

A detailed technical drawing of a railway station platform and tracks. The drawing shows a platform with a building, tracks, and various mechanical components. The drawing is rendered in white lines on a dark blue background. The text 'MOTT MACDONALD' is visible in the top left corner.

**M**  
**M**  
MOTT  
MACDONALD

# From start to finishes

Working with Crossrail Ltd to design the Elizabeth line



Europe's largest infrastructure project, Crossrail, is building the Elizabeth line to increase central London's rail capacity by 10%

Designed to carry thousands of people across the city, the Elizabeth line will be a high-frequency, high-capacity metro railway. It will support London and southeast England's diverse and growing population. Stretching over 100km from Reading and Heathrow in the west, to Shenfield and Abbey Wood in the east, the Elizabeth line runs further and deeper than the London Underground network. Its 42km of tunnels negotiate building foundations, the Tube, utilities, a dock and the River Thames.

Since its earliest stages, the scheme has adjusted to developments in technology and a growing environmental and social conscience to ensure it meets the combined needs of passengers, businesses, communities and the planet. Designed to last more than 120 years and carefully crafted to integrate with infrastructure that, in some places, is more than 150 years old, the Crossrail project has been occupying the minds of Mott MacDonald engineers for almost three decades.

We have worked on Crossrail from its early stages under various roles, advising on the route and its structures, producing solutions for its trains and developing the rail systems that convert tunnels and stations into a functioning railway. From feasibility, through detailed design, and right up to making sure the final-fix cables and brackets work with the finishes, we have taken great pride in helping shape this world-class transport system so that every layer is ready for services to begin.

As designers, engineers and project managers concerned with the details, we also understand that success for this railway will be measured by its passenger experience. The Elizabeth line, for all its engineering innovations and complex construction, will be recognised for its bright, airy stations and journeys that are safe and comfortable. We celebrate this.



# The Elizabeth line

**40m**

maximum tunnel depth

**200m**

length of train (twice the length of a Tube train)

**£42bn**

contribution to the UK economy

**42km**

length of tunnels

**118km**

length of route

**24**

trains per hour at peak between Paddington and Whitechapel

**1500**

people per train (more than double the capacity of a Northern line Tube train)

