ATC's Class 66-hauled concreting train. It will need to pass through here to access sections of STS further west from its base at Plumstead to the southeast.

2. White cladding ready to go up on the bare concrete walls of Liverpool Street's westbound platform. All of Crossrail's underground stations will have a uniform look at this level, featuring predominantly white cladding, but they will have their own bespoke design at street level. At Liverpool Street, its two ticket offices located on Moorsgate and Bishopsgate will have striped ceilings to mimic the pinstripe suits associated with the Square Mile and nearby financial district.

3. A section of STS running through Liverpool Street station that has already been partly concreted into its final position.

Completed heavy floating track slabs, fully jacked into position and with springs and bearings inserted, ready for track laying.

Hydraulic jacks, still in position in Crossrail's eastbound tunnel, that are to be used to raise the FTS to the required height prior to inserting springs and bearings beneath.

A close-up of the holes that accommodate the springs used for FTS, and the metal shims used to lock them in place.

BECHTEL DELIVERS

PAUL STEPHEN speaks to Bechtel's Bill Tucker and some of the global engineering and construction firm's team delivering the central section of the Elizabeth Line

Bechtel is a key player on the Crossrail project and responsible for delivering 26 miles of tunnels and eight of the ten new stations that comprise the central section of the Elizabeth line. Appointed as Crossrail Ltd's appointed project delivery partner (PDP) in 2009 (with its nominated sub-consultants SYSTRA and Halcrow), Bechtel's Bill Tucker (Central Section Delivery Director), is part of the integrated management team (headed up by Crossrail Ltd Programme Director Simon Wright). Tucker leads more than 600 people – nearly a quarter of them from Bechtel, many of whom are in senior programme management positions on the project. Bechtel is also responsible for the implementation of Crossrail Ltd's delivery strategy, making sure there is equal focus from contractors on achieving its vision and upholding its values, such as health and safety, best practice and responsible procurement. Tucker's team is also the main authority for the long list of contractors working on Europe's largest construction project.

Tucker tells *RAIL*: "We sit here today with the Crossrail project 83% complete, and the fact we're on track for the central section to open in December 2018, is a big success which we are not taking for granted. There were always going to be huge challenges on a project that's as big and complex as building beneath central London. We are managing an enormous number of design and construction contracts and our job is to coordinate all of them and make sure they all work in unison for one single programme. There have been more than 150 separate contracts to manage from the first stages of demolition through to final commissioning, but Crossrail Ltd views the project as one railway, so we've had to identify and manage all those interfaces and liaise with industry stakeholders." Tucker, who has been working at Crossrail from the first day of the delivery partner contract says: "We've worked really hard to integrate the team and embody Crossrail's vision of working as one, while bringing Bechtel's capabilities and experience". We try and find the right person for the job, as opposed to saying 'one company is responsible for this, and another firm is responsible for that".

Paul Gibbs, Managing Director Bechtel Infrastructure UK, and Bill Tucker, Crossrail Central Section Delivery Director, Bechtel. BECHTEL.

Bechtel has been helped by one or two innovative, motivational devices to emerge from the PDP partners' toolkit. "As a team, we've helped Crossrail develop a performance management system that uses leading indicators every six months to check if contractors are making extra effort. It's a very new concept to the industry. Putting a performance league table in front of a room of directors can have some amazing effects. So I'd say that measuring performance in this way has proved to be very motivational! I wasn't sure about using it at first, as I was worried it was yet another audit on companies. But I can now say it is a collaborative and forward-thinking way of boosting performance and outputs. It's also proved useful to the contractors, who have started using the rankings as a sales pitch. We've shared this tool with other organisations, such as London Underground and HS2 Ltd, to use for their own projects."

Turning back to Crossrail, Tucker says that the most pleasing aspect of leading the management team has been successfully resolving problems, rather than trying to avoid them. Much of the work took place underground, away from the public gaze but he points to the above groundworks at places like Whitechapel. Crossrail's new station is being built there, above fully operational London Overground and Underground platforms and Tucker highlights it as a good example of successful risk mitigation and liaison with industry stakeholders.

"I could probably list ten things we've encountered along the way where you might say 'this is daunting' but where you relish the challenge. At Whitechapel, we've had to work around passengers and on top of operational railways, mostly at night, in the London Underground and Overground networks. I'm really pleased that we've been able to overcome a number of issues, particularly when they've involved things we didn't expect, such as unmapped utilities. Had we been less diligent, things like that could have had an adverse impact on the programme. But we handled them, and now we are close to completing the station structures, which feels spectacular."

Taking a moment to reflect on the last eight years as part of the integrated programme management team, Tucker says that Bechtel will emerge from the project a stronger company, having shared a wealth of new experience. He says it has been one of the highlights of Bechtel's seven decades in the UK - not insignificant considering some of the company's other infrastructure jobs have included High Speed 1, West Coast Route Modernisation and even the Channel Tunnel, while its legacy has been to permanently change how large infrastructure projects are delivered across the industry.

The steel frame for Whitechapel station ticket hall is being installed above operational platforms for London Overground and Underground. The significant level of risk management and stakeholder engagement required here represents one the Crossrail project delivery partners' greatest challenges, but also successes, says Bechtel's Bill Tucker. CROSSRAIL.

He concludes: "Crossrail is the first client I've worked with that puts so much focus on how things are done, as well as what is being done, and I learned a lot from that approach. The strategy includes so many details about limiting disruption to other people, protecting the environment and tackling diversity in the workforce. 40% of Bechtel's engineers on this job are women. Crossrail has supported a new generation of British women engineers, some of whom are still here, some who have moved on to other UK jobs and some who are now working internationally on other Bechtel mega projects."

Paul Gibbs, Bechtel Infrastructure's UK Managing Director and a former Project Manager at Bond Street station, adds: "At Bechtel we engineer, construct, project manage and finance big infrastructure around the world and I've been fortunate to work on a number of incredible projects. The Crossrail project is special to us and to me; I was PM at Bond Street station from 2010 to 2012 and to come back now and see the progress made is a real privilege."

