

Tunnels

AND TUNNELLING



~ALAN ROGERS~

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GETTING THE GRADUATES

THE SUMMER is exam results season. Universities and colleges compete for the best students. Faculties have a last ditch attempt to persuade prospective students to sign up to their courses. The decision the students make is an important one, the qualifications will be the overriding factor in getting their first job. Choosing the right course is analogous with choosing the right career.

As an industry, our role in all of this is to encourage the best and brightest to embark upon a career underground. We need to excite and inspire young minds. And we need to educate them in the skills and training needed to enter the industry, so that when they commit to a degree course they leave it equipped with the skills needed to pursue a career in tunnelling.

The British Tunnelling Society can be proud of its efforts in this area. The BTS Young Members body has been committed to promoting tunnelling in schools and universities since it was set up five years ago. The committee was awarded the *Tunnels* 2011 Investor in People award for its work in schools and in the civil engineering industry. The group has made efforts to recruit engineers into tunnelling, support their development and retain them.

At the World Tunnel Congress in Geneva earlier this year BTS Young Members chair Petr Salak and BTS chair Damian McGirr called for the creation of a young members group for the International Tunnelling Association (ITA).

Following discussions, the new ITA president, Soren Degn Eskesen called on member nations to form their own young member groups, or if they already existed, to make them known to the ITA. Interest has been shown, and work towards creating young member societies is underway in: USA, Canada, Denmark, Austria, Hungary, the Czech Republic, Greece and Italy. Norway established such a body in 2009 and Australia prior to WTC 2013.

Jon Young
Editor



Obviously missing are India and China. A study by EngineeringUK showed that each year China produces 76,400 engineering graduates and India 124,400 that are globally employable. This compares to just 8,600 in the UK. While the UK and the USA have a better per capita performance for producing globally employable engineers, the actual workforce available from India and China is so massive it could greatly impact on skills shortages faced in tunnelling and other areas of engineering.

Tunnellers are a nomadic bunch. When experienced engineers are posted to a foreign project it is an opportunity to develop the regional understanding of engineering; to get involved with the local tunnelling community and help them develop our profession as an attractive career for local graduates.

The two go hand in hand. A need to make the tunnelling industry more attractive to potential young engineers, and an international platform to allow young tunnellers to interact and exchange ideas in an organised forum. Who better to encourage, or make easier the transition from education to industry than those who have just made it

editor@tunnelsonline.info

What do you think? Send your views to the editor and join the debate



Cover
This issue
Tunnels joins in the celebrations for the 150 years London Underground has been in operation



Next issue
In the next issue, *Tunnels* looks into the operational plans for London's Crossrail – how the network will run in the style of a metro and train service. October will also see the magazine delve into the topics of roadheader technology, and biotenuous growth in subsea concrete

This month...

20 YEARS AGO

Never accept the comforting lie that tunnel projects are too large to fail. Last month the US Energy Department ordered a halt to tunnel work on the Superconducting Super Collider (SSC). The 87.1km of tunnel was 20 per cent complete, and USD 480M had already been spent on tunnel works alone. The entire SSC project was budgeted to cost USD 11bn in total and would have been the largest Hadron collider for the foreseeable future. Acquisition work on TBMs already paid for and preserving shaft and tunnel integrity has been authorised.

Tunnels and Tunnelling, September 1993, p.9

40 YEARS AGO

Consulting engineers have told the Hong Kong Government that a tunnel road link through the steep rocky hills on the north and south sides of the island is a feasible option. A full report of the investigations has been submitted by consulting engineers Maunsell Consultants Asia, and is now under consideration. The tunnel, if accepted, will run from Happy Valley near the north shore of the island to Wong Chuk Hang near Aberdeen in the south. It would be twin tubes around 10m in diameter and 60m apart, each carrying a two-way carriageway. Estimated costs for the tunnel and southern approaches are GBP 14M, while the elevated link to the north and required flyover would come in at around GBP 5.4M.

Tunnels and Tunnelling, September-October 1973, p.13

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DELHI METRO: 8 EPBMs FOR THE PHASE III

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London Underground

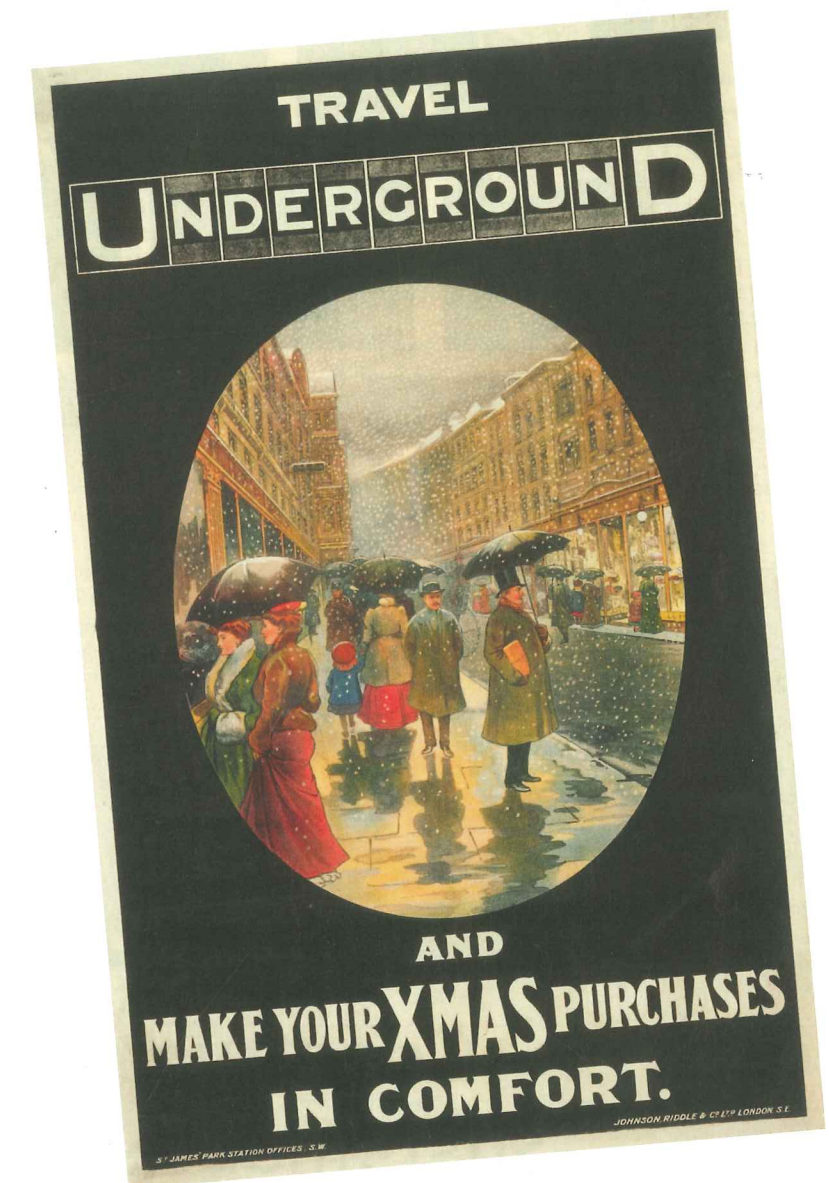
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A new motorway link for the west of Brisbane is formed, as the city completes its Transapex network of road tunnel projects



Above: Early LU poster to grow journey numbers

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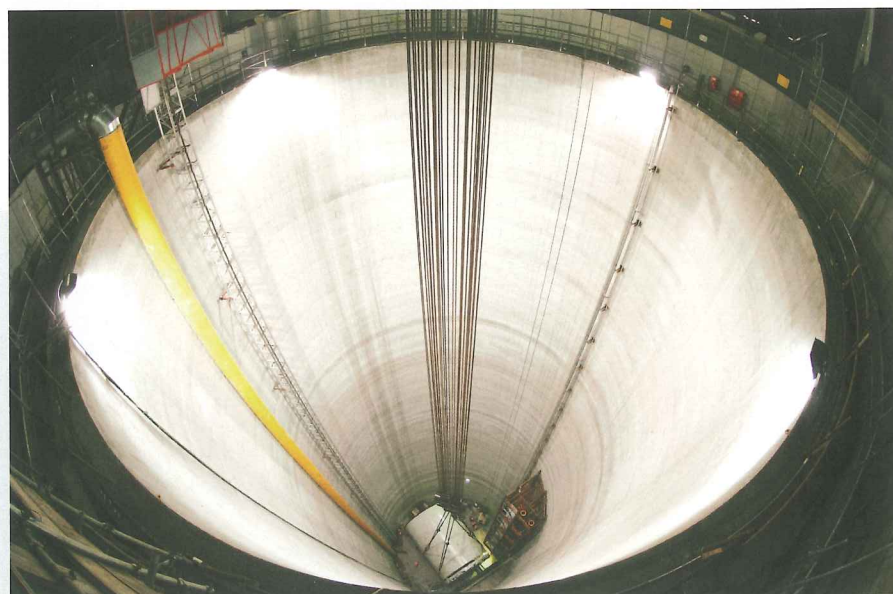
Contributors



James Chappelow
James is a historian and author of papers on the origins of modern engineering. He studied history at Queen Mary, part of the University of London, before going on to lecture in history for some four decades. In this issue James looks at the first 100 years of the London Underground, how it responded to the political and financial challenges; the demands of a rapidly growing city; the disruption of two world wars; and the risks of being the first network of its kind.



Adrian Greeman
Adrian is a freelance technical journalist and former editor of Tunnels and Tunnelling. He has travelled to tunnel and other infrastructure worksites all over the world and his experience is extensive. Adrian has also written on software for engineering, general business interests, infrastructure development and management. In this issue he reports from site on the Legacy Way Tunnel project in Brisbane, Australia following on from his last report on the Brisbane Airport Link project.



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News briefs

NORWAY

More than 50 people were sent to hospital after a lorry caught fire in Norway's second longest tunnel on Monday 5 August, police told local press. The 11.4km Gudvangen tunnel in western Norway, connects the village of Gudvangen by Nærøfjord with the Undredalen valley. By 1pm the fire service had extinguished the fire, 45 minutes after the police received the first reports that a truck was on fire. Every single person evacuated was taken to hospital, police stated. The cause of the fire is unknown.

GREAT BRITAIN

A primary school in Boston Avenue, Southend, was once the site for a network of tunnels dating back to the Second World War, local press reported recently. Builders working at St Mary's Prittlewell C of E Primary School found the tunnels as they carried out excavations at the site to extend the school building. The tunnels are 6ft (1.8m) wide, 9ft (2.7m) deep, and run as long as 40ft (12.1m) beyond where the new classroom is being constructed. They are made from reinforced concrete.

Delhi Metro Phase III design consultancy awarded

India Mott MacDonald has been appointed detailed design consultant by the Hindustan Construction Company/Samsung contracting joint venture for their work on Phase III of Delhi Metro in India.

The consultancy will provide geotechnical, civil and structural engineering services for contract CC34, which is part of the Janakpuri

RIYADH METRO CONTRACTS

Saudi Arabia Riyadh Governor Prince Khaled bin Bandar on unveiled in late July the USD 20.9bn Riyadh Metro Project that calls for construction of a 177.7km six-line automated metro network.

The project design and construction contracts were awarded to three foreign-led consortia, which signed the project package with Arriyadh Development Authority (ADA) in the presence of Prince Khaled.

The Fast consortium, which is led by Spanish construction group FCC, will build three lines totalling 73km in a deal worth USD 7.82bn. The contract includes: the 30km Orange Line to King Khaled International Airport; the 13km Yellow Line, which will follow King Abdul Aziz Road; and the 30km Purple Line from from Abdul Rahman bin Ouf Street to Shaikh bin Hussain bin Ali Street. FCC's partners in Fast include Alstom; Samsung C&T; Strukton, Netherlands; Freyssinet, Saudi Arabia; Typsa, Spain; and Setec, France.

The Arriyadh New Mobility Group (ANM) will construct the 40.7km Red Line from Madina Al Munawara to Amir Saad bin Abdul Rahman Al Awad Road in a contract worth USD 5.21bn. ANM is led by Ansaldo STS and includes civil works contractors Salini-Impreglio and Nema, together with Bombardier.

Finally, the Bechtel-led BACS consortium will

build the 39km Blue Line from Olaya Street to Batha Street and Al Hayer Road, and the 25km Green Line along King Abdullah Road. The consortium includes Aecom and Siemens, and the contract has a total value of USD 7.82bn.

Designs for the Riyadh Metro call for 35.2km of twin-tube bored running tunnels and a further 13.7km of cut and cover work for a total subsurface length of nearly 49km.

The Riyadh Metro, nicknamed the Miracle of the Desert, passes through areas near government buildings, commercial and health centers, educational centers and major universities in Riyadh and its suburbs. The metro will also connect the King Khaled International Airport (KKIA) through the city center and densely populated areas of Riyadh. The metro system will have 96 stations in total, including the main stations, four transfer stations, and five park-and-ride stations. According to FCC, the construction of the network will require 600,000t of steel, 4.3Mcu.m of concrete, and will employ more than 30,000 people, more than half of them in the Fast consortium.

Construction is expected to begin in the first quarter of 2014 and commercial services will start on the initial operating sections in 2018 with the entire network due to be commissioned by 2019.

West to Kalindi Kunj corridor. The project is due for completion in 2016.

The Delhi mass rapid transit system is being expanded to meet increasing transport needs, Mott MacDonald stated. New circular lines will interchange with existing radial lines, improving connectivity and access to the city's metropolitan areas. Contract CC34 involves the design and construction of a 4.5km tunnel from Janakpuri West to Palam by shield tunnel boring machine.

It also includes construction of underground metro stations at Janakpuri West, Dabri Mor and Dashrath Puri as well as interchanges with existing elevated metro stations.

Mohan Gupta, Mott MacDonald's divisional director, said: "Our association with Delhi Metro goes back over 10 years and we have played an important

part in the system's success. We're looking forward to continuing our involvement and will use our knowledge from previous phases to provide solutions in what are often challenging soft ground conditions in Delhi."

Albabstieg Tunnel contract awarded

Germany Strabag subsidiary Ed Züblin as lead JV member has been awarded a EUR 250M (USD 334M) contract by Deutsche Bahn to build the 5.9km Albabstieg Tunnel along the new Wendlingen-Ulm rail line in Germany.

Eight bidding consortia participated in the Europe-wide tender for the construction contract, the company stated last month.

The tunnel, with a north portal in Dornstadt and a south portal in Ulm, will consist of two single-track bores 70m deep connected by eleven crosspassages at 500m

intervals. The tunnelling works for both bores will take place simultaneously from two starting points: downhill from Dornstadt to the south and from an intermediate access tunnel from which both bores will be driven uphill to the north and downhill to the south toward Ulm City.

The joint venture will move approximately 1.4Mm³ of excavated soil and rock material during the construction duration.

The tunnel will be excavated by drill and blast followed by sprayed concrete before a waterproof membrane is applied followed by a final lining of in-situ concrete, an Ed Züblin spokesman revealed in a statement.

The start of the tunnelling works has been planned for the spring of 2014, with the following construction works expected to last four and a half years.

KOREAN FIRM TO BUILD UNDERGROUND POWER PLANT IN NORTHERN SEOUL

South Korea The state-run power supplier Korea Midland Power Corporation (KOMIPO) will build a new thermal power generation plant in northern Seoul, which is to become the world's first-ever urban underground power facility, officials said.

On 5 July, KOMIPO and Doosan Heavy Industries & Construction signed a contract for the latter to supply key parts for two new complex fuel generators to be built in the subterranean space of the

Seoul Thermal Power Plant in Mapo.

The generators, worth KRW 1.18tn (USD 1bn) and capable of producing 800MW, will be the world's first-ever fully underground power generating facility, according to officials.

Doosan HIC is to provide for components such as gas turbines, steam turbines and heat recovery systems, worth KRW 360bn (USD 3.2bn) in total.

The superstructure of the underground

facility will be used as an urban park area for residents, officials also said.

"Underground plant construction, though 1.5 times more expensive than conventional above ground construction, is an effective use of the limited urban space," said a Korea Midland Power Corporation official.

The blueprint was modeled after Tate Modern, the famous power plant-turned-art gallery in London, he added.

Artist closes New York's Park Avenue Tunnel

USA Park Avenue Tunnel, which is closed to pedestrians, opened temporarily to visitors last month. The tunnel has been closed to pedestrians since the 1930s but opened for artist Rafael Lozano-Hemmer's new work.