**10**

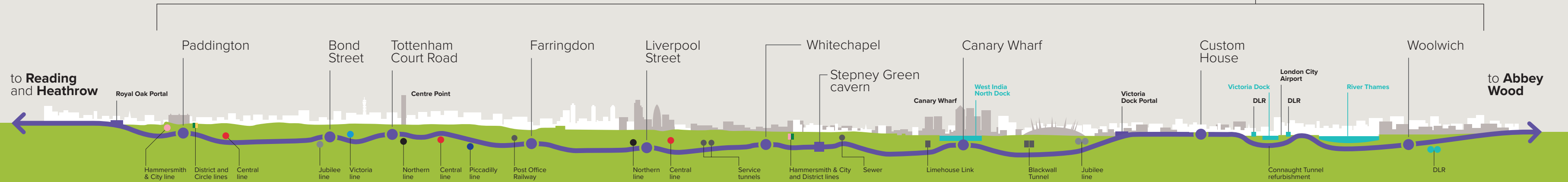
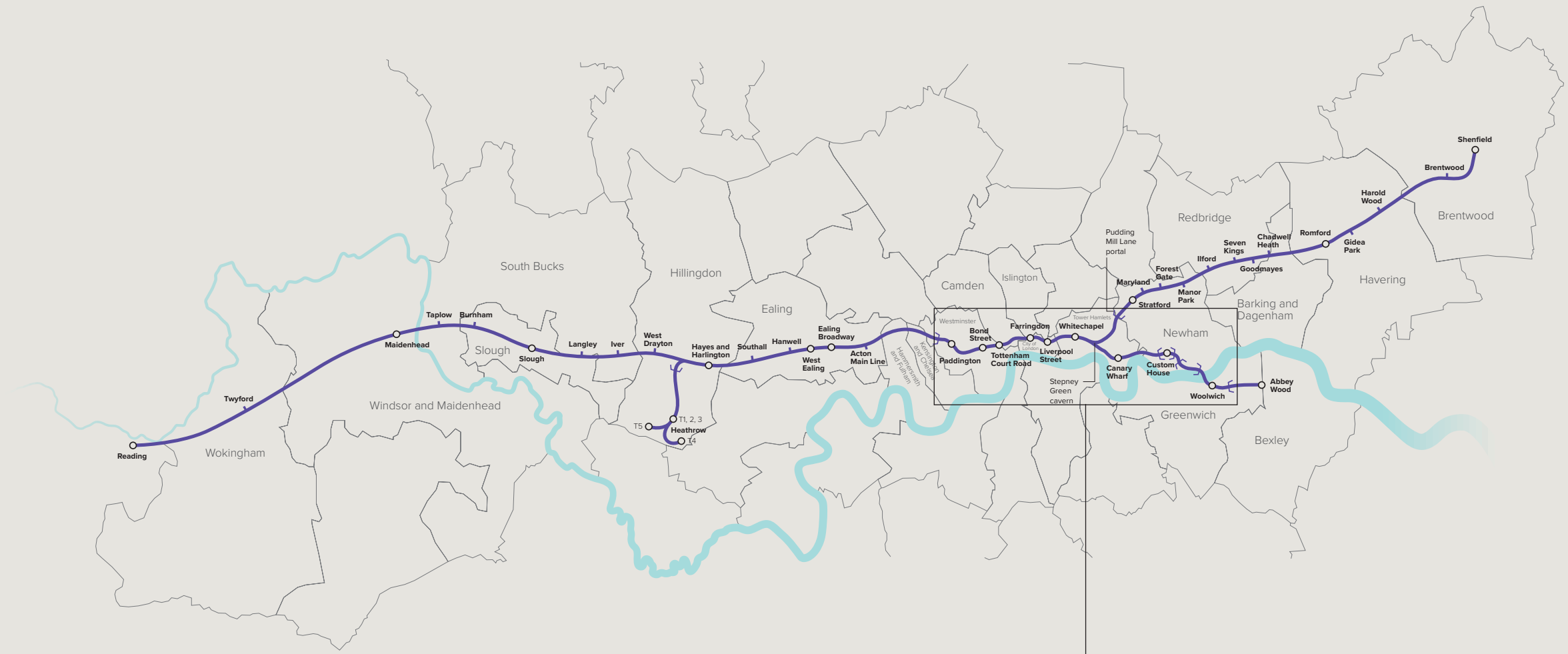
new stations