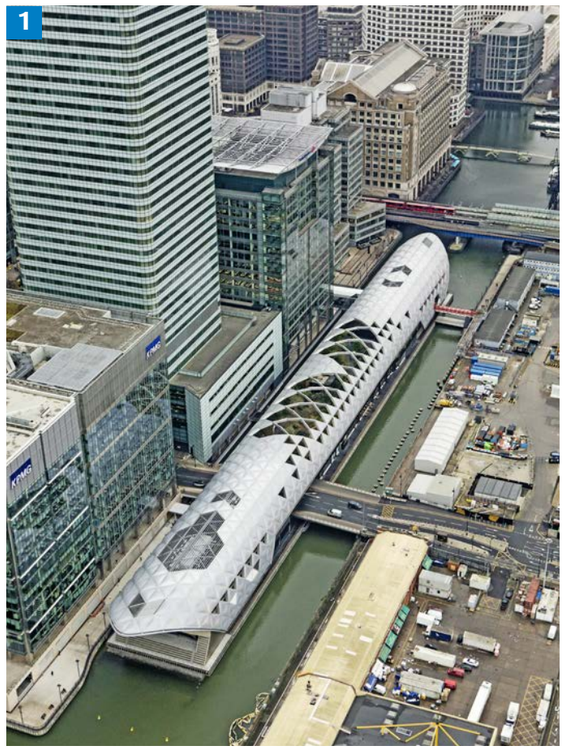
Looking at how lessons and skills learned have been exported from the Crossrail project to the benefit of the global rail and engineering community, Tucker adds: "To test this approach away from Crossrail, a subset of Bechtel's Crossrail team went to Canada to help another project (the Toronto-York Spadina Subway extension), to enable that client to leverage some of the things we've done for Crossrail. Bechtel has also recently been awarded a project delivery contract for the Sydney Metro, and people involved in the Crossrail project will be going there too; I'm very happy that Crossrail Ltd is supportive of sharing the lessons learned in London. This will only serve to develop the railway industry domestically and internationally. I tell people if you want to build something big, it doesn't get any better than the Elizabeth Line." ■

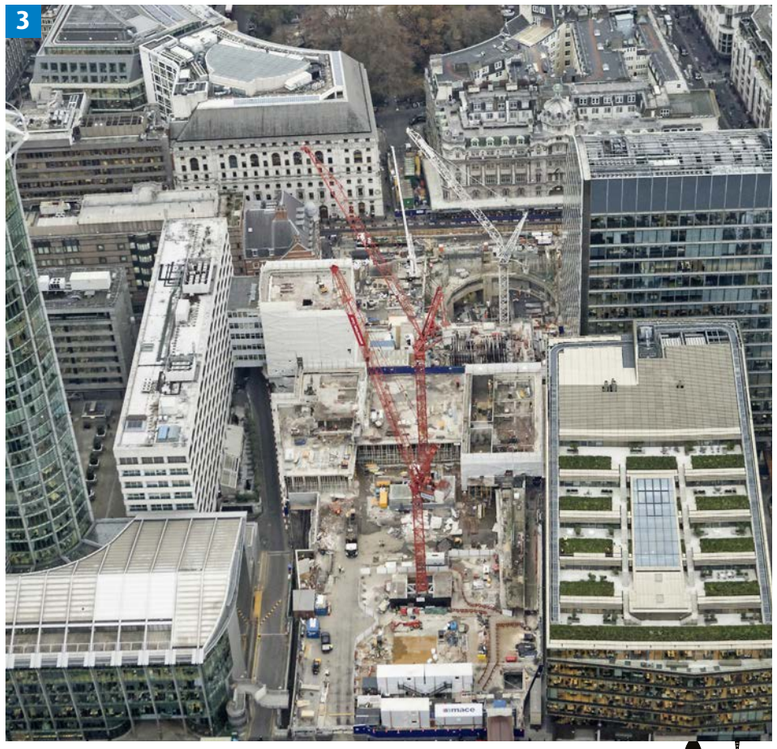
Aerial roots

In December 2018, the first Elizabeth Line services will start running through Crossrail's tunnelled sections deep beneath central and southeastern London, where ten new stations are being built to serve the new railway. *RAIL* presents a bird's eye view of some of the works that can be viewed on the surface, in this series of aerial images

All photography: CROSSRAIL

The eastern end of Farringdon's new station on Lindsay Street, looking northwest towards Smithfield Market. The western end is on Farringdon Road, providing direct access to the Thameslink ticket hall and Farringdon's London Underground station. The design theme of the Eastern ticket hall will reflect that of the nearby Barbican Centre with heavy metal sliding screen gates, while the Western ticket hall has been influenced by the area's jewellery and diamond quarter. The Eastern ticket hall will connect to Barbican Tube station, which can be seen at the foot of the image.