The 1,394ft (424.8m) tunnel was turned into an art show. Visitors will be able to walk through the road tunnel as part of the installation Voice Tunnel. In the middle there was an intercom into which they can speak a message that will then be broadcast out in waves of sound and light.

UK DfT: 20 per cent of rail commuters stand in peak times

Great Britain More than a fifth of rail commuters entering London are forced to stand at the busiest times of the morning rush-hour, Department for Transport (DfT) data shows.

Passengers on some morning and evening services during rush hour are travelling on trains that are carrying 60 per cent more people than they were designed to hold, the DfT data stated.

The most overcrowded service, revealed in a 'snapshot' in autumn 2012,

was the 8.27am Heathrow Express service going to Paddington in London, which carried 786 standard-class passengers, 65 per cent over the capacity figure of 476.

Daelim wins contract to build Sanseong Tunnel connection road

South Korea Daelim of South Korea has won a contract to build Sanseong Tunnel section one connection road (from Geumjeong) ordered by the Public Procurement Service in late July.

The contract amount is KRW 74.1bn (USD 66M) excluding VAT, and the project is scheduled to end within 54 months of the construction's commencement.

This project will connect Gijang-gun east of Busan with Gangseo-gu on the west by penetrating Mount Geumseong. It aims at solving the traffic jam issue in Busan, easing citizens' inconveniences, and promoting balanced regional development.

Daelim is scheduled to build a four-lane, 1km-long underground road and a six lane surface road connected with the Sanseong Tunnel.

Breakthrough on Milan Line Two

Italy The TBM boring Binary Lot 2 of Line 5 of the Milan

metro has completed its drive, Seli announced last month. With breakthrough, the company concludes excavation for the Milan metro project.

Excavation on this stretch began in November 2012 at the Monumentale station for a length of 1,930m, before completing the tunnel at Pozzo Orafi, having crossed three intermediate stations (Cenisio-Gerusalemme and Domodossola).

Milan's M5 line will run north for 5.6km from Garibaldi main rail station to Bignami with intermediate stations at Isola, Zara, Marche, Istria, Ca'Granda, Bicocca and Ponale – from where the shield has already been relaunched on its southbound run after the first intermediate breakthrough.

The design, build, finance operate concession for the project was awarded to a consortium of Astaldi, Ansaldo, Torno, Alstom and ATM for 32 years, including a five-year construction phase. Design and construction of the line will cost some USD 740M and it has been Italy's first major urban transport project to use project finance.

The new line will use rolling stock with automatic, driverless trains. It has been planned such that it will eventually to be extended to Monza, with four intermediate stations. There is also a proposal on the cards

for a westward extension from Garibaldi to San Siro with nine intermediate stations.

Northgate contract approved by Sound Transit Board

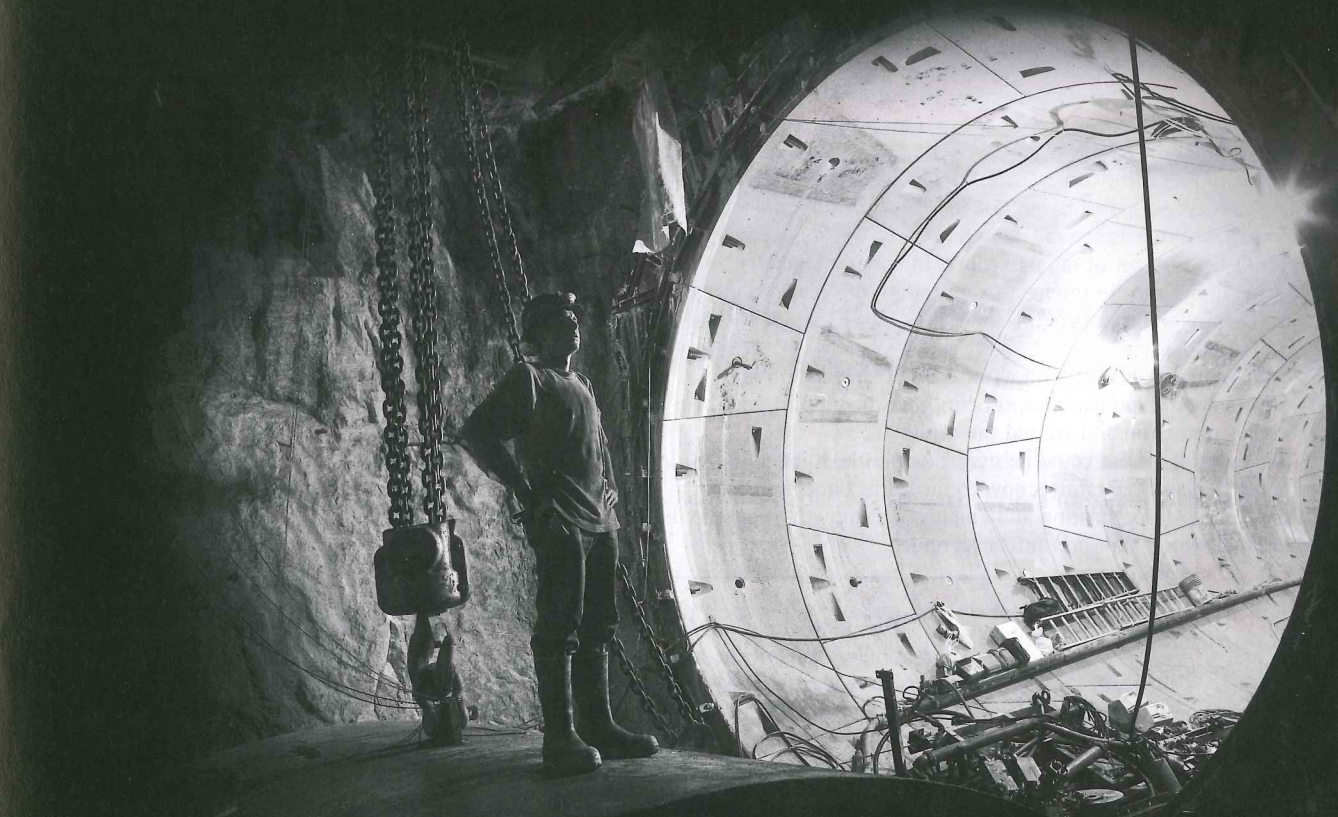
USA The Sound Transit Board in late July approved the Northgate Link Extension tunnel construction contract worth USD 440M in Seattle.

Winning bidder JCM Northlink is a joint venture formed by Jay Dee Contractors of Livonia, MI, Frank Collucio Construction Company of Seattle and Michaels Corporation of Brownsville, WI. The contract concerns 3.4 miles (5km) of twin light rail tunnels between Husky Stadium at the University of Washington and the Maple Leaf Portal near Northgate. In addition to the twin tunnels, the contract includes excavating the underground stations in the Roosevelt and U District neighborhoods and cutting 23 cross-passages.

This is the largest construction contract Sound Transit has ever awarded. The work is scheduled to begin this fall and last just over four years.

JCM recently completed mining the light rail tunnels between downtown Seattle and Capitol Hill Station as part of Sound Transit's University Link project.

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TFL CONSULTS ON SECOND CROSSRAIL PROJECT

Great Britain Consultation on London's second Crossrail project closed last month. Transport for London (TfL) called for options on the Crossrail Two proposed routes that are needed to relieve congestion. Crossrail Two is a reimagining of the abandoned plans for a Chelsea to Hackney tube line.

With Crossrail already set to provide a 10 per cent increase to rail capacity in London, Crossrail Two would add to this, TfL said. The company added that capacity on the transport network is needed to cope with London's forecasted population growth.

Michele Dix, TfL's managing director of planning, said: "We have had a good response rate to the Crossrail Two consultation already."

"Crossrail Two is vital to support London's forecasted population growth to 10 million by the early 2030s."

"The support we have received from Government for Crossrail Two is really good news and allows us to further the business case and examine the funding and financing opportunities to take the project forward."

David Higgins, Network Rail chief executive, added: "London's railways are already the busiest and most congested in the country, with many main lines already operating at, or close to, capacity."

"With the number of rail passengers in London predicted to grow by 30 per cent in the next twenty years, our plans to increase capacity through projects like Thameslink and Crossrail will make a real difference."

"But we must also press on with schemes such as Crossrail Two to make sure public transport continues to support and drive economic growth in and around the capital."

TfL said the project could be operational in 2030 but it is essential that work continues now to meet this target so the future forecasted population and employment growth in London is supported by new transport infrastructure.

Karnaphuli tunnel work to begin this fiscal year

Bangladesh Communications Minister Obaidul Quader said the construction work for the tunnel under the Karnaphuli river in Bangladesh would begin by the end of the current fiscal year.

Quader made the announcement to reporters after visiting renovation work of Baddarhat-Karnaphuli link road in the port city of Chittagong in late July.

The project will be implemented with the financial assistance of China involving BDT 55bn (USD 0.7bn). The funding proposal is now at Economic Relations Division (ERD), he said.

The minister also said the feasibility study of the tunnel has already been completed. After construction of the tunnel, a new city will be built on the other side of the Karnaphuli river, he said.

Samsung C&T gets Singapore Thomson Line contract

Singapore Samsung C&T announced in late July that it had won a USD 225M order from Singapore's Land Transport Authority (LTA) to build a subway line. The company said that it will construct Thomson Line 213, which includes a transfer station and a 379m line in the Caldecott area.

The Caldecott station will become an interchange station connecting the future Thomson Line with the Circle Line, bringing further convenience and connectivity to commuters working and residing in the Thomson Road and Toa Payoh Rise area.

Construction of the station and tunnels will start in August 2013 and is targeted to complete in December 2020.

When the Thomson Line Caldecott station is completed, commuters will be able to enjoy a direct route between Woodlands and Caldecott stations in 25 minutes as compared to the current 40 minutes it takes to travel along the North South Line and transfer to the Circle Line at Bishan.

Dubai ruler inaugurates road tunnel project

UAE The Rashid Hospital Tunnels opened in late June following four years in construction. The tunnels provide direct access to Floating Bridge for traffic from Umm Hurair street, Tariq Bin Ziyad Street and Khalid Bin Waleed Street.

The tunnels have the capacity to facilitate movement of 6,000 vehicles per hour, easing traffic around broadcast roundabout and will make accessing Floating Bridge easier for hundreds of motorists.

The circa 1km bores cost AED 722M (USD 197M). The project consists of twin two-lane tunnels, a pedestrian underpass serving the Rashid Hospital compound and a four-legged intersection on Riyadh street where the tunnels end.

Undersea tunnel project being revived

South Korea The government of South Jeolla Province, South Korea, has resumed the review of a plan to build an underwater tunnel for the KTX bullet train between the

port city of Mokpo and Jeju island.

In June, the provincial government requested the central government for KRW 10bn (USD 9M) as part of the 2014 fiscal year budget for studying and planning for the proposed Mokpo-Jeju underwater tunnel. It will hold an international symposium on the tunnel by next year.

The total length of the high-speed railway is 167km, including a 66km surface interval from Mokpo to Haenam, a 28km bridge section from Haenam to Bogil Island, and a 73km stretch from Bogil Island to Chuja Island and Jeju Island. The total cost is estimated at KRW 14.6tn (USD 10.3bn), with 11 years to complete.

Once the railway is completed, the provincial government expects as many as 15 million passengers will take advantage of the service each year, with an annual saving of KRW 42tn in social cost and 140,000 newly created jobs.

The idea of connecting the southwestern port city with Korea's largest island in the south was first broached in 2007 by the governors of South Jeolla and Jeju provinces. At the time, however, the proposal was shelved because of the astronomical cost to build the world's longest underwater tunnel and technological challenge of cutting the tunnel 160m below the water surface.

Evidence of 9,000 year old London settlement discovered

Great Britain Evidence of humans living on the Thames 9,000 years ago have been discovered by Crossrail archaeologists, the company announced last month. The discovery of a Mesolithic tool-making factory, which included 150 pieces of flint, among them blades, were found at the tunnelling worksite in North Woolwich.

MINOVA Ground Support Systems

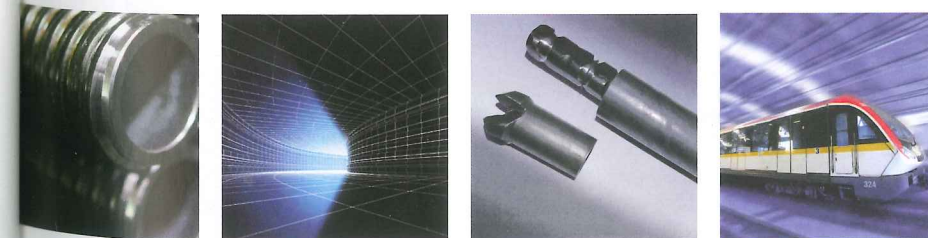


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Ground Support Systems

STUDY TO LOOK AT RAPID TRANSPORT SYSTEM FOR MUSCAT CITY

Oman Options for a Light Rapid Transport (LRT) or Mass Rapid Transport (MRT) serving Muscat City will be the subject of a study mulled by authorities tasked with overseeing the development of a national rail network across Oman.

The proposed study, due to be initiated, will look at opportunities for integrating a future rapid transport system envisaged across the capital city with the national rail network, now officially known as Oman Rail. That interface between the national rail network and the proposed Muscat City rapid transport system will take place somewhere near Muscat International Airport where the main passenger station, dubbed Muscat Central Station, is being planned.

According to officials, a number of options for the location of Muscat Central Station have been developed so far. But in choosing the most ideal location for the establishment of the central station, authorities will look at the site's suitability and proximity to the alignment of the national rail network, it is pointed out.

Plans for a rapid transport system for Muscat underscore the earnestness with which the government, represented by the Ministry of Transport and Communications, is forging ahead in its goal to make rail-based passenger and freight transportation services a reality in the country. Also assisting the Ministry on this front, particularly in long-range planning and prefeasibility studies, is the Supreme Council for Planning.

Conceived as a powerful new driver of economic development and a logistics game-changer, Oman Rail will provide connectivity with the Gulf Cooperation Council (GCC) rail network through the UAE. Further connectivity with Yemen and other GCC states is envisaged in the future.

Jakarta metro civil works contracts signed

Indonesia A ceremony was held at the headquarters of Mass Rapid Transit Jakarta this summer to mark the signing of the first three civil works contracts for the initial 15.2km phase of Jakarta's metro network.

Two bidders were selected to build the 9.2km underground section of the route. A consortium of Shimuzu, Obayashi, Wijaya Karya, and Jaya Construction will be responsible for two packages and a joint venture of Sumitomo Mitsui Construction and Hutama Karya won the third contract.

MRT Jakarta managing

director Dono Boestami confirmed during the event that Oriental Consultants, Japan, has been awarded a contract to provide construction management services for the project. He added that tendering had been completed on the three civil works packages for the elevated section of the line, and the winning bidders will be announced soon. The two remaining contracts, which cover railway systems and rolling stock, are still being tendered.

Speaking at the ceremony, Jakarta governor Joko Widodo said he expects the contractors to begin major construction work by October.

The first phase is due to open in 2017 and will link to the Hotel Indonesia traffic circle with Lebak Bulus in southern Jakarta. The line will have six underground and seven elevated stations. Services will initially operate at five-minute headways and ridership is expected to reach 420,000 passengers per day after three years of operation.

Alice in Auckland

New Zealand TBM Alice has berthed at the Ports of Auckland's Waitemata terminal on board the BBC Georgia, NZ Transport Agency (NZTA) announced last month. The TBM was dismantled for shipping and arrived in 100 separate parts, including 20 containers of small parts.

It will take 10 days to transport all the TBM's sections to the projects southern portal at Owairaka, where it will be reassembled, the agency stated. Some 13 of the 100 loads will be over-sized and they will be moved at night to minimise disruption to other traffic.

Alice is the 10th biggest machine of its kind in the world and it has been built to bore twin tunnels 2.4km long and up to 45m deep to connect Auckland's Northwestern (SH16) and Southwestern (SH20) with three lanes of traffic in each direction.

Makkah Metro contract awarded

Saudi Arabia The role of Program Management Office Consultant by the Development Commission of Makkah and Mashaer (DCOMM) on the Makkah Public Transport Program (MPTP), has been awarded to Parsons Brinckerhoff.

The contract is worth some USD 96.6M and is expected to last 60 months, the company announced earlier this month.

DCOMM has entrusted Makkah Mass Rail Transit

Company (MMRTC) to act as the Program Management Office, to oversee the implementation of MPTP. The project holds great importance beyond the extensive technical requirements, with strong cultural connotations given its prominent location in Makkah in Saudi Arabia, Parsons Brinckerhoff stated.