**31**

upgraded stations

**120+**

years design life

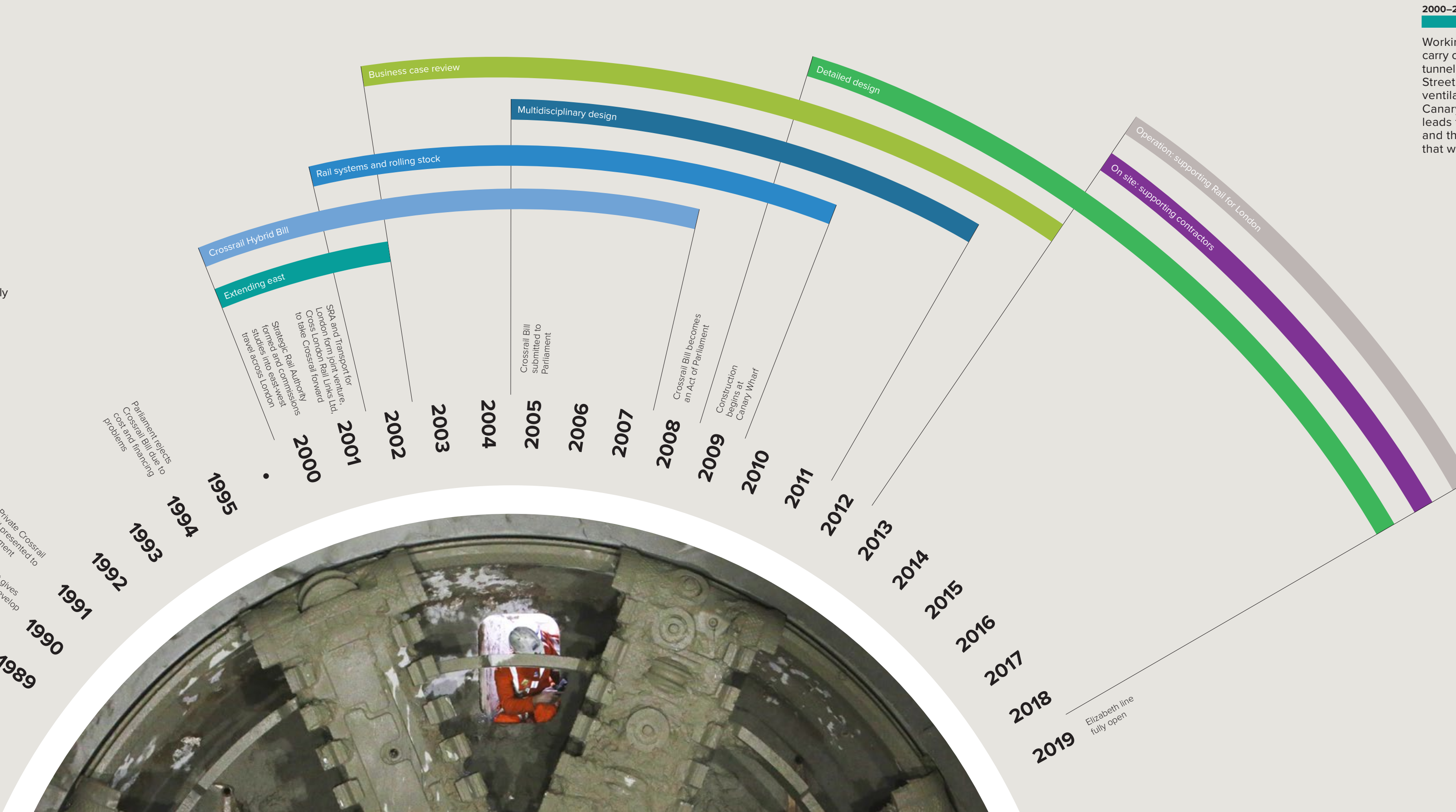


# Every step of the way

Mott MacDonald has had a constant involvement with the Crossrail project since its earliest stages, when the proposed tunnelled route only ran between Paddington and Liverpool Street.

For the 2005 Crossrail Bill, we worked with Crossrail Ltd to design the rail systems and ventilation strategy for the entire route, as well as the engineering design of stations and tunnels in the central and eastern sections. Our care and attention to detail helped the project pass successfully through the three-year public and parliamentary consultation process, eventually leading to permission for construction to begin.

We went on to win a third of the detailed design contracts for the scheme and continued our involvement by supporting main contractor ATC in fitting out the tunnels.



**2000-2007**

Working with Crossrail Ltd, we carry out a study to extend the tunnelled route east of Liverpool Street, as well as a separate ventilation study for the future Canary Wharf station. This leads to a revival of Crossrail and the start of a scheme that will eventually be built.

**2000-2007**

Working with Crossrail Ltd we develop M&E and structural engineering designs for central London stations including Paddington, Bond Street, Tottenham Court Road, Farringdon, Liverpool Street, Whitechapel and Canary Wharf, as well as portals and shafts. Designs for stations and tunnels east of Canary Wharf are developed, including Custom House, Woolwich and Abbey Wood. We help design over-

station developments and assess the environmental impact of the project during construction and after completion, covering water quality, contaminated land, air quality and traffic impacts. These form part of the Crossrail Hybrid Bill documents. We also help develop a new ticket hall design at Farringdon which integrates with upgrades to the Thameslink line. We continue to support Crossrail while the Bill is under parliamentary scrutiny.

**2002-2009**

We progress rail systems, utilities, ventilation, M&E and rolling stock designs for the Hybrid Bill and beyond.