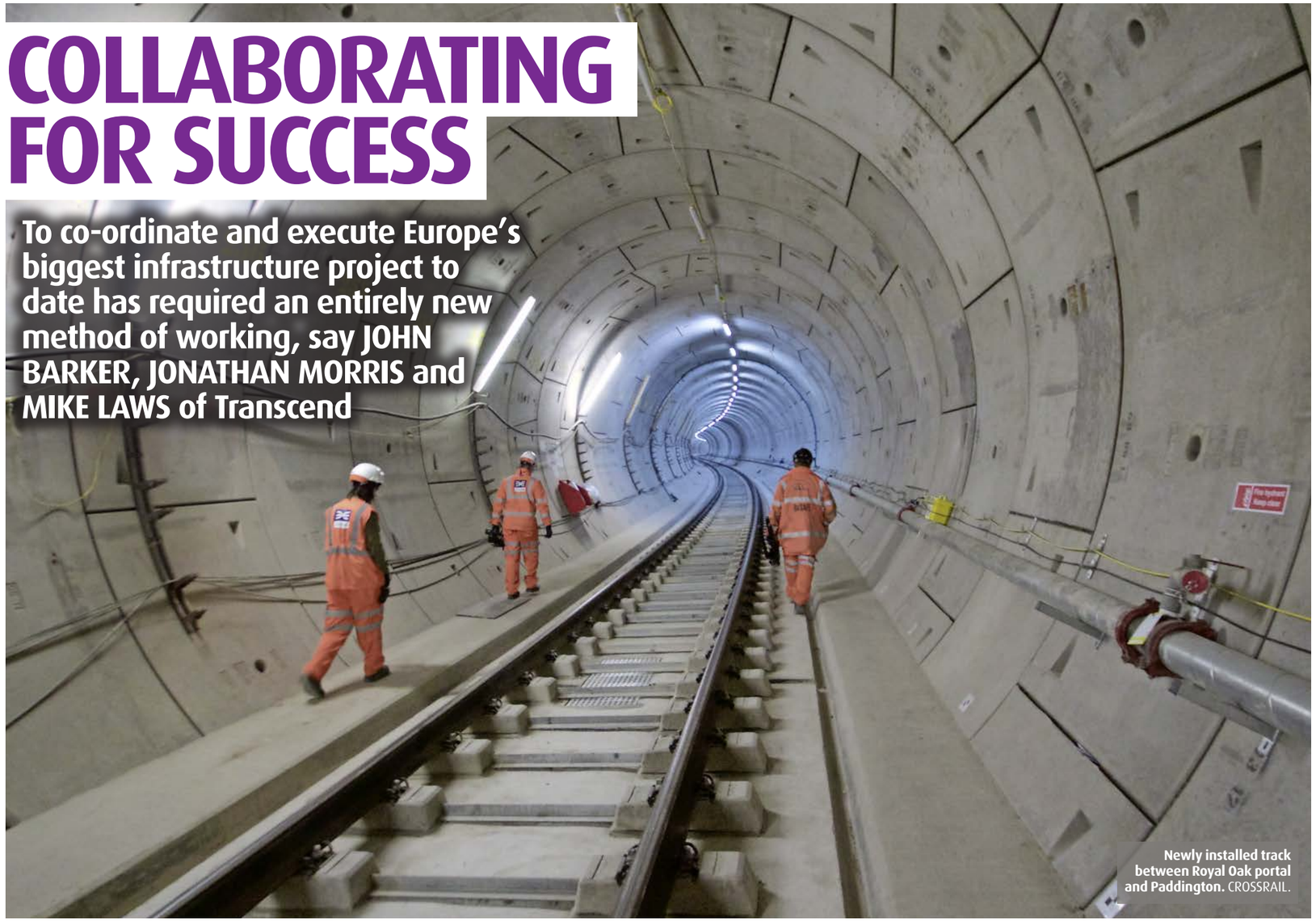
1. The 250-metre subterranean station box at Canary Wharf is surrounded by West India Quay, and below a five-storey mixed use development known as Crossrail Place. It will provide a physical connection between the Canary Wharf Estate and Poplar to the north, while containing more than 100,000 sq ft of retail and office space. It is crowned by a 310-metre timber lattice roof that lets in rain and air to naturally irrigate an enclosed rooftop garden.

2. Looking west from the country end of Paddington station, the new Crossrail station can be seen sandwiched between the south side of Brunel's iconic Victorian train shed and Eastbourne Terrace. A 120-metre steel and glass canopy, located near the centre of the picture, will allow natural light to illuminate the station at platform level, while new cafes and shops are planned at street level.

3. Looking east, and Liverpool Street Crossrail station can be seen stretching from Moorgate towards Broadgate in the heart of London's financial district and adjacent to the eponymous main line station. The top of the picture is dominated by Finsbury Circus Garden, which has been one of the main access shafts during construction and tunnel fit-out. Almost 4,000 skeletons and many Roman artefacts were uncovered here during excavation beneath one of the capital's longest occupied districts.

COLLABORATING FOR SUCCESS

To co-ordinate and execute Europe's biggest infrastructure project to date has required an entirely new method of working, say JOHN BARKER, JONATHAN MORRIS and MIKE LAWS of Transcend



Newly installed track between Royal Oak portal and Paddington. CROSSRAIL.

On May 15 2009, Crossrail broke ground when the then-Secretary of State for Transport Lord Adonis and Mayor of London Boris Johnson drove the first pile into the North Dock on the site of the new Canary Wharf station, scheduled to open in December 2018.

Although this marked the official start of the physical work, it could only happen after a phase of intensive preparatory work, which was triggered by the granting of Royal Assent for the Crossrail Act the previous July.

One of Crossrail Ltd's key tasks during that time had been to appoint both a Programme Partner and a separate Programme Delivery Partner (PDP), to ensure the successful delivery of Europe's largest infrastructure project.

The PDP was a consortium led by Bechtel (see p58-59 and p70-71), while the Programme Partner was confirmed in March 2009 as a joint venture called Transcend, comprising member firms AECOM, The Nichols Group and CH2M (see panel) supported by Turner & Townsend and Unipart.

> "Collaboration is critical to success for Crossrail."
>
> **John Barker, *Programme Partner lead, AECOM***

Programme Partner lead and AECOM's Crossrail and Transportation Director John Barker explains: "We aim to help Crossrail Ltd be a more effective client. From the outset, it was a strategic role to help Crossrail Ltd come up with its overall delivery strategy, and to help manage control at programme level. This included managing the interface with the programme sponsors, third parties and other key stakeholders, and support with other critical work before the major construction contracts were awarded."

Now fully integrated with the client organisation, each Partner has continued to lead in the areas for which they previously held responsibility, adds Barker.

"As Programme Partner we have recognised the importance of a very collaborative approach to enable Crossrail to achieve its objectives and operate as it needs to."