The public transport programme in Makkah is a plan for an integrated system that covers all means of public transport. The project in Makkah includes a network of trains consisting of four metro lines, with total lengths of 114km and 62 stations.

The complete project will be implemented in three phases over 10 years. The Tender prequalification process for the first phase is scheduled to start in December 2013. Phase one will consist of approximately 40km of Metro lines of which 20 per cent will be underground.

Dorgançay drill and blast rigs purchased

Turkey Senbay-Özgün JV, a part of the Bayburt Group of companies, recently purchased seven Sandvik tunnelling jumbos for the Istanbul - Ankara high speed rail relocation project, called Dorgançay. The project includes 10km of tunnel.

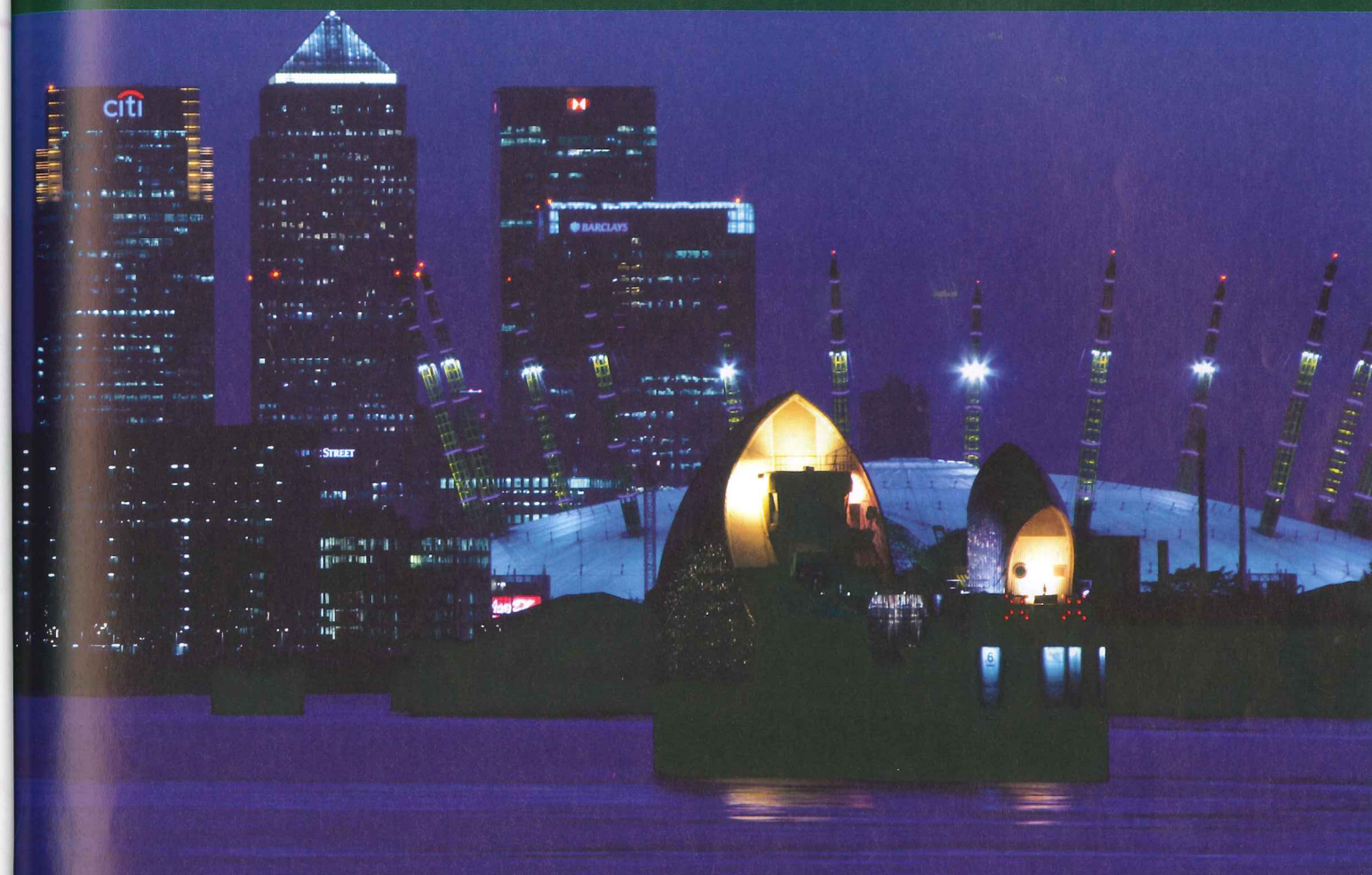
Turkish state railway awarded the Dorgançay project to the main contractor Senbay-Özgün on 10 May 2013.

What do you think?
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Share tracker

Company	June	July	Change (%)
Aecom (NYSE: ACM)	30.10	32.32	▲ 2.22 (7.38)
Atkins (LSE: ATK)	864.5	1,069.00	▲ 204.5 (23.67)
Balfour Beatty (LSE: BBY)	218.7	220.70	▲ 2.0 (0.91)
BASF Global (XETRA: BAS)	72.87	70.46	▼ 2.41 (3.31)
Bekaert (BSE: BEKB)	22.98	26.00	▲ 3.02 (13.14)
Bilfinger Berger (DUS: GBF)	77.06	74.23	▼ 2.83 (3.67)
Caterpillar (NYSE: CAT)	83.21	87.17	▲ 3.96 (4.76)
Costain Group (LSE: COST)	255.25	284.75	▲ 29.5 (11.56)
Ferrovial (MCE: FER)	12.27	12.64	▲ 0.37 (3.02)
Hindustan Construction Company (BOM: HCC)	11.20	10.10	▼ 1.1 (9.82)
Hochtief (XETRA: HOT)	49.50	53.50	▲ 4 (8.08)
Morgan Sindall (LSE: MGNS)	582.00	620.00	▲ 38 (6.53)
Sandvik (STO: SAND)	86.95	83.20	▼ 3.75 (4.31)
Shanghai Tunnel Engineering (SHA: 600820)	8.63	7.73	▼ 0.9 (10.43)
Strabag (LSE: STR)	16.85	16.06	▼ 0.79 (4.69)
URS Corporation (NYSE: URS)	46.70	47.94	▲ 1.24 (2.67)
Vinci (EPA: DG)	38.66	39.33	▲ 0.67 (1.73)

Prices are taken on the 12th of each month. NYSE is in USD. LSE is in GBP. STO is in SEK. BSE, EPA, MCE, STR and XETRA are in EUR. BOM is in INR. SHA is in CNY.

Central bank rates

	Rate (%)
AUD	2.50
BRL	8.50
CAD	1.00
CHF	0.25
CNY	6.00
EUR	0.75
GBP	0.50
INR	7.50
JPY	0.10
NZD	2.50
USD	0.25

Rates are taken on the 12th of each month.

Importantly, the acquisition will be significantly earnings enhancing."

Bekaert announces half year results

Belgium Bekaert made combined sales of EUR 2.14bn, down 5.1 per cent from the previous period. Gross profit stood at USD 330M. Net debt reduced from USD 1.15bn to USD 1bn compared with 30 June 2012. In a statement the company said the lack of consistent indicators of economic recovery are expected to impact profitability, as well as price pressure from an increasingly competitive Asia.

Private bank to finance 15 per cent of Broadlands Hydro-Power Project

Sri Lanka Continuing its role in funding Sri Lanka's vital infrastructure development, Hatton National Bank (HNB) recently joined up with the Ceylon Electricity Board (CEB) to partly finance the Broadlands Hydro-Power Project, which will add 35MW to the national grid.

The construction of the Broadlands Power Station has been given high priority since it is renewable energy which is imperative for the development of the country.

Over 85 per cent of the project will be by way of a loan from the Government of China, while the balance 15 per cent as a loan from HNB. The CEB signed loan agreements with ICBC Bank China and HNB in this regard in Colombo recently.

The dam will be constructed in Kitulgala in the Kegalle District using the Kelani River and the power plant will be constructed in Yatiyanthota town in the Kegalle district.

The dam will be 24m in height and 114m long. The tunnel of the complex will be 3.5km long and 5.4m in diameter.

"One key area of HNB's expertise is funding the country's infrastructure development projects by providing commercial loans under strategic tie-ups, said Ruvini Thenabadu, Deputy General Manager, Corporate & Wholesale Banking.

Keller acquires North American Piling

Great Britain Ground engineering specialist Keller announced in July that it had completed acquisition of North American Piling. The cost of the handover was CAD 227.5M (USD 219.7M) with a possible further CAD 92.5M (USD 89.3M) depending on performance. Keller chief executive Justin Atkinson said: "The board has identified Canada as a key target market and this acquisition of a complementary piling business represents an excellent opportunity to

build substantially on Keller's existing presence in that market.

"North American Piling is a market-leading business with attractive margins positioned in growth markets, including the resource-rich regions of Western Canada.

"The business has a strong record of growth delivered by an experienced management team who are transferring to Keller.

Oil price



103.1
June 2013

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July 2013

Values are taken on 12th of each month.

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SPARVO BREAKTHROUGH

TBM Martina broke through the last wall in the southbound carriageway of the Sparvo tunnel, main contractor Toto Costruzioni Generali announced last month.

The Herrenknecht-built machine was the largest diameter TBM, until Hitachi Zosen's Alaskan Way Viaduct Replacement Scheme machine took the record.

A ceremony took place on site to celebrate the result. The tunnel was designed by Autostrade per l'Italia.

Martina was being used to build the twin-tube road tunnel located between Bologna and Florence. The tunnel is 2,431m long and 13.6m wide. It will accommodate a triple-lane carriageway, including an emergency lane, 3.75m wide each. The tunnel will be equipped with 10 bypass - two of them for vehicles - and 17 SOS posts for emergency calls.

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London Underground 1863-1913

A MUDDLE OR A MIRACLE?

The dawn of world metro construction broke less than a kilometre from *Tunnels'* London offices a century and a half ago. Historian **James Chappelow** starts from the beginning



NO MIRACLE has ever been more taken for granted than the London Underground. A mere 150 years ago it did not exist. Within 50 years the main arteries of the best known system in the world, to be immortalised in Harry Becks ingenious map of 1933, were throbbing with life. Londoners had embraced a revolutionary form of transport. Its impact was to be phenomenal. London's transport system was transformed and the city's consequent growth was explosive. There was nothing inevitable about this. No grand plan was ever made; government played the role of permissive onlooker; finance and potential profits were uncertain; the technology was untried or non-existent; and the travelling public greeted the idea with fear and trepidation. Yet, by the outbreak of the First World War in 1914, the vision of 'descending into hell' to get to work had become an established fact in the minds of Londoners.

By 1860 London had become the first

James Chappelow
James has lectured in history for some four decades, with a recent engineering focus



World City. With a population of 2.8 million, London was the largest city in the world. It was the hub of an ever-expanding Empire and a Capital City that acted as a magnet for workers of all types. Around a quarter of a million additional people travelled into London to work every day. To this may be added many others who came to London as sightseers on excursions. To get around the city they had the choice of horse drawn omnibuses, their own private carriages or simply to walk. By such means no fewer than six million people attended the Great Exhibition during 1851. The mid century railway boom led to many new railway termini around the edges of the City - the limits of railway penetration into the City having been set by Parliament in 1846 - and, although much of the railway traffic was freight, still more people were enabled to travel up to London as rail passengers. The situation was becoming chaotic and it seemed that a point of complete gridlock was imminent. The size of the problem may be illustrated in that an estimated 6Mt of horse manure had to be disposed of in London each year by the middle of the century.

CASTING AROUND

The Victorians were far from blind to this problem. A multitude of solutions were put forward. Additional surface railways were ruled out not just by Parliamentary Committees but also by costings and common sense; much of the land was owned by the rich and privileged with very high ideas of compensation and if all the possible railways were to be built there would be little of London left as a city. Rival plans included sky walkways and different forms of underground transport. The vision that won the day was that of Charles Pearson. His plan was for a huge central station for the City with underground railways connecting the main-line termini that were developing at the edge of London. Pearson's standpoint was that of a social



2.8

The population of London in millions, making it the world's most populous city

Left: Excavation for the down side tunnel wall at Craven Hill Gardens, Paddington, during construction of the Metropolitan Railway's South Kensington extension
TfL

reformer. He wanted to make it easier for the poor of London to move out of their slums and travel easily and cheaply into London from new towns planned for locations such as Hornsey or Tottenham. The 1854-5 Commons Select Committee on Metropolitan Communications took a favourable view of Pearson's arguments and recommended the construction of an underground railway to connect the various termini with a central station at Farringdon.

Financing such a scheme proved problematic. Pearson's

Below: Cut and cover on the Metropolitan Railway extension to Kensington. Work begins on the retaining walls
TfL



laudable reforming zeal needed to be linked to the promise of financial return to potential investors. Victorian governments did not offer State subsidies. Fundamentally, many had doubts about the very concept of an underground railway. Nothing like this had ever been tried before. An article in *The Times* on 30th November 1861 suggested that Londoners would never choose "to be drawn amid palpable darkness through the foul subsoil of London". As the engineering methods were untried or even unknown, it is unsurprising that there was a great fear of subsidence with the consequent danger of endless claims for compensation. Financial backing for the Metropolitan Railway Company was slow to materialise. While the Great Western Railway was prepared to invest GBP 175,000 the Great Northern was more reluctant. By 1858 the company was so

"Londoners would never choose to be drawn amid palpable darkness"

desperate for funds that it spent GBP 1,000 in an effort to find more backers. Pearson was very actively involved in this process and through his position as solicitor to the City of London Corporation he was able to secure a deal whereby the Corporation allowed the Metropolitan to buy land in the Fleet Valley for GBP 179,000 and in return they invested GBP 200,000 in shares, which were later sold at a profit. This was a very unusual step for a public body to take in the 19th century but it gave the Metropolitan Railway a lifeline.

ROUGH BEGINNINGS

John Fowler (later Sir John) was appointed the engineer for the project. The whole length of the new line was to be cut and cover, except for a 700 yard (640m) long tunnel under the hill of Mount Pleasant in Clerkenwell. In engineering terms the process was straightforward. The 2,000 or so railway navvies – who lived up to their reputation for drinking and brawling as well as suffering death from disease and accidents – worked in two shifts to dig a hole and construct a brick lining, install the railway and then cover with brick archways, with cast iron cross-girders being used in some places. At the west end of the line – from Paddington (Praed Street) to Kings Cross – the process was simplified by following the route of the New Road (now Marylebone Road and Euston Road) as this negated the need to knock down houses. At the eastern end, however, as the line went through the Fleet Valley, a measure of house clearance was required. The Metropolitan Railway claimed that this displaced only 307 people but opponents of the railway put the figure much higher – the highest being 12,000 people displaced. There was little effort to compensate these people who were among the labouring poor of the area. It was in the Fleet Valley that the most difficult engineering problem occurred when in 1862, after a heavy rain storm, the Fleet sewer collapsed, flooding the works. The sewer had to be rebuilt. Costs were mounting by this time and an extra GBP 300,000 had to be raised on the promise of a five per cent dividend.

WORLD'S FIRST

The official opening of the Metropolitan Line was on 9 January 1863. Some 600 shareholders and guests joined the train at Paddington and spent two hours inspecting each station before arriving for a banquet at Farringdon Street at 3pm. Famously, the Prime Minister, Lord Palmerston, refused the invitation on the



"Prime Minister Lord Palmerston would wait until his death to go underground"

30

The number of passengers, in thousands, that travelled on the first day the Tube was open to the general public

grounds that he would wait until his death to go underground. On the following day 30,000 people travelled on the new line on 120 trains that were run in both directions.

While there were very positive comments on the innovative gas lighting in the carriages – where the lights were good enough to read newspapers – complaints began immediately about the atmosphere created by the steam engines that pulled the trains. Isambard Kingdom Brunel had claimed that, "the passage of a train through a tunnel creates such a commotion and change of air that I do not know of any difficulty in any tunnel that I am acquainted with." The passengers on the Metropolitan Line would not have agreed with him. Fowler himself attempted to design a better engine and Daniel Gooch, the Great Western Engineer, worked on the diversion of steam to cold water tanks and briefly coke, rather than coal, was tried – but soon found to be more toxic. The problem of the choking effects of the engines within even these shallow tunnels was never solved. If there was a delay or breakdown, the tunnels, trains and stations might fill with steam; three deaths were in some measure linked to the fumes; and local chemists made up a 'Metropolitan Mixture' for those who seemed to need it after a journey. The only cure would be electrification of the line.