**2005-2011**

We produce multidisciplinary designs for Farringdon, Liverpool Street and Whitechapel stations, as well as the complex Stepney Green junction.

**2008-2018**

We win a third of detailed design contracts, including Liverpool Street station, sprayed concrete lined tunnels, tunnel and shaft ventilation, tunnel M&E, rolling stock and depots, signalling, traction power, overhead line equipment and platform screen doors. We also work on advance projects at Pudding Mill Lane portal and Paddington station. We work with Crossrail Ltd on the materials and workmanship contract.

**2013-2018**

Joint venture contractor Alstom TSO Costain appoint us as engineering consultant for tunnel fit-out. The contract involves design and installation of tunnel equipment, including 48 ventilation fans, 66 drainage pumps and 40km of walkways, fire mains and lighting. We also provide systems engineering and technical assurance support and assess electromagnetic interference.

Working with Siemens, we review and test human-machine interface (HMI) designs for station operation, including closed-circuit television and customer information systems. Working for main contractor Balfour Beatty, we develop detailed M&E and structural designs for Woolwich station and provide systems safety, reliability, availability and maintainability support.

**2013-2018**

To ensure the smooth transition from Crossrail project to the Elizabeth line, we are advising infrastructure manager, Rail for London, so the commissioned railway meets operational and maintenance requirements.



# Designing Crossrail

Sustainable solutions for a modern railway

**Platform screen doors**  
Helpfully indicating where passengers should wait on a platform to board a train, these full-height features provide platform edge protection and create separate zones for the tunnel and platform environments, enabling more efficient ventilation control during normal and emergency operation. We developed the concept design and worked with the manufacturer to ensure the doors comply with performance requirements.

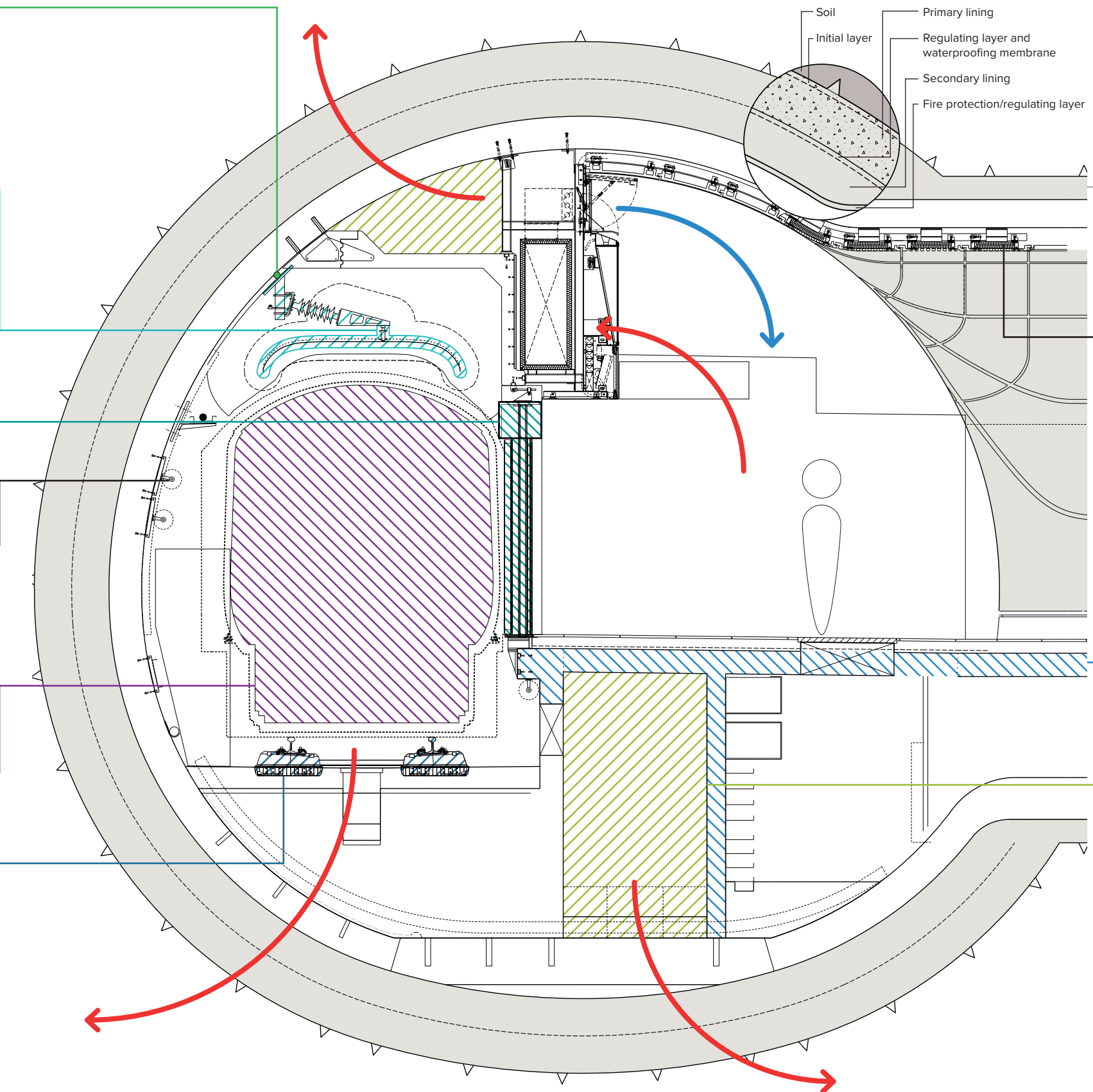
**Amazing train**  
In the early stages of the project, our pedestrian modelling simulations demonstrated that each carriage needed more than the usual two doors per side to enable people to get on and off safely and comfortably in the time available. Our fire and life safety studies supported the feasibility of open gangways. These, and other design parameters, were described by our 'reference' train. All station and tunnel systems and structures were designed in accordance with this, since the actual Elizabeth line train would not be commissioned for a number of years. We followed advances made by the rolling stock industry to help develop Crossrail Ltd's specification for light-weight, energy-efficient and low-maintenance trains. TfL, working in close partnership with train manufacturer Bombardier, developed the detailed design of the Elizabeth line's state-of-the-art trains.