"The way the Programme Partner role has manifested is that we now deploy people who work across a range of functions in the integrated client management team - for example, in the programme controls function, where key people are responsible for reporting, scheduling and cost and risk management. We also deploy senior people across the technical directorate, including engineering management, quality assurance, technical integration and regulatory approvals. We've also taken a key role in providing support in other areas such as the Innovation Programme and logistics teams, thereby providing specialists across a diverse range of important disciplines."

Earlier this year Transcend achieved a significant milestone having contributed 1,000,000 work hours to the project, with some people still in continuous service since the commencement of the original Programme Partner contract in 2009.

Mike Laws, of CH2M and Crossrail Ltd's Head of Reporting and Head of Programme Efficiency, explains that the three joint venture partners had come together for their considerable and complementary skill sets, providing a balanced capability offering, chosen by Crossrail.

"The joint venture recognised the strength of engineering in AECOM, the Programme management expertise of CH2M, and the strategic advice specialism and industry authority of The Nichols Group. We came together to create the Transcend joint venture."

"AECOM was brought in for its experience on major railway projects from across the world, and to bring its engineering knowledge to Crossrail. CH2M was preferred because of its knowledge of programme controls in particular, Nichols was selected for its strategic and programme management expertise and extensive knowledge of the UK rail industry."

Barker adds: "The motivation of working on such an inspirational project has really driven the collaborative spirit and the willingness to work together on all the teams."

"As businesses, we've learned a huge number of lessons, but on a personal level, one of the biggest things I've learned from Crossrail is that collaboration is critical to success. We have prided ourselves since day one on our willingness to work well, not just with our own Transcend colleagues, but with everyone in the integrated team and beyond, challenging each other and respecting each other in pursuit of common goals."

"Infrastructure programmes in the UK are growing in scale, and that's encouraging companies to form joint ventures due to the demands for a wide range of skill sets and resources. So you need joint ventures to form with strong breadth and depth, like Transcend, but they can only be successful with collaboration among themselves and with the client. We are very proud of the relationship we've had with each other and Crossrail Ltd, its partners and stakeholders, and the motivation of our staff to make it the huge success it has been to date. We now have to see it over the line."

The Transcend team will continue to support the Programme during its remaining stages while the stations are completed and through the commissioning of the railway's operational systems. The finished railway will then be handed over to Transport for London next summer, before the new tunnelled section opens to the first revenue-earning passenger services as the Elizabeth Line in December 2018.

Jonathan Morris, of The Nichols Group and Crossrail's Programme Integration Manager, concludes: "With the Programme nearly 85% complete, we are now in the complex final stages as we integrate the new stations, tunnels and rail systems into a coherent, safe, functioning, end to end railway.

"Work includes the testing of the railway that has been built, preparing for its handover to the operators, and handling the governance that will allow us to transition from a construction programme to an operational railway. Transcend is very heavily involved in all of those areas, and making sure all remaining milestones are successfully completed." ■

Transcend: who's who

AECOM is a global provider of technical and management services to a broad range of markets, including transportation, infrastructure, energy and environmental. AECOM employs nearly 100,000 people across the globe and is involved in major capital programmes in the UK and more than 150 countries worldwide. In 2015, it was also appointed as one of four consulting teams to develop detailed plans for Crossrail 2 by Transport for London.

CH2M has more than 25,000 employees worldwide and has provided management services for high-profile and large-scale construction schemes, including the Panama Canal expansion, and London Tideway Tunnels for Thames Water in the UK.

The Nichols Group is an independent leading consultancy with industry authority. For over four decades, Nichols has provided strategic advice and support on large iconic programmes and complex projects in a range of industries. This includes vast mega rail experience in the UK and overseas. Its UK clients include Network Rail, Transport for London, Department for Transport and the London 2012 Olympic and Paralympic Games.

Testing times for Crossrail 2

ANDREW MOURANT finds out why things have gone a bit quiet on the Crossrail 2 front

Crossrail 2 will run from northeast to southwest London through 24 miles of twin tunnels at an estimated construction cost of £31.2 billion, but more detailed plans will not be revealed until the Government has approved the scheme's business case. JACK BOSKETT/*RAIL*.

These are crucial days for Crossrail 2, London's next great infrastructure project, which aims to provide a seamless link between the capital's north and south. Transport for London (TfL) is waiting - perhaps with a degree of trepidation - to see what the Department for Transport (DfT) will make of its business case.

It all boils down to money, but no one seriously expects C2 to run away with the public purse, as has the electrification of the Great Western line. Its supporters, however, point to Crossrail 1, which appears to be on time and within budget. And if anything, C2's projected cost has shrunk slightly from figures quoted last year.

Crossrail 2 is a proposed south-west to north-east rail line, based on the Chelsea-Hackney route. It will feature a twin 24-mile tunnelled section between Wimbledon and Tottenham Hale and New Southgate, connecting to existing National Rail routes in Surrey and Hertfordshire.

When *RAIL* interviewed C2 Managing Director Michèle Dix this time last year, she had plenty to say about funding, the business case and the technical challenges. But when we called for an update, TfL was notably reticent, as though fearful of rocking the boat while DfT money men and technical advisors are poring over their case.

Both parties were vague about when that verdict might be delivered - guesses revolved around late spring/early summer. However, it was possible to glean some clues about elements of the latest thinking from London Chamber of Commerce and Industry (LCCI) which, earlier in April, hosted Dix at a business breakfast.

The LCCI is anxious for C2 to go ahead, but still wary about the financial burden the capital might incur. "Nowhere else (but London) do (business and residents) have to pay so much. The cost of doing business here is constantly increasing," says policy manager Siwan Puw.

The chamber is "perfectly happy with the business case", though it might find the bill hard to swallow if London is asked to contribute more than 50% through various money-raising devices, such as the infrastructure levy. In fact, TfL's latest estimate is for a final cost of £31.2 billion, a little less than the £32.6bn - designed to cover all eventualities - that Dix spoke of last spring.