The tunnels and stations of the Metropolitan are, of course, still in use, but the modern traveler might find few similarities. The track in each direction had three rails so that the wider gauge Great Western trains could use the system for through trains from Paddington, just as the Great Northern trains also used it but on standard 4ft 8 1/2 inch gauge – which was also



Far left: The line passes from cutting into tunnel. Retaining walls are nearly finished, tunnel arching is already TFL

Left: The impact of cut and cover tunnelling is clear. Access to the houses is from stepping stones TFL



Above: Metropolitan Railway work at Praed Street, Paddington TFL

used by the Metropolitan's own trains. Cheaper early morning trains with a fare of 2d (two Old Pence) were introduced from 1864 and over 300 workmen used them daily. The gradual movement away from the overcrowded slum areas was thus encouraged by the availability of cheap transport. The line was also heavily used for freight. A special spur was soon added to transport animal carcasses to Smithfield. (It is often forgotten that the Underground system continued to be used for freight until well after the Second World War).

Purely in terms of numbers, the Metropolitan was a success, with 11.8 million passengers in the first year at a daily average of 32,000. At the end of that year a dividend of 6.25 per cent was paid out to shareholders. This was sufficient encouragement to lead to the formation of other railway companies to join in on the act. Parliament was inundated with new schemes and a House of Lords Committee of 1863 called for "an inner circuit of railway that should abut, if not actually join, nearly all the principal railway termini of the Metropolis". The Metropolitan Line had already achieved the northern arc of this circle and the newly formed District Line began from 1868 to work on the southern section from South Kensington to Blackfriars, making use of the newly built Thames embankment as much as possible. Progress was slow. There were fewer opportunities to build on the routes of roads.

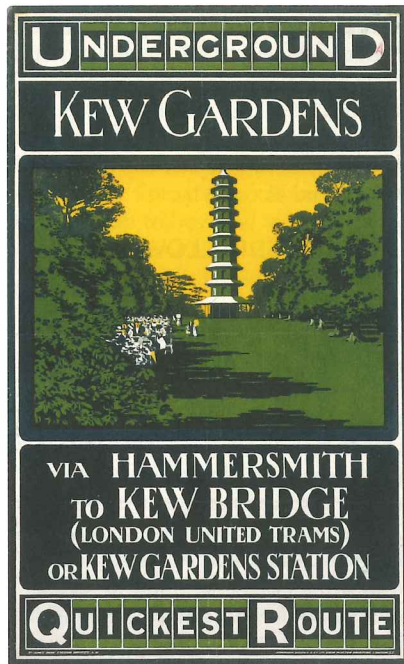
More properties had to be purchased and demolished but this time they were in areas where the owners were more capable of resisting and demanding more compensation. The work was immensely disruptive and capital for the project hard to come by.

UNEASY BEDFELLOWS

Cooperation between the two companies, which might have seemed an obvious solution, became impossible because of the personal rivalry between James Forbes, who took over the management of the District Line and Edward Watkin, who held the same position in the Metropolitan Line. Neither man saw the completion of the Circle Line as a priority and both were more concerned with the development of their lines as surface lines to the outskirts of the expanding Metropolis. Such plans were of great importance in the development of suburban London but they meant that the Circle was not completed until 1884. Symbolic of the continuing disputes between the two companies was the extraordinary fact that Metropolitan trains ran clockwise around the outer track while District trains went anticlockwise on the inner track. This was the only line to effectively be planned through a Parliamentary Committee and it is perhaps unsurprising that it was not commercially viable until the other deep lines were added to the system and connected to it.

The tunnelling shield – usually known as the Greathead shield although first developed by the Brunels for their tunnel under the Thames which was opened in 1843 – combined with the soft and undisturbed clay deep under London to allow for the building of the first lines that can rightly be called 'The Tube'. The shield had a 12ft (3.7m) diameter; it was moved using 210t thrust hydraulic jacks to move it forward; and it was used in conjunction with mechanical diggers called 'the Thompson' which cut with saw edged buckets. The shield was followed up by prefabricated cast iron segments to form the tunnel walls. This was much easier than building a brick arch. With this system the first deep tunnel for the London Underground was completed from Stockwell to the City – now part of the Northern Line – to be opened as the City and South London Railway in 1890.

Obviously, there could be no question of using steam trains through these deep tube tunnels. The initial intention was to use cable traction. In 1888, however, the first experiments in electric traction



Left: This Kew Gardens poster was published by the Underground Electric Railway Company in 1908 to encourage Tube excursions. The artist is unknown. TEL

were being made, in Berlin by Werner von Siemens, in Ireland on the Bessbrook and Newry Railway and in Brighton on Magnus Volks seafront railway, which is still in use. Electrification was started in 1889 using two electric lines of direct current, which was the system that was adopted eventually by the whole of the network. As previous history might suggest, it took the District and Metropolitan 15 years to convert from steam to electric and only after further acrimonious disputes. Electric engines were used at first to pull the trains but these proved problematic – especially as some of them were so heavy that they caused shaking at surface level – and they were eventually replaced with the now familiar powered coaches, known as electrical multiple units. All electrification was completed by the First World War.

The success of the City and South London Railway stimulated a boom in tube construction. The Waterloo and City Railway (soon labelled and still

Tunnels would like to thank the London Transport Museum for access to its photo archive

known as 'The Drain') was opened in 1898; the Central London Railway – the middle section of the Central Line – opened in 1900; and the Bakerloo, Piccadilly and Hampstead Tube (now Northern Line) all opened between 1906 and 1907. The new lines, particularly the Central Line, tended to follow the route of roads as it was cheaper to do so. This gave some of the lines sharp curves, particularly noticeable for Regent Street on the original Bakerloo Line. The 'padded cells' of the City and South London Railway (there were only tiny windows at the tops of the carriages) were soon replaced with carriages that were light and comfortable and not so different from modern trains. Journeys were relatively cheap. The Central Line was known as the 'twopenny tube' and this became the standard fare for some time. For reasons of simplicity, the different classes in carriages disappeared and experiments with separate coaches for women did not last. Lifts were installed to take passengers to the platforms. The first escalator was not installed until 1911, but they soon became a feature of the system.

The ambitions of a remarkable American, Charles Tyson Yerkes, lay behind the final spurt in tube building. It is difficult to characterise Yerkes. He has been dubbed 'the Doggy American' and his career hardly bears close scrutiny if a typical turn of the century businessman or entrepreneur is being sought. His Chicago background – where he had modernised and expanded the tram system – showed him to have a cut-throat and cavalier attitude to business. His own guiding principle in business had been, "Buy up old junk, fix it up a little and unload it on other fellows." Having fled from Chicago in 1900, Yerkes sought new opportunities in London – a city that seemed ripe for further underground development.

By 1900 there were already schemes for further tube lines. Parliamentary approval had been given. Finance was the problem. The Baker Street and Waterloo Line was the most ambitious, at three miles long and with stations at Oxford Circus and Piccadilly Circus. Whitaker Wright's London & Globe Finance Corporation was founded in 1897 to raise the capital for the project. The work was started but the money ran out before 1900. Wright was found guilty of fraud and committed suicide in 1904. Yerkes saw his chance, acquired the line in 1902 and added it to other holdings he had to form the Underground Electric Railways Company of London Ltd. It was this company that was to become London Transport in 1933 and by 1914 only the Metropolitan Line remained independent from the UERL.

Having gained control of the rights to build the new lines – such as what was soon called the Bakerloo line (to the dismay of The Times) – Yerkes set about finding the money. The principal source turned out to be the USA where Yerkes seemed to have little difficulty in convincing investors that the plans for new Tube lines in London were sure winners. Money was also raised across Europe. Yerkes sold promises of high yields in the future and raised the huge sum of GBP 18M to build the new lines. He also managed, by fair means and foul, to hold off challenges from other American investors, including J.P. Morgan. Yerkes died in 1905 having set in motion the construction of three major tube lines. He died before the financial losses became apparent to the shareholders.

At the end of its first fifty years London's underground railway had become an established and irreplaceable part of the transport system. It had already taken on many of the characteristics that are still recognisable today. From chaos came creation: a new heart for London. The Underground was the only practical solution to keep the great city on the move. Its full impact on the city was yet to be revealed. Londoners not only came to rely on their Underground but the people had also formed a great emotional attachment

Further Reading

- Christian Wolmar: *The Subterranean Railway*. Atlantic Books
- David Bownes, Oliver Green & Sam Mullins: *Underground. How the Tube shaped London*.
- Claire Dobbin: *London Underground Maps. Art Design and Cartography*
- T.C. Barker & M. Robbins: *A History of London Transport*.
- John Day and John Reed: *The Story of London's Underground*.
- M.A.C. Horne: *The Metropolitan Line The District Line The Northern Line and The Bakerloo line*
- D.F. Croome: *The Piccadilly Line*
- B. Bobrich: *Labyrinths of Iron*



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Typical installation of the RST Profile Monitoring System for Tunnel Concrete Segments with an RST flexDAQ Datalogger System.

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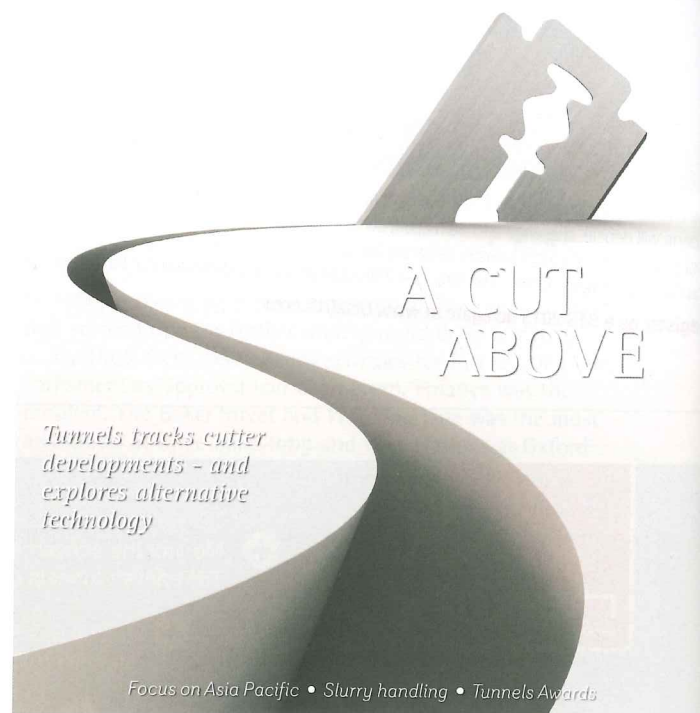
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London Underground 1913-1963 WAR AND PEACE

As the world lurched into the most bloody period in history, London Underground entered a golden era of management and vision. Historian **James Chappelow** continues the story up to the years of decline

FOR LONDON Underground the 20's and 30's were heady days. The system reached its apogee in terms of style and service. It was managed by men of unparalleled effectiveness and vision. As its network expanded – albeit on the surface as well as underground – so the size and shape of modern London itself emerged. It led the world in terms of architecture, art and graphics to stamp a corporate image that remains globally familiar. As the dominant partner in London Transport, it demonstrated the potential for success in a public corporation. At either end of these decades London Underground played its part in serving the Nation and contributing to victory in both of the World Wars.

At the start of the First World War in 1914 the London Underground was poised for growth. All but the Metropolitan (together with the Hammersmith and City Line, which it owned) were incorporated in the Underground Electric Railway Limited, which had been formed by the American tycoon, Charles Tyson Yerkes. During the war the Underground seemed to pursue a business as usual policy. The Bakerloo Line was extended to Watford and the Central Line to Ealing Broadway. Posters suggested a rather relaxed attitude to the war. One of 1913 showed a humorous view of punting on the River Thames with slogan, 'Up the River by Underground'; one of 1915 showed a view of the planets with the words, 'By Underground to Fresh Air'; and another of the same year an idealised view of the country-side with the calming slogan, 'Why bother about the Germans invading the country? Invade it yourself by Underground!' To be fair, there were also many examples of the more expected recruitment posters and warnings about dangers of the war displayed.

The most serious danger in the First World War in London was bombing either by Zeppelins or planes. From the start of

86

The number of stations in operation at the outbreak of the First World War

the war, sheltering in the deeper tubes was encouraged. There were very few alternatives as this form of warfare was new. Luckily, the raids were few and far between. The 86 stations were thought to have a capacity of 250,000, although 300,000 sheltered in stations in February 1918. Whenever the attacks were more frequent about 100,000 used to go to shelter in the system before any warnings were given. There were complaints about this as they interfered with the passengers. As the Underground was perceived as safer and with the additional numbers due to many troops moving around the capital, the use of the system increased dramatically during the war. People became more accustomed to using the underground.

Eventually, it was decided that trains should proceed slowly during raids.

The other obvious impact of the war was on the workers themselves. Many men either volunteered for the forces up until 1916 or, thereafter, were conscripted. Only the job of train driver counted as a

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"Churchill himself intervened to make sheltering in the Tube official policy in October 1940"

reserved occupation. All other jobs could be taken by women. Although managements were reluctant to employ women at first, by 1915 there were female booking clerks, ticket collectors, porters and lift attendants. Women had also taken on the job of train guards by 1916, which made them responsible for the safety of the passengers on the trains. Over 4,000 Underground Railway staff joined the forces, and, as is attested on the War Memorial that can still be seen in Baker Street Station, many of them were killed in the conflict. After the war the women lost their jobs as the men returned.

SECOND WAR

The impact of the Second World War from 1939 to 1945 on the London Underground was much more profound and dramatic. The war was not unexpected and plans for the emergency were made as early as 1937. It was rightly feared that the bombing of London was an inevitability. A London Transport Air Raid Precautions Committee was formed. The main thrust of its work was to ensure that, as far as possible, the transport system in London would be kept running. This was important not just so that the city itself might continue to function as the country's capital but also to provide for all the necessary additional movement of people occasioned by the war. The evacuation of over half a million children, for example, could not have been accomplished without the help of an effective and well organised transport system, with the Underground network at its heart.

The flooding of the system was regarded as a possible wartime danger. The tunnels under the Thames were only 10ft (3m) below the surface and it was thought that they might be fractured by bombs. For a short time in 1938 – when there was thought to be danger of war during the Munich Crisis – the tunnels were blocked with concrete plugs and through services suspended. This was an unsatisfactory solution, and by the time of the outbreak of war there were

Above: Wartime saw social reforms for the role of women in society
TFL

152

The number of people killed directly due to bombing in the London Underground during WW2

25 flood gates at 19 stations. They each weighed 6t and were worked electronically from Leicester Square. The danger was not just from the river but also from water mains and sewers. On 14 October 1940 at Balham 64 shelterers were killed as the station filled with water and sewage. Mercifully, such disasters were infrequent, as were direct hits on stations by bombs.

After the experiences of the First World War it had been decided that it was more important to keep the tube running than to let people shelter on the platforms. The management has rejected the idea of turning the stations into public shelters given the risks of overcrowding and the concomitant insanitary conditions. Not unnaturally, most Londoners opposed this restriction when the Blitz started in 1940. The first raids were on 7 September 1940. When the crowds turned up at Tube stations to shelter it was impossible to turn them away. It was not long before every available space in the 79 deep tube



Above: Excavation work on the Northern Line
TFL

stations was occupied by over 170,000 shelterers – dubbed 'Tubites' by the press – each night of the Blitz. Churchill himself intervened to make sheltering in the Tube official policy in October 1940.

In reality there was little to be done to stop this. Instead the shelterers had to be organised. "Period Reservation Tickets were issued by Local Authorities and Casual Shelter Tickets, valid for one night only, could be obtained as an emergency measure during an alert. The scenes in the stations during the Blitz have provided very familiar images, as have the sketches made by artists such as Henry Moore. The shelterers were not just left to fend for themselves. The provision of food gives some idea of how quickly the Underground adapted to the situation – and this can be seen in film material available at the London Transport Museum. Eventually, there were 120 station canteens and 1,000 workers employed at six centres for food preparation. "Tube Refreshment Specials" toured the system to bring tea and cocoa and baskets of buns and other nourishing food for the shelterers. This provided more opportunities for women to 'do their bit' in the war effort and morale was much boosted in this way. The shelterers in some stations, such as Swiss Cottage, produced their own newspapers and from 1940-41 there was a general magazine called "The Subway Companion".