**Power and performance**  
We worked with Crossrail Ltd to design the traction power strategy for this high-capacity, high-frequency railway. Our efficient autotransformer-based traction system is one of the first in the world to be used in an underground metro setting.

**Reliable and easy to maintain**  
Recommending a 'fixed rail' contact for overhead line electrification in the central tunnels, makes this hard-working connection between the train and its power supply simple to maintain and easy to repair.

**Tunnel rail systems**  
We supported contractor ATC in rail systems fit-out, which included producing drawings and specifications and reviewing the choice of equipment for lighting, low-voltage power distribution, cable management, signage, fire mains and hydrants, pumped drainage, cross-passage fire doors and ventilation systems. We also checked compliance with safety standards and reviewed access for maintenance and operation of equipment.

**Considerate track**  
Noise and vibrations travelling from the railway can disturb nearby recording studios and concert halls. We worked with Crossrail Ltd to develop the concept design for the track bed to limit these effects and later went on to independently verify its performance.



**Single source**  
Working with Crossrail Ltd, we managed the database for materials and workmanship for the project.

**Vast caverns and curving walls**  
We worked with Crossrail Ltd to design curved and cavernous underground spaces, such as station platforms, using sprayed concrete lining. The process used here involves excavating the ground in a carefully managed sequence and building up two layers of fibre-reinforced sprayed concrete either side of a waterproofing membrane. A fire protection layer completes the structure.

**Station design**  
Liverpool Street station is located in the heart of London's financial district. The platform sits 34m below ground and is the deepest on the Elizabeth line. We worked with Crossrail Ltd and TfL to design the station's structure to integrate with two different Underground stations at either end. The innovative design for one of the access and ventilation shafts at the station enabled it to be built quickly and safely.