The momentum seemed firmly behind what Dix called "a big bold scheme that London wants and London needs… with benefits from the Solent to the Wash." The then chancellor, George Osborne, had sanctioned the expenditure of £80 million – half the £160m price of an environmental impact statement and all work needed to prepare for a hybrid bill to go before Parliament.

Much has been made of the enormous long-term economic benefits - hopeful forecasts that Crossrail 2 will support up to 200,000 jobs, enable 200,000 new homes to be built across the southeast and yield productivity benefits of more than £100 billion to the UK economy.

Across the C2 supply chain there will be apprenticeships and investment in training, and there will be continuity, with teams of Crossrail 1 technical experts involved. Such are the hopes of the LCCI. It wants potentially productive overseas students who've graduated from British universities with useful knowledge and skills to be free to remain in the UK, so they can apply their qualifications to C2.

Last spring, few had seriously contemplated the economic consequences of Brexit and its effect on government thinking about big spending projects. It's hard to find anyone who thinks C2 will be scrapped, but there's unease about a potential delay to passing the required legislation.

Doubts have seeped out from within government about whether the route offers best value for money, even though C2 says it has done all the evaluations. Any slippage would dismay the LCCI. "We don't want to be playing catch-up, instead of being ahead of the game," says Puw.

"Michèle Dix suggested that by having rigorous consultation before submitting the bill you could tease out parts of the legislation that might cause hold-ups in committee - though that hasn't stopped HS2 from being bandied around the Lords and Commons.

"That government asked for a revised business case does raise concerns and increases the need to keep up the pressure - there was a call for action to make the case." But as Dix pointed out to her breakfast audience, there's a new challenge - with Brexit destined to eat up so much Parliamentary time, a C2 hybrid bill, along with a lot of other things, risks being squeezed.

One option suggested at the meeting was to build C2 piecemeal - beginning with a station at either end of the line followed by intervening stops, as sources of money become available. But as Dix points out, complex and expensive stations along with things such as ventilation shafts are integral to the overall plan.

Last July, Network Rail said that by autumn it would publish updated plans for technically problematic and contentious station sites, such as Balham/Tooting Broadway and King's Road, Chelsea. But that's all gone quiet. "We're awaiting government approval of the business case before we make our revised plans publicly available," an NR spokesman said.

However, it's continuing to work on looking at where costs could be saved, preparing for future public consultations and how Crossrail 2 would link into existing transport infrastructure.

In September, TfL and NR summoned a range of experts from the engineering, design and construction industries who could become involved in C2's next stage. The gathering was "intended to encourage collaborative working and early innovation, drive down costs, ensure the railway can be delivered on time and represent the best value for money."

> "The LCCI is anxious for C2 to go ahead, but still wary about the financial burden the capital might incur."

Recently, leaders of some of the UK's largest construction companies wrote to Chancellor Philip Hammond with a plea to continue funding development of Crossrail 2 - "to show the world that the UK is open for business, despite its looming exit from the European Union."

The shadow of self-interest is also looming. Observations made some time ago on C2 by David Leam, infrastructure director at London First, seem ever more relevant: that for London to swallow half the bill will involve "creativity and, inevitably, an element of pain", and that the construction industry must ask itself "searching questions" about costs. ■

Invisible investment

PAUL STEPHEN scratches beneath the surface of Network Rail's work on the southeastern end of the Elizabeth Line and discovers that the money being spent now will bring benefits for decades to come

Apart from the 26 miles of tunnels constructed by Crossrail Ltd beneath central London, Network Rail is responsible for delivering £2.3 billion worth of work above ground, where the Crossrail route utilises parts of the existing network.

This includes modifying 28 existing stations, and is largely concentrated on enhancing the Great Eastern Main Line between Liverpool Street and Shenfield, and the Great Western Main Line between Paddington and Heathrow Junction and Reading.

It also includes upgrading a much shorter section of track on Crossrail's south-eastern arm, however, running alongside the North Kent Line from the Plumstead eastern tunnel portal to Abbey Wood, where a new terminus station is being built for Crossrail, to act as an interchange with Southeastern's existing through services.

Work began in 2013 and is rapidly nearing completion, on what is effectively a three-mile construction site in preparation of the first Elizabeth Line services, which will run on this section in December 2018.

For two miles to the west of Abbey Wood station, the two-track formation of the North Kent Line needed to be widened into a four-track corridor to accommodate the two new Crossrail tracks, emerging from Plumstead tunnel.

To create sufficient space, the North Kent Line tracks had to be moved five to six metres further south for a distance of two miles, and then gradually slewed from their new positions to reconnect with the old alignment, approximately a mile to the east of Abbey Wood station.

The task of widening the alignment was complicated by the high water table of the surrounding land, which used to be marshland until it was drained and then urbanised by Victorian developers during the 19th century.

> "The single biggest challenge has been building this through a housing estate."
>
> **Peter Hume, *Senior Programme Manager, Network Rail***

NR's solution was to drive 1,800 concrete piles up to nine metres into the ground, to support wide concrete ballast slabs, placed on either side of former two-track alignment.

This was expensive as well as challenging, and almost three quarters of the £150 million budget spent by Network Rail on this section of Crossrail was invested in building these earthworks and drainage courses.

Finding adequate room for four tracks was also problematic for NR's engineers, requiring the demolition of several end-of-terrace properties and the compulsory purchase of some sections of adjoining gardens.

"The single biggest challenge has been building this through a housing estate," explains Network Rail's senior programme manager Peter Hume. "There are 2,000 residences that encircle a site over three miles long.

"You can't see where a huge amount of our investment has gone, as it's been done below ground level to solve that drainage problem."

The project also required a great deal of logistical planning. Trackwork had to be carefully carried out in phases, in order to support the early establishment of a railhead and temporary logistics centre at Plumstead tunnel portal for engineering trains, used for the ongoing fit-out of the tunnels and stations by Crossrail contractor ATC.