ROSE TINTED

Happy memories of being safe as a tube shelterer have long been retold. Myths have also been created. Alongside the sing-songs were the snoring and the smells. There were insufficient toilets and the shelterers were crowded behind white lines on the platforms to allow for passengers to continue to use the trains. On many of the lines the trains continued to run late into the night as well as early in the morning. There were still disasters. Some 152 were killed directly due to bombing. On 3 March 1943, 173 people were killed in a crush on a staircase that happened because a mother carrying her baby had tripped

"On 3 March 1943, 173 people were killed in a crush on a staircase because a mother carrying her baby had tripped in the dark"

in the dark. You had to be near a station to be able to shelter there. As the war went on so more people began to choose not to shelter in the Tube – although numbers increased when the V1 and V2 attacks started in 1944. The numbers who sheltered in the Tube tend to be exaggerated. In fact, only four per cent of Londoners regularly used the Tube stations as shelters.

Despite all the dangers and privations of the War, the London Underground made a significant contribution to the war effort. Many of the employees went off to fight; women took on almost all of the jobs – and this time kept them after the war; there were relatively few casualties due to enemy action; and the system as a whole was quickly repaired and in use after damage. There was much about which the workers and managers could justly feel proud in 1945.

GOLDEN YEARS

The interwar years of the 20s and 30s were the Golden Age of the London Underground. In large measure this was due to the work of Albert Stanley (from 1920 Lord Ashfield) and Frank Pick. Stanley, who became general manager of the Underground Electric Railway Company of London (UERL) in 1901, provided great vision and drive for the company, while Pick, the assistant general manager, worked with dedication, devotion and attention to detail to give the company clear leadership. Both men were seconded to the government during the Great War which gave them invaluable insight into the working and thinking of the civil service.

They both understood that London needed a properly integrated transport scheme – which made them open to Herbert Morrison's idea of London Transport – and they were willing to make use of any government funding that might become available. They knew that the system's survival and growth was dependant on subsidies.

Plans were made for the expansion of lines before the First World War. These were put into effect in the 1920's. The Central Line was extended to Ealing Broadway and the Hampstead Line was pushed on from Golders Green to Edgware – an area that had no alternative main line train services.



The City and South London Lines and the Hampstead Line were also linked at Euston. These changes were partly financed by the Trade Facilities Act, which was the response of the post war government to the crisis of high unemployment. It was not a direct subsidy, but the UERL benefitted to the tune of GBP 5M. The integration of the Hampstead Line with the City and South London on what is now the Bank branch of the Northern Line did lead to a very rare but disastrous tunnel collapse in 1923 near Borough station, which set off a huge gas explosion which left a great crater in Newington Causeway. It took a year to clear up this mess.

South of the River, the extension from Stockwell to Morden was completed in 1926 – all in tunnels until it neared Morden. To the North, the extension to High Barnet was not started until 1937 and it was only then that the line took up the name 'Northern Line'.

The extension of the Piccadilly Line had to wait for the passage of the Development (Loan Guarantees and

Above: Work underway during the interwar period using the Greathead shield
TFL



Grants) Act of 1929. This was part of the Labour Government's response to the growing economic crisis. Under this scheme, the government paid the interest on the loan that was needed to build the new lines all the way out as far as Cockfosters to the north and Northfields to the west. All this work was completed within three years – a stunning achievement.

This was all done in style. An attempt had been made to use a consistent style in the station design on the Yerkes lines before the First World War. Leslie Green was responsible for

"The London Underground had become a national institution"

this. The very familiar blood red glazed tiles may still be seen at the entrances of many central London stations.

The keen eye will also be able to spot Art Nouveau design features on numerous details within the stations, as on ventilation grilles.

This early excursion into corporate branding was followed up in 1908 with the first appearance of the red circle with blue bar for the name of the station. In the 1920s this became the logo for the Underground as a whole and then from 1933 the emblem for London Transport as a whole – including the buses. The new Underground lettering, with a larger U and D at either end was also introduced – by Pick – in 1908. Edward Johnson's alphabet became standard for all Underground posters and notices from 1916.

The architect Charles Holden became the principal designer for the new stations of the 1920s and 30s extensions. He worked very closely with Pick. They went together on a tour of Scandinavia, Germany and the Netherlands and Holden was heavily influenced by the latest modern trends in public architecture.

Pick's influence was to insist not only on excellence in building design but also that the same principles were applied to all the features of the station. While the stations may have different shapes, there had to be a consistency of design.

Above all they had to be welcoming and passenger friendly. Many of these stations are still in use and stand out as architectural jewels in otherwise drab suburban developments. Holden's greatest triumph was the newly designed Piccadilly Circus station, which was opened just before Christmas 1928.

GUIDE LINES

The most significant gift to posterity from this period was the Underground Map of Harry Beck. This was first designed in 1931 and fully circulated in 1933. Up until then all the maps had been geographical in nature and, as the system had extended, had become increasingly complex and perplexing, especially to those now used to the Beck interpretation.

Beck produced a diagrammatic guide to the Underground with no attempt to represent the surface geography or present the real distances between stations. Straight lines are used with angles of 45 and 90 degrees only. Whether or not electronic circuit diagrams inspired Beck is debatable – most think not.

What is not debatable is that Beck, a UERL employee, was very badly rewarded for his work: he received just over GBP 10 in 1933. He did not share in the royalties for a plan that has been copied in so many different forms ever since. The Harry Beck map has stood the test of time.

The 20's and 30's were the era of Metro-land. Strictly, this term applies to the housing developments that sprouted along the Metropolitan Line to the North and West of London. A great deal of land had been acquired by the company as the line was extended and the process of development had started before the First World War in places such as Rickmansworth, Uxbridge, Northwood and Watford. The company formed the Metropolitan Railway Estates Company and from 1919 to 1930 its director was Robert Hope Selbie, the General Manager of the Metropolitan Line. The housing developments were advertised in the Metro-land magazine which sold the country-side idyll that had become in easy reach of London both for work and play. The irony was that as more houses were built so the

quality of the countryside deteriorated. House sales of Metro-land were a financial boost to the Metropolitan Line.

The UERL was not blind to these opportunities. When Yerkes insisted that the Hampstead line be taken as far as Golders Green, he saw the potential of the green fields that lay at the end of the line. By 1914 there were 471 houses at Golders Green, where there had been just a farm. Just north of the station the building of Hampstead Garden Suburb was also under way. Wherever the Underground was extended, so London itself grew – very rapidly in the 20's and 30's. The southern end of the Northern Line had effectively linked what were a series of villages.

The population of Morden in 1926 was around 1,000. By 1931 the census showed that it had grown to over 12,000. Development was particularly strong when the Underground reached an area that was not well served by alternative cheap transport, such as Arnos Grove, where all the spare land was snatched up by builders. The housing boom went on until 1934 and it transformed what became the London suburbs. The Underground was a key factor in this in giving a shape to the initial developments.

UNFINISHED BUSINESS

This Golden Age of the Underground was not sustained after the war. There was a crying need for investment in 1945 after six years of making do and patching up. The austerity of the immediate post war period meant that little progress could be made. Nationalisation in 1948, although a logical step, left much to be desired.

As the Underground reached its centenary in 1963 it was easy to see that at the very least a facelift was needed. The London Underground had become a national institution, but one with a question mark over its head ☹

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Further Reading

Christian Wolmar: *The Subterranean Railway*. Atlantic Books
David Bownes, Oliver Green and Sam Mullins: *Underground. How the Tube shaped London*.
Claire Dobbin: *London Underground Maps. Art Design and Cartography*
T.C. Barker & M. Robbins: *A History of London Transport*.
John Day and John Reed: *The Story of London's Underground*.
M.A.C. Horne: *The Metropolitan Line The District Line The Northern Line and The Bakerloo line*
D.F. Croome: *The Piccadilly Line*
B. Bobrich: *Labyrinths of Iron*
Alan A. Jackson: *London's Metroland*

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London Underground 1963-2013 FUNDING GAP

Highlights such as the Jubilee Line Extension stand out from the economic mire of the past 50 years. The second half of the 20th century was not kind to a Britain newly stripped of superpower status, or the capital's metro, which following WW2 entered a half century of neglect and underinvestment



WITH THE nationalisation of Land Transport in 1948 it became a part of the behemoth that was the British Transport Commission (BTC). It was a period of state control of services, but this was an interesting step as it effectively renationalised a public sector entity. The Treasury effectively controlled the BTC. With a nation crying out for improvements to health, a need for electricity and major new house building projects; London's infrastructure needs were perhaps a secondary concern. Money and steel were in short supply, but due to works between the wars, the Underground was in fairly good condition.

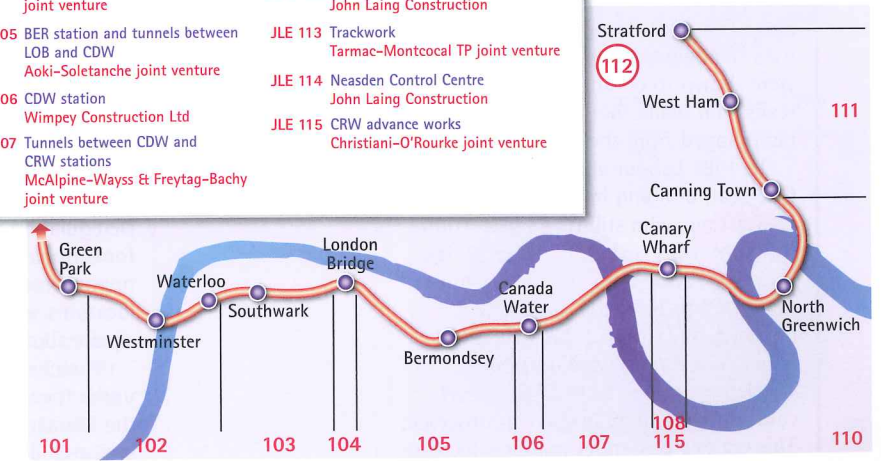
This was a blessing, as now any expense over GBP 50,000 had to be referred directly to the BTC by the new London Transport Executive (LTE). With the necessarily higher investment costs of underground rail systems, the focus switched to buses. Planned extensions of the Central Line and the Northern Line were scrapped. At this time, London's Underground was described as the best in the world. From this lofty peak, though it had already begun the decline. By 1965, the number of cars on London's roads had quadrupled from the 1950 figures to two million. During this

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- | | |
|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| JLE 101 Escape shaft and interchange tunnels at Green park station
Tarmac Construction Ltd | JLE 108 CRW station
Tarmac-Bachy joint venture |
| JLE 102 WES and WAT stations and tunnels between GRP and WAT
Balfour Beatty/AMEC joint venture | JLE 110 NOG station and tunnels between CRW and CAN
McAlpine-Wayss & Freytag-Bachy joint venture |
| JLE 103 SOU station and tunnels between LOB and WAT
Aoki-Soletanche joint venture | JLE 111 CAT and WEH stations; STR station (platforms only); formation between CAT and STR and NLL formation
John Laing Construction |
| JLE 104 LOB station
Costain-Taylor Woodrow joint venture | JLE 112 Stratford Market Depot
John Laing Construction |
| JLE 105 BER station and tunnels between LOB and CDW
Aoki-Soletanche joint venture | JLE 113 Trackwork
Tarmac-Montcocal TP joint venture |
| JLE 106 CDW station
Wimpey Construction Ltd | JLE 114 Neasden Control Centre
John Laing Construction |
| JLE 107 Tunnels between CDW and CRW stations
McAlpine-Wayss & Freytag-Bachy joint venture | JLE 115 CRW advance works
Christiani-O'Rourke joint venture |

Below: Figure 1, The alignment of the Jubilee Line Extension project



period, accusations of long-term damage from low investment levels have been leveled at the network. No LT reports from this period show any planned maintenance programmes. Historians Barker and Robbins described the period as having "characteristic features of public handling of investment projects in mid-20th century Britain," meaning delays and irrelevant caveats.

BTC was abolished in 1963 in favour of direct ministerial control of the network. However, this didn't benefit the budget. Records show GBP 1.1M available for improvements annually.

In 1970, LT became part of the local government body, Greater London Council (GLC). However, since the New Works Programme of the 1930s, the Underground had languished through three decades of neglect. LT was in debt, and behind.

The Conservative Party GLC leader Desmond Plummer argued that the debt should be written off. Then and only then would he take the reins. Grants came in from central government, and the future was brighter than it had been for a long time. Spending was to be increased by an order of magnitude over the next 20 years to GBP 275M on essential renewal (lifts, escalators). Despite a good deal of success, 'violent policy shifts' were characteristic as party control of the GLC fluctuated. Annual passenger numbers had fallen below 0.5bn for the first time since the end of the war due to jobs moving out of central London, recession, and car popularity.

ONE FOR THE ROAD

In 1973 local elections changed the game. Labour won 47.4 per cent of the votes for the GLC election, 58 seats to the Conservatives' 32. Some seats were not won again until the 1997 Labour landslide, so great was the win.

One of the key reasons given for the 1973 shift to the political left is the Conservative policy of major road building in London. Ring roads were shown to be unpopular, and the realisation made that cars should be discouraged from the city centre.

In 1981 Labour again won the GLC seat, bringing in left-wing Ken Livingstone, who still runs for election to the Mayor's seat to the present day. There was an idea to entirely abolish fares, but in the end a 1/3 cut was imposed, and dubbed the 'Fares Fair' policy. Zonal fares were introduced, which allowed the birth of the travel card. Another surge in use was observed. This era saw passenger numbers increase

Timeline of key events

- 1963 – London Transport Executive becomes London Transport Board, reporting directly to the Transport Minister
- 1968/69 – Victoria Line opens between Walthamstow Central and Victoria, the first computer-controlled underground railway in the world, with automatic trains and ticket gates
- 1970 – London Transport transferred to Greater London Council, a local government
- 1971 – Victoria Line extension opens to Brixton, the first line built south of the River Thames since the Northern Line in 1926
- 1975 – Moorgate Tube Crash. The most lethal incident in Underground peacetime history. Forty-three passengers lose their lives as a train fails to stop at a dead end
- 1977 – The first airport link created, as the Picadilly Line Extension opens to Heathrow Central (Terminals 1, 2, 3). Later extended to T4 in 1986 and T5 in 2008
- 1978 – The first female train driver begins work on the District Line
- 1979 – First stage of Jubilee Line opens between Charing Cross and Baker Street, where it took over the former Bakerloo Line branch to Stanmore
- 1980 – London Transport Museum opens
- 1983 – Introduction of zonal fares and Travelcard following political fighting
- 1984 – London Transport removed from GLC control, renamed to London Regional Transport (LRT) and reporting to Secretary of State for Transport
- 1985 – London Underground Ltd (LU) formed as a subsidiary company of LRT but still in public ownership
- 1987 – Kings Cross Fire. Thirty-one passengers are killed.
- 1999 – Jubilee Line Extension opens from Green Park to Stratford and original spur to Charing Cross closes
- 2000 – Transport for London (TfL) established as London's new transport authority
- 2002/03 – PPP contracts drawn up for maintenance and upgrading all lines on behalf of LU with two private infrastructure companies: Tube Lines and Metronet.
- 2005 – A coordinated suicide bomb attack is executed against London Underground trains and London buses. The 7/7 attack cost the lives of 52 people and stands as London's worst terrorist incident
- 2007 – LU carries one billion passengers for the first time
- 2007 – London Overground is created as part of TfL to manage some suburban rail services, East London Line closes for rebuilding, extension and transfer from LU to London Overground management
- 2010 – Extended East London Line reopens
- 2011 – Crossrail construction commences
- 2012 – London Overground completes orbital rail links
- 2013 – London Underground celebrates 150th anniversary

2

The number of cars in millions on London's roads by the year 1965

to 6M per day (2.2bn per year).

Arguments between GLC, Government and LT saw fares fluctuate. Bromley argued that as it had not an Underground station, it should not have to pay towards the subsidy. The challenge was upheld by judges. Livingstone complained that the judgment was politically motivated, but to comply with the law, fares doubled to cover the costs. Passenger numbers dropped to 5M per day and traffic is said to have worsened.

In 1982 the Balanced Plan called for a 25 per cent reduction in fares to strike a compromise. This was implemented in 1983, and effectively it reduced fares to levels when Livingstone assumed power.

London's financial sector exploded into life in the 1980s under the new Conservative Prime Minister Margaret Thatcher. Deregulation and tax breaks heralded a new era of prosperity for central London and the City. By the mid 1980s, the decline in passenger numbers had been reversed, as central office locations soared in price and popularity, with the price per square foot at a record GBP 70 (by 1994 it was to be GBP 5-10).

Thatcher abolished the GLC in 1986, and LT was taken under the wing of London Regional Transport (run by the Ministry of Transport), renationalising it. This period's organisation brought about two extensions, for Heathrow and

King's Cross Fire and Fennell

The King's Cross Fire took place on 18 November 1987 at 7.45pm. A fire had been 'smouldering' (the fire department was not required for 'smoulders' and was only to be called when staff could no longer control the fire) under a Picadilly Line escalator for half an hour when it suddenly erupted, causing the deaths of 31 people. It was common for people to smoke on the escalators leaving the Underground, despite the total ban on smoking following the Oxford Circus Fire a few years before, and a discarded match was identified as the cause.