**Cool, safe and comfortable**  
We worked with Crossrail Ltd to design the tunnel ventilation system, which includes shafts, cross-passages and fans to control the movement and temperature of air. This involved co-ordinating under-platform exhaust, tunnel ventilation, platform draught relief, station ventilation, tunnel smoke extract, station smoke extract and station cooling. Noise from the fans had to be managed within the context of each station and shaft, both being unique to their setting.

Heat from trains is extracted through the tunnels and then removed by fans, while cool, fresh air is drawn in, as needed, to create the best environment for travel. Heat generated from braking is extracted via fans to under-platform plenums.





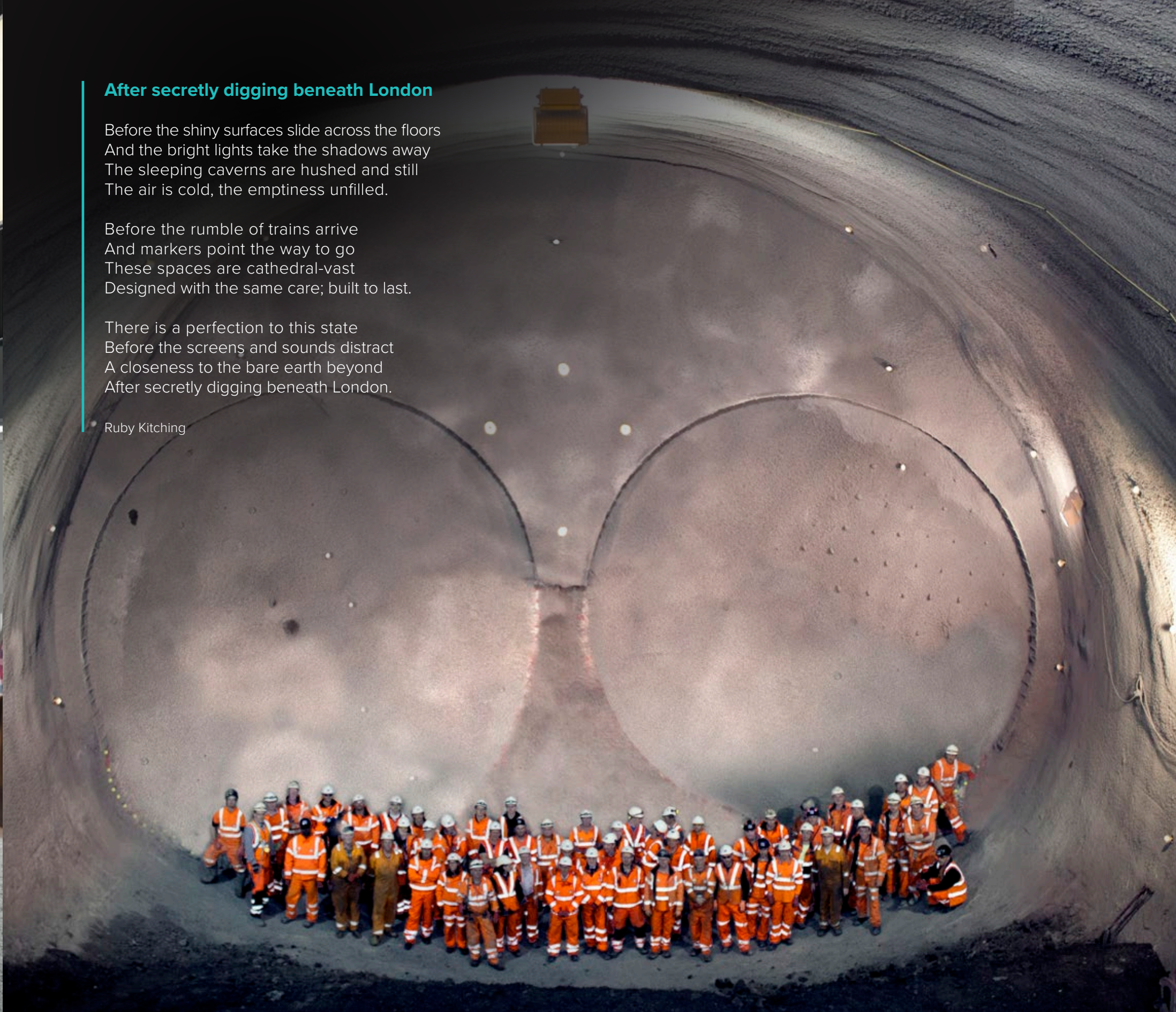
### After secretly digging beneath London