This end of the three-mile worksite was, therefore, completed first, so that ATC could stable its concreting factory train at Plumstead, and an overhead gantry crane could be erected above sidings to supply engineering trains used for trackwork, and all other necessary works, some of which are ongoing.

A £30m permanent depot will eventually be built here for maintenance rail vehicles, which will be operational in early 2019.

It was also important to conduct the work in stages in order to keep Abbey Wood open, a station used by some 4,500 people during the morning peak.

With the North Kent lines moved south, both of Abbey Wood's original two platforms have been demolished and rebuilt, to form two new island platforms.

The southernmost of these was completed first, and a temporary station building erected so that Southeastern services could continue to serve the station while work ➤

An aerial shot of Abbey Wood station, showing where a level crossing was once situated in the area beneath the white roof of the new station, until being replaced by the flyover in the far right of the shot in 1975. Network Rail encountered an unhelpful legacy from the crossing during the station build as it was necessary to divert up to 90 separate utilities to enable the construction of new foundations. CROSSRAIL.

A Down Southeastern service occupies Platform 2 at Abbey Wood on March 24, demonstrating the close proximity of the fully energised North Kent running lines to the island platform constructed for Crossrail to the right. The Crossrail tracks were due to be tamped by the end of April, ahead of the installation of signalling and communications equipment. PAUL STEPHEN.

Network Rail's Crossrail Programme Director Matt Steele (left), and Senior Programme Manager Peter Hume inspect the Abbey Wood site on March 24, less than 24 hours before a full line possession commenced to erect overhead line equipment. PAUL STEPHEN.

A high-speed crossover has been built at the western end of the station, with the concrete plinths for overhead line equipment visible on the right-hand side. Contractors are also erecting separation barriers between the two Crossrail tracks and those of the North Kent Line. This is required because Crossrail utilises overhead electrification and Automatic Train Control (ATO) that both require different competencies for track workers than those working with the third rail and conventionally signalled adjacent North Kent Line tracks. PAUL STEPHEN.

> "What's been carried out here has been so extensive that no further work should be necessary for at least 20 years."
>
> **Peter Hume, *Senior Programme Manager, Network Rail***

➤ began on the northern island platform, and the new station building itself, which is elevated above all four running lines.

Disruption has therefore been kept to a minimum, adds Hume, apart from a series of brief full-line possessions, an unavoidable measure due to the close proximity of fully energised 700V DC lines to the building works. The scope of the trackwork means that future enhancement and renewal work should be kept to a minimum, however, limiting the need for any future possessions.

"The project has taken four years. We could have shut the station completely and diverted Southeastern trains to do it faster, but the industry view was that Abbey Wood is too busy to close. To get round that we developed a strategy using conventional line possessions that allowed people to carry on travelling, and with minimal impact.

"100% of the railway assets have been replaced. What's been carried out here has been so extensive that no further work should be necessary for at least 20 years. This section of track will be maintenance and renewal free for a long time."

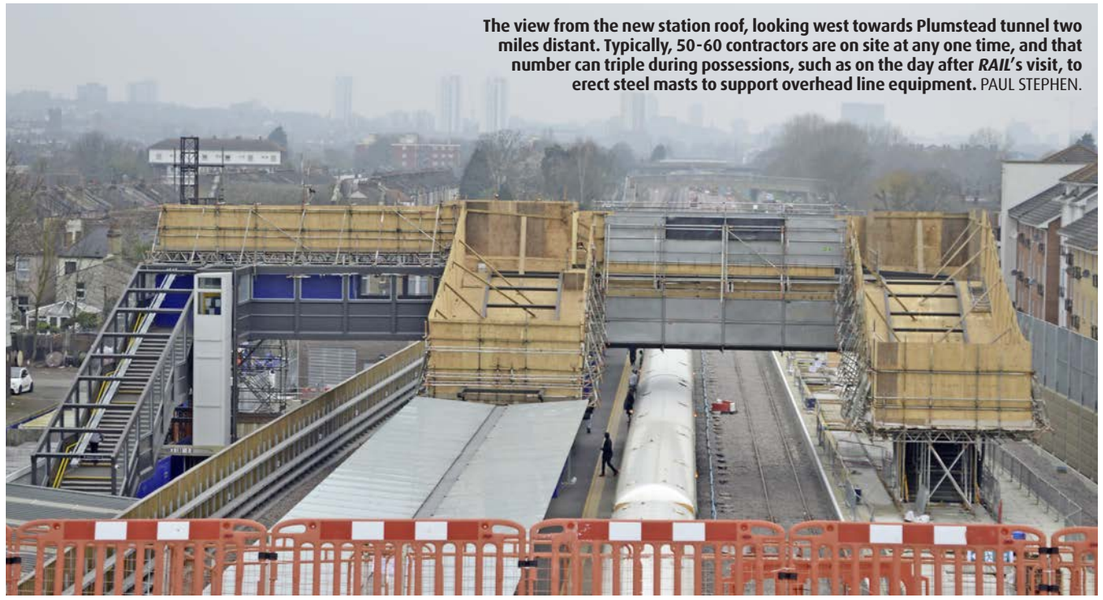
The station design itself had to cater for up to 20,000 people using Abbey Wood in the morning peak, with half of those interchanging to Elizabeth Line services, and the rest consisting of local journeys.

Due to the local drainage problems, a further £20m had to be spent on building the extensive foundations and concrete support structure required beneath the elevated concourse, while £25m is being spent on the concourse itself. The primary contractor on-site leading all the works is Balfour Beatty.

The station's distinguishing feature is a gently curving roof shaped like a manta ray, formed by glulam (glued manufactured timber) wood panels installed by Austrian firm Wiehag, that are covered in zinc. Beneath the roof, the station building has been constructed using 31 tonnes of steel beams and girders.

It makes a bold architectural statement, but the new station has also been designed to deliver more functional improvements to the economically depressed local area, via its integration with adjacent flyover, Harrow Manorway (the A2041).