The fire was not a phenomenon, and likely preventable. Of 46 fires between 1956 and 1988 that were studied for the resulting Fennell Report, some 32 were attributed to smoking. Two weeks before the disaster, gaps were observed between the escalator treads, and the skirting boards caused by the 'crabbing' movement of the escalator, which would allow material to drop through and a fire to flourish. Also, some 30 per cent of the fire cleats were missing. The 'ethos' of the Underground was also questioned in the report, with professional engineer 'barons' responsible for their respective disciplines, and each unwilling to trespass on the territory of the other. This, along with long service periods and the rarity of external appointments to management positions closed the organisation, and compartmentalisation led to little exchange of ideas.

The full recommendations are listed in chapter 20 (p.163-) of the report, and are listed in priority order. The adoption of the recommendations, and the bringing of the declining organisation up to code was rapid, but expensive.

the Jubilee Line.

Under the Thatcher regime, contracts for peripheral functions could be let out to the private sector. For the first time, London Underground (LU) was forced to tender out its work requirements in a competitive environment. However, funding was often not enough to cover the investment required and there was interference and a short-term mindset. It was during this time that the Kings Cross Fire disaster took place. One of only two peacetime incidents to claim more than 12 lives in the entire 150-year history of the Underground (see box, right).

ACCOUNTING FOR LOSS

The inrush of funds following the Kings Cross Fire was cut back again having brought infrastructure up to the new codes, and due to the economic recession in the early 1990s. In October 1991, LU announced that it was heading for an unforeseen GBP 35M deficit, meaning that substantial cuts across a range of its activities were necessary. The Transport Committee invited LU to give evidence on 5 December 1991, but the session was hampered by a 'lack of information' on the Underground's budget for the FY 1990-91. On 4 December, written evidence re-estimated the gross deficit at GBP 93M, with a net budget shortfall of GBP 52M.

The situation was seen as serious enough to warrant a full report from the Transport Committee. It was found that much of the revenue increases projected were "optimistic guesswork" with actual growth of 0.5 per cent versus four per cent predicted. However, much of the cost increase was regarded as justifiable to comply with the Fennell Report safety recommendations following the Kings Cross Fire. The report recommended the Department of Transport should allow the organisation to borrow forward on 1991/92.

While the organisation's accounts may have taken a nose dive, ticket prices did the opposite. The recession saw journey numbers fall by 11 per cent, which was mitigated by a ticket price increase of 40 per cent. Revenues increased, as they had before 1990, but now they increased due to fare rises, rather than a swell in demand. As the decade progressed, passenger numbers shot up while fares also saw continued increases. Prices rocketed by 60 per cent from 1993-1999, well ahead of

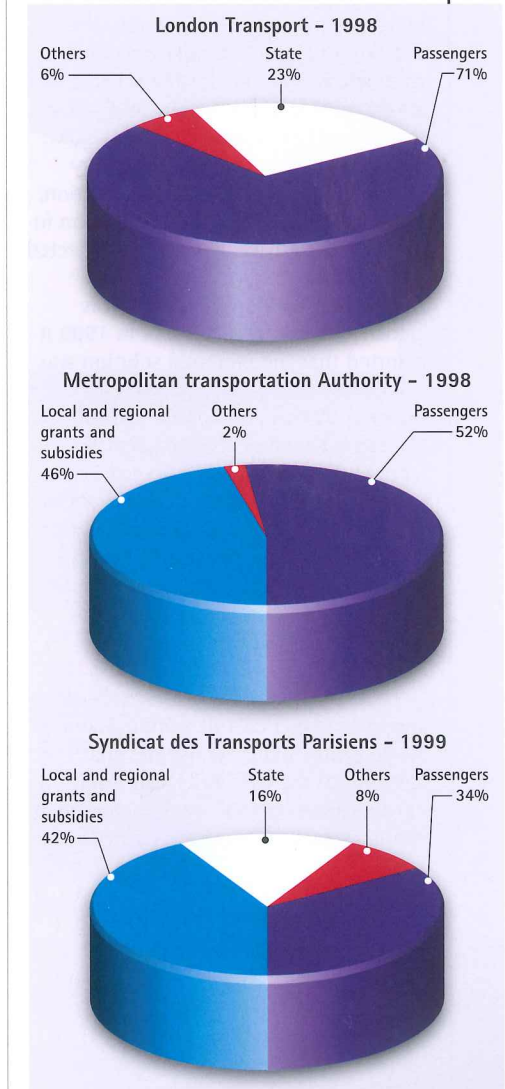
the 19 per cent inflation for the period.

SEEING OUT THE MILLENNIUM

The Jubilee Line Extension (JLE) brings the history of the Underground to the end of the 20th century. This line was heavily influenced by pressure, and the promise of funding, from Canary Wharf developers Olympia & York (O&Y). However, planning and construction was not a smooth process. The private developers went bust, eventually only funding around five per cent (GBP 150M) of the project, and construction of the Millennium line was delivered 20 months late and GBP 1.4bn over budget, coming in November 1999 at a GBP 3.3bn cost. A close thing, as political pressure insisted the line be running in time for the 'Millennium Experience'.

Speaking in 1999, Clifford Mumm of Bechtel, who took over JLE project management in September 1998 was lenient on his predecessor, Hugh Doherty. He pointed out that large scale projects such as the JLE are tackled by

Right: Figure 2, Diagram showing source of funding coverage as a percentage of costs. As the Millennium approached, London Underground leaned heavily on passengers



LU maybe once a lifetime, and that by the time the next one comes along, any lessons of large project delivery will have once again be forgotten. Indeed, many of the 'old hands' credited a lot of the civil engineering quality to Hugh Doherty's management. His was seen as an impossible task to marry the political demands of the client, LU; its paymaster, the government; and the fact that such a demanding project just couldn't be built in the available time and budget.

The '80s boom was critical in the planning of the JLE. O&Y decided to build Canary Wharf if the DLR could be extended to Bank with four-minute train frequencies, and paid GBP 68M to LU for the project. The extension opened six months late, and even three years later trains were infrequent.

In 1988 as the first Canary Wharf piles were being driven, O&Y asked what would be needed for a second rail link. The Waterloo and Greenwich Railway was the result and government approved, but according to Michael Shabas, former transport vice president of O&Y, LT's ambitions to build Crossrail were a sticking point. O&Y went directly to contractors, and bids for the scheme that would route around the city and relieve the Central Line came in at GBP 450M. Allowing a year to get parliamentary powers, and four years for construction, the organisation expected completion in 1993. On LT advice, government rejected the proposal.

The East London Rail Study was launched, external to LT, and in 1989 it reported that the preferred solution was a JLE from Green Park, via Waterloo. However by this point, O&Y struck back. It prepared analysis showing that with modern technology the scheme could be built for GBP 700M with GBP 500M recovered by fares, and a further GBP 400M in road user benefits. It told the government that no private contribution was necessary, and 'joked' that the government owed O&Y money for coming up with the scheme.

O&Y eventually paid GBP 150M, and auctions further east determined some of the route. Shabas concludes that the rejection of the O&Y offer was tragic, but that government now attaches great importance to early private participation.

GENERATION PPP

In 2003 control of the Underground was transferred to the Mayor of London, Livingstone, with the network becoming part of Transport for London (TfL). In April that year, London Underground completed transferring responsibility for care, maintenance of

Further reading

Bownes, D, *Underground: How the Tube shaped London* (2012)
 Brux, S, *London's Jubilee Line Extension*. (1996)
 Gaffney, D, *Funding London Underground: financial myths and economic realities* (2000)
 ICE Transport Board, *World best metro practice - meilleur metro mondiale: papers from a conference at the ICE, London*. (2002)
 London Underground Ltd, *Jubilee Line extension: NATM particular specification*. (1994)
 Mitchell, B, *Jubilee Line extension: concept to completion*. (2003)
 Museum of London Archaeology Service, *Jubilee Line Extension project: archaeological excavations in Westminster*. (1995)
 National Audit Office, *London Underground PPP: were they good deals?* (2004)
 NCE, *Jubilee Line extension: NCE supplements, Feb 1994, Sep 1996 and Oct 1999*. (94-99)
 Parliament: Commons Transport Committee, *2nd report: LU's financial deficit*. (1990)
 Parliament, *London Underground (Victoria) Act 1991*. (1991)
 Powell, K, *The Jubilee Line Extension*. (2000)
 Schabas, M, *Burnt offering: Jubilee Line Extension*. (1994)
 Times, The, *Going ahead on the Victoria line: special report on the ICE*. (1985)

60

The percentage increase in ticket prices between 1993 and 1999, vastly higher than the rate of inflation

assets to the private sector through a PPP, one of the most complex private finance agreements in the public sector. TfL called the move an antidote to decades of underinvestment that resulted in regular asset failures; acceptance of poor performance & management to "perfect the art of apology".

The arrangement was due to run for 30 years. For the first eight years, billions of pounds would be paid to three private sector companies: Tube Lines, Metronet BCV, and Metronet SSL. The investment came with weighty expectations: the restoration and upgrade of the Underground's assets. However, in TfL's report at the end of the first year of the scheme, it pointed out that even with full implementation, the assets would not be restored to a state of good repair until 2025, an "unacceptable eternity".

The infrastructure companies (Infracos) delivered mixed results. In some areas, station and line upgrades were delivered under budget, but in some key areas more serious failings were observed. For example, three years in Tube Lines had failed to raise performance on the Northern 'misery' Line to the standard of the Jubilee and Picadilly lines. In December 2005, London Underground issued Tube Lines with a Corrective Action Notice – a serious measure – for poor performance over a two-year period. The Metronets were significantly behind on station delivery. A significant turnaround was needed. Managing director of London Underground Tim O'Toole said, "The Tube is too important for the PPP to be allowed to fail."

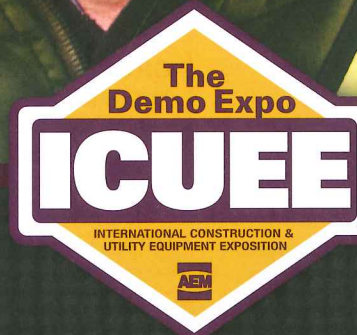
In July 2007 Metronet collapsed. Administrators were called in after the organisation racked up a GBP 2bn overspend. But Metronet could not be allowed to fold; it was vital to the daily operation of the Underground. In May 2008, TfL took control of Metronet to deliver its obligations.

The public was out of pocket as much as GBP 410M and the Auditor General declared the contracts left the government without effective means of protecting the taxpayer. Tube Lines seemed to be able to make ends meet, with some suggesting that its practice of subcontracting all work out, rather than keeping it in the consortium was the reason. However, this was not to last, and following shortfalls, Tube Lines was also brought in house in 2010, ending the PPP era. The Mayor, TfL, and rail unions all hailed a successful move and the potential for future savings. One clear benefit had emerged from the PPP system – the concessions cemented long term maintenance funding for London Underground as never before. With Crossrail, Crossrail 2, and the Tube improvement plans; work seems set to continue at pace



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London Underground 2013- FACING THE FUTURE

The population of London is expected to reach 10 million by 2030, and the future of the Underground is crucial to supporting this growth. **Neil Moss**, principal tunnel engineer, and **Keith Bowers**, profession head for tunnel engineering, both of London Underground, review possible future developments in the near future



LONDON IS experiencing sustained growth. The population is projected to rise from 7.6 million in 2007 to around 10 million by 2030. The number of jobs in the city is projected to rise by approaching 20 per cent in the same period.

To retain its world class status the city will depend heavily on the future maintenance and further development of its infrastructure systems including the transport network of which London Underground (LU, the "Tube") is a key component.



Keith Bowers
Keith is LU's head of profession for tunnel engineering, and is a longstanding member of the *Tunnels* editorial advisory board



Neil Moss
Neil is principle tunnel engineer at LU. His experience on tunnel project stretches back to 1989, most recently based in London

GROWTH IN DEMAND

The London Underground is the busiest it has ever been. In recent years annual passenger journey numbers have risen steadily reaching over 1.2bn in the 2012/2013 year. On a typical week day over 4M individual journeys are made.

On Tuesday 7 August 2012 during the London Olympic Games a record peak of 4.57 million passengers used the Tube. Looking ahead current projections suggest annual journeys will reach 1.5bn by 2020.

The reasons for this growth include both the growth in the city and the steadily improving capacity and reliability of the public transport system. At the same time car ownership in London is in slow but consistent decline.

Underground civil engineering assets have a long life cycle. Significant parts of current network have now been in service for well over a century. Looking forward the challenge is now to enhance the infrastructure so that it can continue to cope with this projected demand generations into the future.

LU'S VISION FOR THE FUTURE

LU's corporate vision is to meet these changing needs by providing "a world-class Tube for a world-class city".

In recent years the company strategy to achieve this has developed to include a formal recognition that the best use of technology is one of the essential elements underlying this. In other words there is recognition that we need to be open to new methods and materials for future work on the system. This is both an opportunity and a challenge for the underground construction community.

Of course the city cannot stop while infrastructure works

go on. In practice the biggest challenge for many major works on the railway is to develop the engineering in such a way that new works do not disrupt day to day passenger services unless absolutely essential.

INFRASTRUCTURE PROGRAMMES

LU has committed to a programme of line and station upgrades. The line upgrades deliver new signalling systems and in many cases also new trains, to increase capacity by pushing more trains through the existing infrastructure.

The recently completed signal upgrades on the Jubilee and Victoria lines have successfully increased capacity. However these alone will not satisfy demand. The Northern line signalling system is being replaced and automatic train control introduced. The sub-surface lines are being upgraded with new trains and new automatic signalling. Once these programmes are delivered by 2018, the upgrades of the remaining deep Tube lines, already in feasibility and development stages, will then commence, delivering a new generation of trains and new signalling with automatic train control.

To support the train capacity improvements there is a parallel programme of station improvements. Major projects are currently underway at Tottenham Court Road, Bond Street and Victoria stations. These all include major tunnelling and civil engineering works. The next tranche of projects has started with the recent award of contracts for the Vauxhall Station upgrade and the Bank Station capacity upgrade. The Bank Station capacity upgrade is a significant project that will construct new southbound running and station tunnels on the Northern Line together with step-free access to the Northern Line and new links between the Northern and Central lines.

LU is already working on plans for the next stations to be upgraded. These include Holborn, Camden Town and Elephant & Castle where feasibility plans are being drawn up. This programme will require significant underground construction

The redevelopment of the Vauxhall, Nine Elms and Battersea areas is being supported by the proposed extension of the Northern line from Kennington to Battersea. This would be the first new extension to the Underground since the extension of the Piccadilly line to Heathrow Terminal 5. The Northern Line Extension scheme consists of twin running tunnels from junctions on the Kennington Loop via a new station box

4.57

The number of passengers in millions that used the Tube during one day of the 2012 London Olympics and set the record

1.5

The number of annual journeys in billions expected to be reached by the end of the decade

"We need to be open to new methods and materials for future work on the system"

at Nine Elms to a new station box at Battersea. Overrun tunnels will be directed towards Clapham Junction.

Although the major projects grab the headlines there is significant investment in day to day maintenance. The Track Partnership, a partnership of London Underground and Balfour Beatty is halfway through a track renewal programme. Traditionally civil engineering maintenance has been carried out at regular predefined intervals. This is being challenged particularly in drainage where a risk-based repair and maintenance regime using hydraulic design rather than replacing like for like is being implemented at the same time as the track renewal.

There is growing support for a plan to extend the Bakerloo further out into South London although no confirmed plan to proceed yet exists. The alignment would require some tunnelling to connect the existing tunnels with one of the suburban rail lines.

Beyond the current plans it is clear that more upgrades will be required to match the rising demand.

TECHNOLOGY

LU has committed to implementing



Building Information Modelling (BIM) level 2 into future projects. BIM has the potential to deliver the following benefits:

- Reduction of whole life cost, risk and carbon;
- Reduction of construction waste and rework;
- Design coordination across multiple disciplines;
- Timely delivery of buildings and infrastructure projects; and
- Increased confidence and efficiency in decisions making.

BIM is not restricted to buildings and structures, currently rolling stock are the most advanced with regard to BIM, as the new stock types have been designed using Level 2 BIM processes and technology. The laser scanning (LiDAR) is being routinely carried out to generate the base 3D models necessary for BIM.