Before the shiny surfaces slide across the floors  
And the bright lights take the shadows away  
The sleeping caverns are hushed and still  
The air is cold, the emptiness unfilled.

Before the rumble of trains arrive  
And markers point the way to go  
These spaces are cathedral-vast  
Designed with the same care; built to last.

There is a perfection to this state  
Before the screens and sounds distract  
A closeness to the bare earth beyond  
After secretly digging beneath London.

Ruby Kitching



## The scale and elegance of the Elizabeth line's underground spaces are this railway's most defining features

Bond Street, Tottenham Court Road, Farringdon, Liverpool Street and Whitechapel stations have been designed with spacious circulation routes. They are clad in glass-fibre reinforced concrete panels that have been cast to reflect the shapes engineered from the ground. Travelling down an escalator to platform level, along a cross-passage and onto a train, junctions merge and sight-lines broaden. The experience is fluid and welcoming.

These forms and volumes have been achieved thanks to a tunnelling technique called sprayed concrete lining (SCL). For Crossrail, the process involves excavating the ground in a carefully managed sequence, and building up two layers of sprayed steel-fibre reinforced concrete either side of a waterproofing membrane. A fire protection layer completes the structure.

The main advantage of SCL is that it offers a quick and safe method of supporting large excavations and does not limit them to orthogonal geometries. Just as above-ground modern architecture has been exploring exciting amorphous forms, construction of the Elizabeth line demonstrates that subterranean spaces can as well.

This is a new style for London's underground rail network and is only possible because of advances in computer modelling, analysis software and construction equipment, which have made designing and building curved, non-standard shapes more straightforward. SCL has also been used to connect vertical shafts with horizontal running tunnels.



## TfL's new trains bring together world-class passenger experience and state-of-the-art design

The new, stylish, accessible and spacious Elizabeth line trains have been designed for passenger comfort and safety. Each carriage has three double doors, making boarding and alighting easy. Featuring the latest technology to support modern travel and communications, they were designed by TfL, in close partnership with Bombardier. Weighing about 20% less than most mainline trains, they feed electricity back into the power supply when braking – using 30% less energy – while still delivering fast journey times.

Elizabeth line trains were manufactured some 10 years after designers started working on Crossrail's rail systems, stations, depots and tunnels. From 2002 onwards, we worked with Crossrail Ltd on a document describing how the trains should look and operate to inform civil engineering and railway design. Where a range of solutions was feasible, our engineers set flexible targets for weight, power and

maintenance, for example, so advances being made by manufacturers in bogie design, regenerative braking and diagnostics could be accommodated. This 'reference train' was updated as more information became known over time, and eventually formed part of Crossrail Ltd's specification. Tenders returned by train manufacturers responded to this document. We went on to verify the commissioned train's compliance with the Railways (Interoperability) Regulations 2011.

We worked with Crossrail Ltd to produce a train specification that achieved the right balance of functionality, sustainability and passenger comfort. Flexibility built into it enabled manufacturers to respond with different solutions, such as a nine-carriage train, where each carriage is only slightly longer than more common 10-carriage trains, while still carrying the same number of passengers.