This elevated road has made walking around the area difficult, and has formed a visually intrusive physical barrier through the area since its construction in 1975.



The view from the new station roof, looking west towards Plumstead tunnel two miles distant. Typically, 50-60 contractors are on site at any one time, and that number can triple during possessions, such as on the day after *RAIL*'s visit, to erect steel masts to support overhead line equipment. PAUL STEPHEN.

Abbey Wood station before redevelopment began in 2013. NETWORK RAIL.

The view at concourse level on March 24, prior to interior fit-out. The main timber roof beams are 45 metres long, which is the equivalent of four London buses end to end. The new concourse measures 1,500m² (the size of six tennis courts). PAUL STEPHEN.

New staircases, walkways and a granite-paved concourse will dramatically enhance pedestrian access between the areas of Thamesmead and Bexleyheath located on opposite sides of the railway, while stimulating more than £10m investment from local councils on improvements to the surrounding urban area.

It has also had a regenerative effect on Abbey Wood, with a new supermarket already opening close to the station, and 1,500 homes under construction nearby. Meanwhile, planning permission has been granted for a public plaza, library and a further 220 new homes.

The new concourse will also contain retail units to closely resemble a high street, reinforcing the station environment's feel as a thoroughfare linking the two communities.

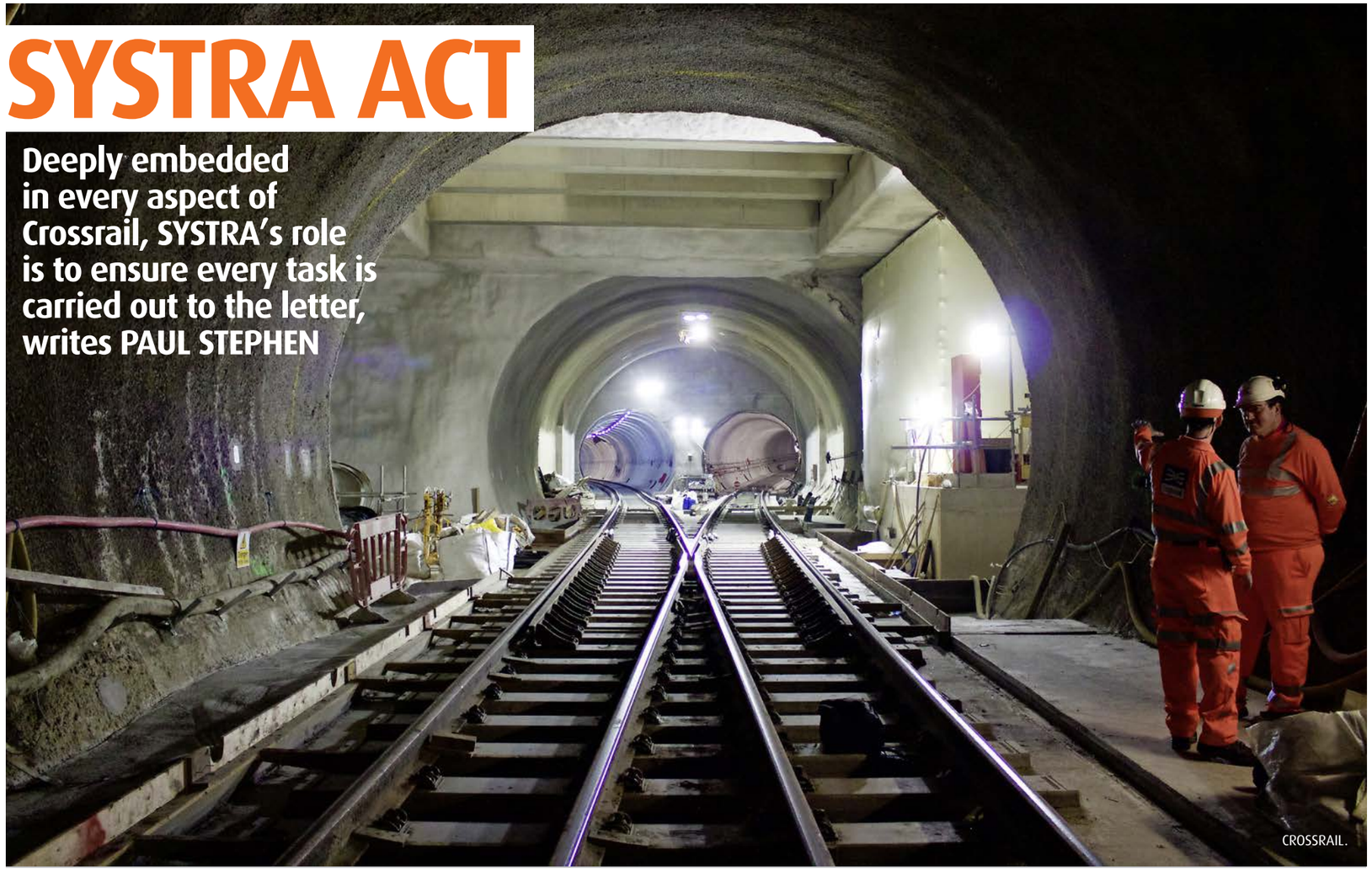
Now that the external structure is complete, the emphasis will shift onto the station building's internal fit-out, before it is ready to open to Southeastern customers in October.

That month will also mark the end of Network Rail's involvement in the project, as the Crossrail island platform and running lines are handed over to Crossrail Ltd to begin dynamic testing and commissioning, in advance of the full station opening in December 2018.

Matt Steele, Crossrail Programme Director at Network Rail, concludes: "This is one of my favourite sites as it's an opportunity to leave something iconic and make a bold architectural statement. It's also a rare chance to build some all-new railway." ■

SYSTRA ACT

Deeply embedded in every aspect of Crossrail, SYSTRA's role is to ensure every task is carried out to the letter, writes PAUL STEPHEN



CROSSRAIL.