The challenge for the next decade is to harness the advances in information technology to create smart infrastructure thereby reducing costs and more efficiently using the limited manpower available. In other words rather than continuing the current fixed interval manual inspections we should start to implement rail mounted automated laser scanning or digital imaging to support less frequent physical inspections. Although these technologies have been around for a decade or so they are getting more precise and improvement in post-processing is resulting in quicker review cycles. We are routinely scanning escalator shafts when the escalators are removed for maintenance.

These scans are used to build precise models of our structures that are incorporated into the BIM model for the station. These scans are unlikely to be repeated for several decades and therefore provide a valuable record.

Improvements in wireless technology are beginning to impact on monitoring for infrastructure protection. In the last year we have deployed several wireless mesh networks where tiltmeters have been used to monitor deformation of the tunnel lining. We have also developed and deployed Smartplank and Smartstep. The former is a simple wireless device to measure the strain in timber planks

"A range of safety, health and environmental issues were yet to be considered"



Above: Rolling stock advances improve line capacity and passenger experience

and thereby investigate the load development in timber headings. The device can work autonomously or in a mesh with other monitoring devices. The Smartstep is an instrumented escalator step that is interrogated wirelessly at intervals to monitor the impact of construction works on the escalator. The development of both these devices recognises that most of the new infrastructure that we build in the future will be very close to our existing operational infrastructure.

Over the last 20 years we have seen increasing use of mechanised sprayed concrete technology and this has had a positive affect on the health of operatives by reducing the amount of manual handling and working at height. However because we must work around our existing infrastructure there is inevitably hand work, ring building and the installation of heavy beams.

Our challenge must be to develop a better understanding of the composite behaviour of concrete and steel to reduce the member sizes and thereby making best use of our existing skills to avoid hazards to health as well as safety.

Maintaining a team of high quality trained staff is a key element of our strategy. Our current projects rely on SCL to a greater or lesser extent and we have struggled to ensure that there are sufficient trained operatives.

This skill shortage was identified by Crossrail and led to the founding of the Tunnelling and Underground Construction Academy (TUCA) at Ilford.

The pace of technology change is rapid compared with the life cycle of railway assets. Looking back two or three decades tunnelling in London was very different to today. Hand excavation was much more readily accepted. Mechanised tunnelling usually meant an open face shield in good clay. Sprayed concrete was only just arriving in the city 20 years ago. A range of safety, health and environmental issues were yet to be considered.

If we look forward more than a few years it is hard to envisage what specific new technologies may influence the railway. However, it is possible to anticipate some of the issues that will be the likely future challenges.

ENERGY AND SUSTAINABILITY

It seems inevitable that sustainability and energy consumption must become even higher priorities for future engineers. Underground railways are heavy users of electrical energy, which was historically relatively readily available and low cost in London (at least in comparison with some other world cities). In the future, energy cost for operating may well rise and there will be increasing debate over what energy sources are appropriate.

We will also become more conscious of embedded energy in our construction and minimising this may become a more significant driver for our new build works. At present London

tunnel structures tend to be very robust and to feature large quantities of sprayed or cast in-situ concrete primary support that is disregarded in the long term. This means that there is potential to reduce consumption through efficient design with our current materials but also a challenge to designers to realise the benefits without incurring unacceptable risks.

It is also possible that new structural materials may be found to replace some of the current concrete and steel. We already see limited use of some polymers in LU structures. These include fibres for fire protection in concrete and carbon fibre composites for structural repairs. As an industry we need to be open to future use of more sophisticated but structurally efficient composite materials, with cement/polymer composites likely to be amongst the leaders.

CLIMATE

Climate change is now widely accepted as a significant issue affecting future planning.

On the Underground cooling to maintain comfortable conditions is already a significant issue. LU is currently introducing new air-conditioned trains to the "Sub-surface lines." The deep lines in the LU system have smaller tunnels and smaller trains, which present greater technical challenges for heat management. LU has invested in systems including improved tunnel ventilation and ground water cooling systems but at present does not have a complete air conditioning solution suitable for trains that spend most of their time underground. As more people use the system the demand for this is likely to increase.

Another aspect of climate change is the potential for more frequent or more severe extreme weather events. In 2012 Hurricane Sandy had a severe impact on the infrastructure of New York and highlighted the potential vulnerability of underground structures. London has protective measures including the Thames Barrier but even these systems have a finite design life and future provision must be considered.

USER DEMAND

Increasing demand not only means more intensive services during the traditional peak periods but also greater use of the LU system at other times. The peaks have become longer time periods and there are now also peak demand periods at weekends. There is also an appetite for services running later into the night as was piloted during the London Olympics.

A practical consequence of this is that there will inevitably be pressure to minimise the time available to access the underground sections of the railway for routine maintenance at night and other closures of the railway for maintenance purposes. As a result there will be pressure to identify any technologies that reduce the need for man access for routine purposes such as inspection. Perhaps we need to consider more fundamental challenges. For example the possibility of simplifying the assets. The basic elements of the railway date back to the century before last. In the future perhaps it may no longer be appropriate to use a system of steel wheels on steel rails with lineside signalling equipment.

If future designs could reduce the fixed assets to a tunnel containing a low wear guideway with perhaps a simple communications spine all the other complex systems could be within the train. As the train returns to depot every day maintenance of train mounted systems can be much less disruptive than sending personnel into the tunnels.

INDUSTRY CONTRIBUTION

The challenges in efficiently maintaining and developing an old and busy railway network mean that there is always a

need to apply the best available skills and technologies. When the use of the network is intensifying over time it becomes even more important. LU is keen to ensure that these opportunities are not missed.

Historically railways such as LU tended to rely on relatively prescriptive standards to ensure satisfactory performance from works. While beneficial in some respects this approach did not encourage the supply chain to propose better value solutions. More recently the greater use of performance specifications has allowed greater flexibility but there is still scope to improve practice.

In common with other major clients LU has recognised the potential benefits from early contractor engagement while planning works. Recently the company has piloted its own model of pre-tender industry consultation for the proposed Bank Station Capacity Upgrade with positive results.

Outside the world of large scale procurement LU has also provided other tools to aid suppliers in bringing new practice to the railway. Notable amongst these are an on-line approved products system (www.lu-apr.co.uk), which allows third parties to propose new materials and systems for use on the railway. This provides a relatively simple route for suppliers with innovative products to get them tested and, if they are successful, made readily available for future use.

Additionally Transport for London (LU's parent organisation) has established an online "Innovation Portal" (www.tfl.gov.uk/tfl/innovationportal). The portal provides an accessible route that allows anyone to contribute suggestions or highlight new opportunities that might benefit the railway.

Collectively these mechanisms should provide real opportunity for those with good ideas to contribute to improving the transport system in London.

CONCLUSION

Since the start of London's Underground 150 years ago, the system has evolved to satisfy increasing passenger demand. With demand at record levels and still growing the challenge facing LU is keeping the city moving while upgrading and expanding the network.

To meet this challenge and deliver the promised efficiencies and lower operating costs we must investigate new materials and technologies but we must also make more efficient use of current design technology. This will free up further capital to extend and improve the network in future

editor@tunnelsonline.info

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FOREVER YOUNG

At WTC 2013 in Geneva, the British Tunnelling Society put forward a proposal to work towards the creation of a young members group for the International Tunnelling Association. For those who aren't aware of what such a group could get up to, *Tunnels* gives this brief look at some BTSYM activities

The BTSYM Chairs

Petr Salak 2013 – present
Tom Kavanagh 2012 – 2013
Anita Wu 2010 – 2011
Kate Cooksey 2008 – 2010

Call for ITAYM

At WTC 2013 in Geneva, BTSYM chair Petr Salak (Dr. Sauer & Partners) and BTS chair Damian McGirr (Donaldson Associates) issued a call for an ITA Young Members group based on the model of the BTSYM. The creation of the Young Members Group would be, the lobbyists hope, followed by the creation of the full ITAYM group. Such an entity would aim to help the ITA look after the new generation of tunnelling professionals, and could be an essential arm in carrying out the aims and ideals of the ITA.

Salak explains, "The continued success of the BTSYM has led us to make this proposal, which we hope to see realised at WTC 2014. If our initiative will motivate other countries to establish their own Young Members Groups it will be great achievement and right move for our industry."

Following discussions, the new ITA president, Soren Degn Eskesen called on member nations to form their own young member groups, or if they already existed, to make them known to the ITA. Interest has been shown, and work towards creating young member societies is underway in: USA, Canada, Denmark, Austria, Hungary, the Czech Republic, Greece and Italy. Norway established such a body in 2009 and Australia prior to WTC 2013.

IT'S A hot July day in London as the latest email has dropped into the *Tunnels* inboxes. The British Tunnelling Society Young Members (BTSYM) have organised its latest site visit. No sooner has *Tunnels* seen the invitation, than a follow-up note reveals all the places have been filled.

The popularity of the group that turns five this year has gone from strength to strength. Founded by Kate Cooksey in 2008, its regular news mailers reach 200 people, having so far offered more than 20 talks, 15 site visits and 10 school visits. In 2013 more than 40 active members are working to achieve goals of the BTSYM.

For the aim has not just been to benefit existing young tunnellers, with workshops and the like, but also to draw university, and even schoolchildren towards the industry.

Perhaps the greatest achievement in this regard came late last year, when a conference organised by the group was so over-subscribed, even the overflow rooms were heaving. The given purpose of the conference was to educate young tunnel engineers, and to expose university students to the profession.

This year the BTSYM came up with the idea of workshops. Each workshop would aim to inspire the next generation with case studies and hopefully act as a knowledge transfer tool. Some workshops will include a debate to encourage participation, and to ensure a good understanding of the topic. These workshops will encourage experienced tunnelling professionals to interact with young members.

Another new project is the teaching pack. A suite of five tunnel-themed lessons is being developed for 11 to 14 year olds. Each pack will contain a presentation, requiring no previous knowledge on the part of the teacher; detailed lesson plans and teacher notes; activity sheets and learning material and student worksheets to record the outcome. Lesson plans cover designing a tunnel, through geology and excavation with some practical application.

With new moves to expand into the international field, the movement towards young member societies and groups looks set to continue to gain popularity and increase its usefulness to the industry

btsym.committee@gmail.com
www.britishtunnelling-ym.org.uk

BTSYM aims and aspirations

The group is open to any tunnel professionals or students under the age of 33. They list seven aims of their organisation:

- To further their own tunnelling knowledge
- To raise the profile of the tunnelling industry
- To promote tunnelling as a career
- To help improve training of young professionals by conducting talks, workshops, site visits
- To help improve academic programs
- To endorse networking of young engineers and students within the tunnelling industry
- To organise tunnelling conferences for young members

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TEC is involved in challenging international projects such as Busan Geoje Fixed Link in South Korea (recently opened to traffic), the Coatzacoalcos tunnel in Mexico. The 19 km long FehmernBelt Fixed Link between Denmark and Germany and the 30 km long Hong Kong Zhuhai Macao Fixed Link in China.

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LEAVING A LEGACY

April saw the first breakthrough on the two drives for Brisbane's Legacy tunnel, a new western city motorway link for its Transapex network. **Adrian Greeman** visited the project

Adrian Greeman
Is a technical journalist and a long-standing regular contributor to *Tunnels*



TBMS WERE the obvious choice for the twin drives of the 4.6km-long Legacy tunnel in the Queensland capital of Brisbane. Not only are hard rock machines well suited to the sound igneous rock underneath the houses of the well-off western suburbs, but also because there were machines available in the city.

"We are using the Herrenknecht machines which drove the tunnels underneath the river for the Clem 7 link," says Matteo Ortu, tunnelling construction manager for the three-company Transcity construction group that began work on the AUD 1.5bn (USD 1.44bn) project in 2010.

"They have been recently reconditioned by Herrenknecht."

The manufacturer has an Australian depot near Brisbane Port where the work was being done.

MAKE DO AND MEND

Acquiring and using the machines makes obvious sense in that the geology is similar, though not identical to the first tunnel. The TBMs also happen to be the right size and capacity. Like the Clem 7, which opened in 2009, the Legacy tunnel will be a twin, two-lane motorway, running beneath and into the central part of the city, which has been growing more and more congested.

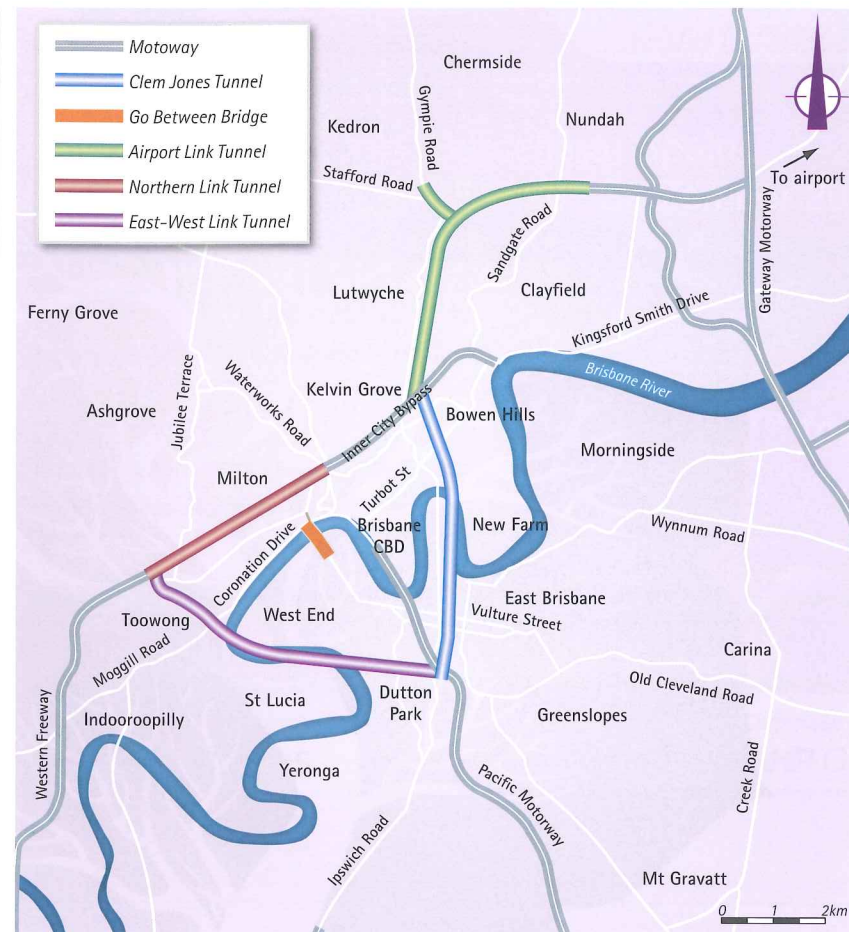
The first, Clem 7, tunnel runs from the southern suburbs underneath the Brisbane river, and the new tunnel will bring in traffic from the west. It is part of a roughly triangular 'ring' of underground links for the city which sits on the Brisbane river estuary some 20km from the Pacific coast. One of the fastest growing in Australia, it has been becoming increasingly congested.

The Transapex project, as it is called, has so far seen the building of the Clem 7 and the Y-shaped Airport Link into the northern suburbs and as the name suggests to the airport near the coast. Legacy will serve the western and inland side of the city, relieving traffic loads coming in from the Western Freeway, which currently passes through the university area and a well-off western residential sector. It will carry flows underground to link with the important Inner City Bypass. A fourth tunnel is planned that will complete the triangle in the south (see box, page 49).

FUNDING

The new tunnel is being funded somewhat differently to the first two tunnels, which have seen major financial difficulties since they began. Both these were full private public partnership schemes with long period toll concessions that have been undermined by the onset of the world credit crisis and lower toll revenues than expected.

For the Legacy tunnel, formerly known as the Northern Link, the Brisbane City Council has let the project on, essentially, a design and construct basis to Spanish tunnel and civil infrastructure company Acciona. The company takes the lead in a joint venture with Italian tunnel construction specialist Ghella and Brisbane-based BMD Constructions. A 10-year concession, for maintenance only, is part of the contract paid on an availability basis, but tolls will be collected and disbursed directly by the client, using a separate operating company.



Above: Figure 1, Brisbane's Transapex project spans the centre of the city

Opposite, top: Figure 2, The Legacy Way tunnel and sites

Opposite, bottom: One of the two Herrenknecht TBMs used on the tunnel

"It has a fairly high quartz content, which makes it quite abrasive"

Design work for the tunnel has been subcontracted to a 'design alliance' of US consultant URS, GHD and Cardno.

For construction the western end of the project, rather than the busier inner city end, sees most of the action. A major operations site here houses all backup and stores for the project and the starter pits and portals for the TBMs. Work started here in April 2011.