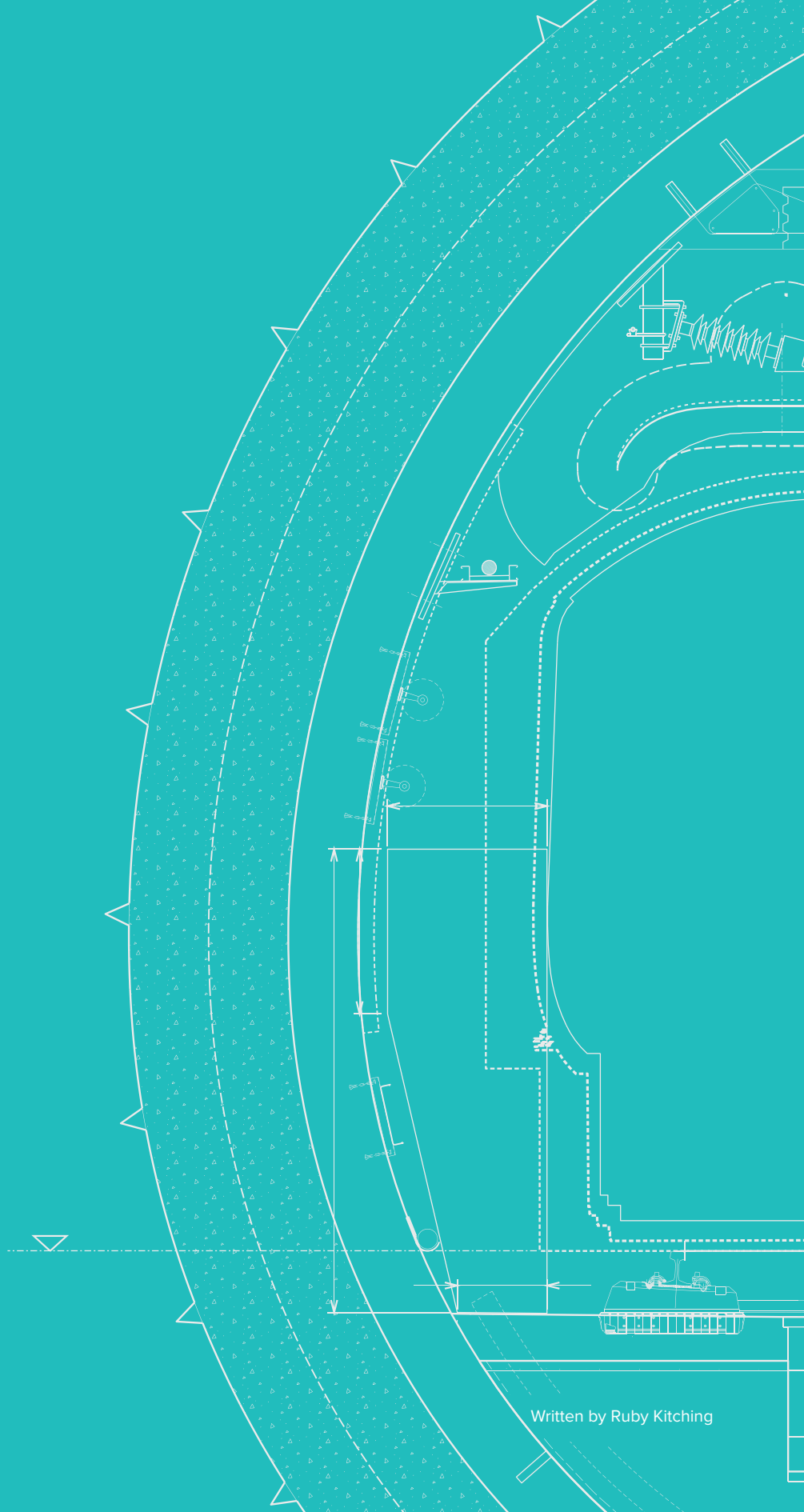
### Elizabeth line trains

- Air-conditioned, walk-through carriages to maximise space
- Onboard closed-circuit television for passenger security and real-time travel information
- Fully accessible for wheelchair users
- Constructed using strong, lightweight materials such as aluminium for the body shell
- Equipped with intelligent lighting and temperature control systems to reduce energy consumption
- Automatic train operation and the latest automatic train protection systems for safe and efficient services
- Regenerative braking for 30% less energy



# Opening opportunities with connected thinking.

[mottmac.com](http://mottmac.com)



Written by Ruby Kitching