In order to deliver Europe's largest construction project at a cost of £14.8 billion, it's no surprise that Crossrail Ltd needed an exhaustive strategy.

With a veritable army of designers, contractors and other stakeholders carefully assembled prior to the first spades being plunged into the ground, the importance was paramount in employing an overarching plan to prevent any of these individual components from losing sight of the project's main aims.

The strategy eventually developed by Crossrail Ltd therefore had several strands. Naturally it featured an outline of the project's complex delivery programme. But it was a declaration of the company's vision and values, including a firm and unshakeable commitment to achieving best practice, sustainability and responsible procurement for the duration of the build.

The strategy spelt out not only what would be delivered and by when, but crucially how the project would be delivered, in a manner subscribing to these high standards and strict ethical codes.

To execute this strategy, SYSTRA were part of the team with Bechtel and CH2M, appointed to serve as Crossrail's Project Delivery Partner (PDP) in 2009.

From before the start of tunnelling in 2012 right through to the commencement of passenger operations in December 2018, the PDP forms a core part of Crossrail Ltd's integrated management team, overseeing the development of detailed designs, procurement, construction and commissioning.

It is also responsible for managing the consultants and contractors working on all phases of the project, and where Crossrail interfaces with its many external partners and stakeholders, including the likes of Network Rail, London Underground and the National Grid.

> "I'm in charge of delivering the traction power feeder stations that take power from the National Grid."

Xavier de Vimal,
Head of Traction Power and OHLE, SYSTRA

Additional day-to-day responsibilities of the PDP encompass rigorous cost and quality control, plus ensuring that all of the obligations and legal conditions set out in the Crossrail Act 2008 are fulfilled. This includes the register of undertakings and assurances that Crossrail Ltd gave to local authorities, heritage and environmental organisations, and other bodies or individuals that made objections during the consultation, which was held before the Crossrail Act was passed.

Calling on a wealth of major infrastructure delivery experience, SYSTRA currently assigns 25 of its employees and affiliated consultants from across the globe to the PDP, although its contribution was as high as 80 during peak construction.

It has demonstrated the full range of its expertise by providing managers with expertise in a wide variety of areas, including construction, planning and engineering, in addition to cost engineers, project managers, field engineers, document controllers, contract administrators and business managers. With seemingly no limit to the skills SYSTRA is able to call on, it has also provided Crossrail's lead archaeologist, plus a 4D modelling and a building information modelling (BIM) co-ordinator.

Although involved in all aspects of Crossrail, as part of the PDP consortium SYSTRA has specialised in railway systems.

The firm supplies resources for tunnel electrical engineering, overhead line and traction power, signalling, safety systems, communications, quality management, traffic management and co-ordination, site logistics, and noise and vibration attenuation.

Project Field Engineer Howard Crane is PDP Supervisor's Representative for system-wide main works installation. He oversees the fitting out of Crossrail's 26 miles of tunnels, currently being conducted by the ATC joint venture (formed of Alstom, TSO and Costain).

He explains: "My job is to focus on quality assurance and certification. We take forward the design brief and specification and make sure the contractors deliver it. With so many contractors self-certifying their work, we provide a collective warranty for the railway, and oversee the work to make sure we're getting it right.

"Our role is to progressively ensure we end up with a compliant railway, and I need to gather a body of evidence to demonstrate that we have delivered.

"We scrutinise everything such as a loose bolt or blemish in the concrete, to ensure they are identified and rectified quickly. And we encourage all contractors to raise issues as early as possible. It's much easier to deal with a fault sooner rather than later in a project.

"The biggest risk to a project of this scale - which can be very repetitive and uses a vast amount of material - is getting products which are inferior, but we've avoided this through having robust procedures in place."

Crane supervises a multi-disciplinary team of five inspection engineers. Together, the team has continuously analysed the performance of contractors in order to measure how well the Crossrail supply chain is performing against the project strategy's vision, values and other deliverables.

By enabling contractors to see how they rank, Crane says that an element of competition has been introduced that has resulted in impressive increases in performance.

He adds: "Over the last six years we've gathered a lot of data on contractors through performance assurance frameworks, and scrutinising their environmental performance, quality and data management. We've been able to create a league table across the entire project where we can see who is operating at a world-class standard, and then who is merely being compliant.

"If done right you can incentivise these organisations to do better, as they are very competitive and they know that this is very powerful information for the procurement of future projects."

With Crossrail over 80% complete, the focus has now shifted towards railway system installation, testing and commissioning, with Crossrail's Head of Traction Power and OHLE, Xavier de Vimal, who was brought in from SYSTRA France, now extremely busy.

In addition to managing all technical aspects of more than 26 miles of overhead conductor rail to energise Crossrail's fleet of Aventra trains when they begin using the tunnels, de Vimal is also managing the technical interfaces with Network Rail's overhead line equipment and the delivery of the traction feeder stations that take the power from the National Grid to feed the Crossrail Central Operating Section overhead line and Network Rail's Great Eastern Main Line overhead line up to Shenfield.

He takes these added complexities in his stride, however, as a powerful example of SYSTRA's immense range of capabilities.

He concludes: "As Head of Traction Power and OHLE, I provide technical assurance to the Crossrail chief engineer for the traction power and overhead electrical line systems. I'm also in charge of delivering the traction power feeder stations that take the power from the National Grid.

"For me, the biggest risks are the technical interfaces between the Network Rail and Crossrail overhead line equipment (catenary and contract wires) at Pudding Mill Lane and Westbourne Park, and how to deliver them.

"It's very busy and challenging, but that's why I like it. The next stage for me is energisation, and then dynamic testing, fault-finding and monitoring.

"And, we are all working towards handing over the completed railway to Transport for London next year and look forward to the opening of the Elizabeth Line in December 2018." ■

> "Our role is to progressively ensure we end up with a compliant railway."

Howard Crane, ***Project Field Engineer, SYSTRA***

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