The first job ironically for the TBM drives was some drill and blast. This firstly formed the initial starter pit into the rising ground on the tunnel alignment, along with a secant piled wall to hold back weathered ground at the back. But, but importantly drill and blast was used to create a 560m-long tunnel from the excavation area to a spoil disposal site in the Mount Coot-tha hills just under 1km away. Fortunately a still working quarry for high grade rock is located there with deep and now vacant areas big enough for the large quantity of spoil from the two drives, around 1Mm³ altogether. The quarry, conveniently, is owned by the city council.

TREADING CAREFULLY

"The plan was always to use a conveyor system for the spoil," says Ortu. This would save some 96,000 truck movements during the project he says, reducing noise and road traffic, an important consideration even at the western end of the project.



The site is situated in a district of pleasant tree-lined avenues and housing, many of the buildings original 'Queenslander' style houses dating back a century or so, and in some cases heritage listed. Minimising disruption has been critical.

But the overland conveyor mooted at the beginning would have extended more than twice the length without a short tunnel from the site. Now by passing through a 20m² cross-section bore, the spoil disposal needs just 870m of conveyor running 15m to 35m deep. The tunnel also contains the spoil underground reducing dust impact.

It ends at a 180-degree distributor conveyor in the quarry. The tunnel took four months to excavate, using an Atlas Copco drill rig.

Noise and disruption is further reduced at the site by enclosing the working areas of the portal and immediate tunnel servicing within a soundproof building. "It is straightforward enough," says Ortu, "just a steel frame with acoustic panelling."

Behind the portal building are site offices, and backup supply facilities including tanks, pipelines and mixing points for grout to the machines, water and water treatment plant and ventilation. "We also have an onsite paramedic facility," says Ortu, "and our own workshop and spare parts store, with a relatively large stock so that we can be fairly independent."

The TBMs, christened Joyce and Annabel began their drives from the 10m-deep, covered starter pit at the end of the site.

28

Tonnes in the thousands is the spoil system's capacity per hour

560

Metres of tunnel connected the excavation to the spoils disposal site

They are Herrenknecht double-shield machines refurbished and modified.

"They now have a shorter backup train than before with a segment unloading facility and erector, and a conveyor spoil system," says Ortu.

Each makes a 4.3km-long section with the remaining 300m of tunnel in cut and cover works at either end.

The Italian company has its own methodology for drives says Ortu, which focuses the logistics of the TBM process very strongly around segment erection only with the other activities of the tunnelling kept very much as follow up in the tunnel behind. "We have studies that carefully to optimise the sequences and increase efficiency," he says.

Conveyors are supplied by Herrenknecht subsidiary H+R and run down each of the bores and then connect into one conveyor within the start area. From here they continue outside and into the tunnel to the quarry. Capacity of the spoil system is some 2,800t/hour.

The machines themselves have rock cutter heads, with grippers at the side and jacks at the rear. "We use 19in cutter discs," says Ortu.

For most of the drive these are used to get through Bunga Phyllite, which he describes as an intermediate grade metamorphic rock, with high foliation.

"It has a fairly high quartz content which makes it quite abrasive," he says and wear on the cutters is substantial, with an average of five to seven needing to be changed daily. "There is a four



hour maintenance break each day when we do that.”

Unfortunately the mineral content of the rock makes it mostly unsuitable for concrete he says. “It also produces quite a high proportion of fines rather than a sharply delineated chip structure.”

The spoil is useful for road base in the tunnels and site use.

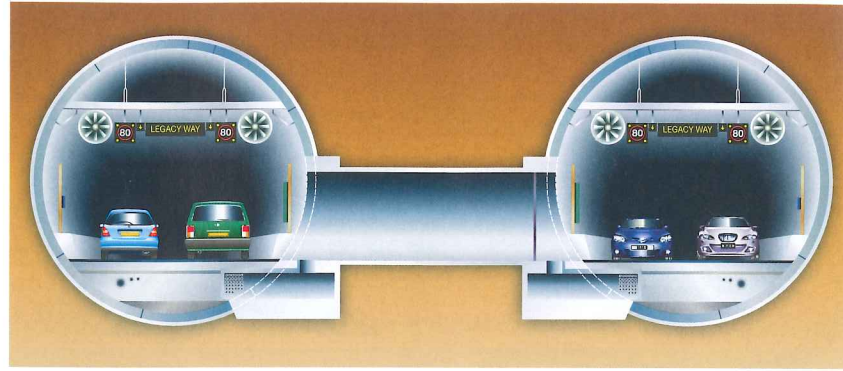
For the launch of the machines an interesting reaction system was used tied into the rock rather than a traditional reaction frame. The and artificial segment rings but pushed off from partial rings formed from just invert segments in the base of the launch cradle just outside the portal.

Once fully in the ground the machine formed its first full segment ring against a special steel reaction ring attached to the portal block with ground anchors through the secant pile wall. The steel ring provided reaction for the first few rings then until the machine was sufficiently far into the ground for the tunnel to provide its own reaction.

The tunnel lining is a universal ring says Ortu. “The ring has eight segments 350mm thick and 2m-long plus a half size key.” A possible 17 positions are usable for the ring orientation to form curves and adjust the direction if necessary. A standard VMT laser and target guidance system gives information for that.

“Segments are designed for minimum ring build time,” he says. “They are all of parallelogram or trapezoidal shape.”

An additional precast invert unit goes in afterwards to form a flat floor to the tunnel during construction. This is important for the delivery vehicles, which are the rubber tyred units increasingly favoured as a means of avoided rail installation in tunnel construction. In this case the units are specially made by French firm Techni-Métal Systemes which was acquired by Herrenknecht in January this year. Rival manufacturer



Above: Figure 3, Twin tunnels will accommodate two-lane traffic

Below, left: April of this year saw the first breakthrough on the project

Below, right: A section of excavated tunnel

Metalliance has supplied the man riders, however, which carry the crews to the machine each shift.

The segments themselves are made at a precast works ‘down the highway’ using CBE forms and carousel. “The reinforcement is a steel fibre supplied by Maccaferri,” says Ortu.

A relatively small holding area is used to store the rings at the back end of the acoustic shed from where they are lifted into the starter pit below with two portal cranes, a 60t unit and a larger 260t unit. The two cranes had been used for the TBM assembly initially and the larger unit was required mainly for the head shield.

That operation took 80 days for the first machine and 73 for the second says Ortu, “which we did ourselves though with technical input from Herrenknecht.”

Now the cranes lift the segments down in groups of three onto the delivery vehicle which rakes them to the back of the machine where a fast unloader unit moves them forwards to the segment erector at the machine.

The segments are flat faced within the ring but have a grooved connection in the centre of the longitudinal joint. Two plastic cylindrical rods are pre-fitted within the grooves, one each side of the segment to provide shear connection strength.

The rings are then linked ring to ring with a specially shaped connection rod from Fip in Italy, explains Ortu. The dowel slot into holes in facing joint of the segment and remain protruding until the next segment is slid over.

“This system of dowels and jointing rods allows us a very quick erection time for the rings,” says Ortu, “and has helped achieve good accuracy on the ring fits with minimal ovalisation.” A possible problem with the fast double erection sequence of a telescopic machine is ‘stepping’ between rings or lips where one segment is not precisely seated against the next. Ortu says this has been kept to a minimum.

Once erected the rings are grouted in a two-stage process. First is grouting from tailshield, for the bottom 120 degrees



Fitting the pieces

Brisbane has been one of the fastest growing cities in Australia, in one of the fastest growing regions namely southeast Queensland. Population growth has slowed somewhat but is still expanding with a high influx of new residents both from other parts of Australia and immigration from abroad, drawn by job opportunities in the minerals sector the warm climate and pleasant beach and surfing coastal areas like the nearby Gold Coast and Sunshine Coast.

The city is car orientated but became more and more congested in the 1980s and 1990s. The Gateway bridge 8km downstream across the river estuary relieved the city of through traffic from New South Wales to the north and was recently doubled in size, with corresponding upgrades in its motorway links. Within the city the Transapex project conceived in 2004, is a five stage project to provide mainly tunnelled motorway routes through from the city suburbs and to bypass the central business district.

First part was a north-south connection across the river from the south, a nearly AUD 4bn project completed in 2010 as a public private partnership. At the north end it connects via interchanges and ramps with the inner city bypass and the Airport Link (see *Tunnels International*, May, p.21), originally conceived as an extension to the Clem 7 but in fact a major project itself.

A smaller tunnel across the river was also planned, though it has been replaced by a bridge, the now completed Go Between bridge.

The AUD 1.8bn (USD 1.66bn) western motorway link, is the section currently under construction. It has been renamed the Legacy Way in honour of a military cemetery and park which lies at its outer end.

A final component linking the outer end of the Legacy tunnel southwards to the existing Pacific Highway that runs through the central city from the south is planned.

of the ring, to avoid grout moving too far forwards to the machine head.

“Rather than pea gravel, a fast grout is used mixed from cement and PFA with various accelerators and retarders” he says. These include sodium silicate and other additives, supplied by Mapei.

As the machine moves forwards there is further grouting done through the segments from pumps on the back of the TBM train. “We did some full scale trials on the grouting to ensure that the voids were being filled but we were not grouting up the machine head,” he says.

Grout is supplied to the machines through a pipeline system from the backup yard above, rather than using delivery in tanks on the tunnel vehicles.

It comes as two components mixed at the end and further retarder in the mix ensures that the lines do not get clogged while they are waiting for the pumping sequences.

The system set up, both in the machine itself and the logistic supply, has allowed good progress, says Ortu, with the second of the machines achieving some excellent drive rates on its 4,260m bore.

Completed in April this saw an average of 30m a day achieved but at one point a maximum 49.7m in one day. According to Transcity project director Fernando Fajardo a “maximum of 248.82m was achieved in one week and a 30 day maximum of 787.78m.”

The first of the two machines will not make quite the same progress because it has had to stop along the way to allow for the construction of three cross passages between the two bores, which are about 10m apart. These are not the final cross passages, but rather an initial set required for construction safety purposes.

“For the final tunnel there are cross passages every 120m,” says Ortu. Most of these are for tunnel safety and evacuation purposes. Each is 4m wide and 3.5m high and will be fitted with safety doors allowing tunnel users to escape to the opposite bore in the event of accidents and in particular a

potentially deadly tunnel fire.

Additional tunnels are needed however bringing the total of the connections to 35. The remaining tunnels in between the escape tunnels are primarily for substations, and in one case for hydraulic sump purposes at a low point in the tunnel alignment.

All the cross passages are being excavated primarily with hydraulic rock hammers, and possibly some controlled drill and blast, says Ortu. For safety purposes, remote-operated Brokk excavator units are being used for the work, a Brokk 400 and a Brokk 800.

“The advantage of using Brokks is their capacity to operate in confined spaces, while still achieving the same performance as larger excavators, and their remote control safety features,” says Ortu.

The smaller unit will use a half tonne hammer and the larger a 1.2t variable frequency hydraulic rock breaker, he says.

With the excavations complete there is extensive fitting out to be done for the tunnels. A key feature of this is installation of a smoke deck within the tunnel allowing for a highly controllable venting system for fumes and smoke in the event of fire. Vent flaps will be able to operate every 60m to isolate areas of fire and exhaust hot gases and smoke.

The TBMs meanwhile have to be disassembled. This will take place underground in the last short 100m section of the tunnel alignment, which has been built in a cut and cover at the western end of the project, an area called Kelvin Grove where the new road will connect into the city bypass. Keeping the excavation top down has helped with the complex traffic management required for the works at either end, to keep existing ‘flows’ of traffic moving, at least as well as they have in the past.

“The reception chambers have been built by a top down method with secant pile walls,” says Ortu. They form part of the tunnel and are already roofed so that machines cannot be dismantled with standard cranes.

“We are using a system of strand jacks to lift the various components of the machines,” he explains.

After that there remains M & E for the tunnels, lighting, monitoring video and fire detectors, variable message signs and lane control signalling and the automated tolling gantries. Like all tunnels in Australia these have to allow interchangeable tolling with other parts of the country.

The tunnel is due to open next year and looks well set to do so at present

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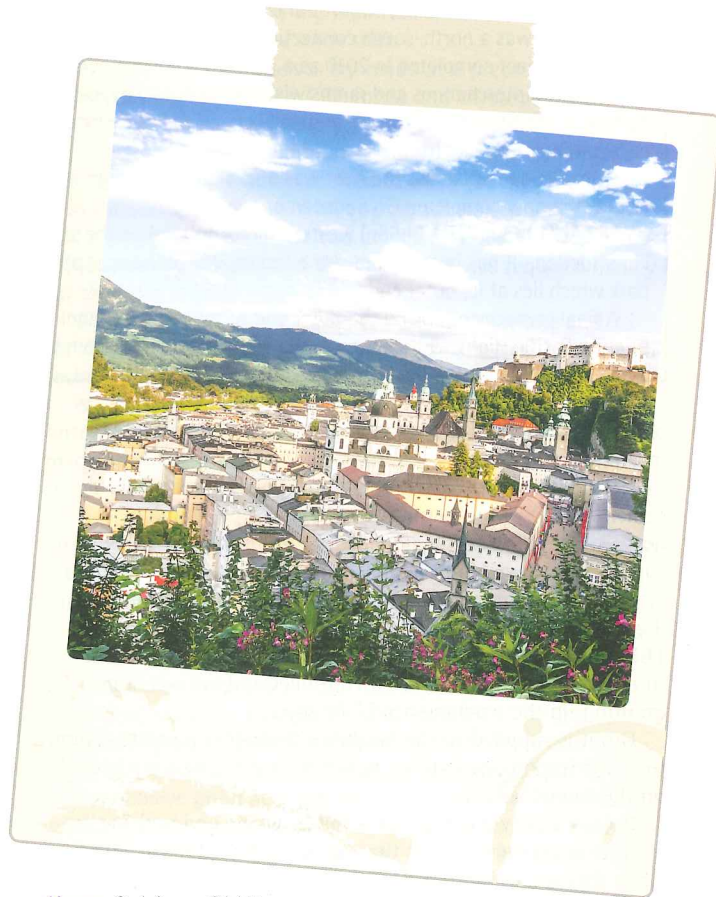


AUSTRIA IN AUTUMN

The 62nd Geomechanics Colloquy
10-11 October
Salzburg, Austria
Salzburg Congress
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www.oegg.at

Birthplace of Mozart and brimming with breweries, the OeGG's Geomechanics Colloquy in Salzburg next month will bring together the country's underground experts and visiting international guests

THE AUSTRIAN Society for Geomechanics (OeGG) is holding its 62nd Geomechanics Colloquy in Salzburg, 10-11 October. Session topics cover four areas: power water conduits, special measures in soft ground, international large projects and challenging shafts. The colloquy will begin with workshops on 9 October looking into the characterisation of fault zones and failure prediction in geotechnics, and there is a field trip on the following Saturday. Sessions will be accompanied by a technical exhibition. The conference languages will be German and English



Above, Salzburg Old Town showing churches

Getting there

Salzburg's W.A. Mozart Airport is 4km from the city centre and a taxi or public bus ride is roughly 15 minutes.

Due to the short distance between Munich and Salzburg, Munich's Franz Josef Strauss Airport is another option for travellers. Rail connections from Munich Airport via Munich East Train Station take passengers to Salzburg in just 2.5 hours. Railway timetables can be accessed directly at www.bahn.at or www.bahn.de. The 180km stretch of highway between Munich and Salzburg on Highway A8 is covered in one hour and 45 minutes by car. A highway sticker is required from the Austrian border at Walsertal. Stickers can be purchased at the border.

Field Trip

The field trip to the S10 Mühlviertler Highway will take participants to the Tunnel Götschka in the morning and Tunnel Neumarkt in the afternoon.

Currently under construction, Tunnel Götschka is expected to open to traffic in 2015. The 4.4km-long twin tunnels are being excavated from both portals located in the southern offset of so-called Bohemian Granite with 17 cross passages. With an inclination of 3.6 per cent, the northbound tunnel (to Prague) will be equipped with three lanes, while the southbound tunnel (to Linz) will have just two lanes. The southbound tunnel is expecting a breakthrough in October, and the northbound to follow in two months.

The existing single tube Tunnel Neumarkt will be extended and a second tube will be added. The existing southbound tunnel will be extended 80m to the south and 525m to the north by cut and cover method. The final total length will be 1,970m.

Salzburg

There is a number of tourist attractions right on the doorstep of Salzburg Congress, not to mention in the city as a whole.

It's the birthplace of Mozart and a UNESCO World Heritage Site since 1997. Be sure to enjoy the city's picturesque alleys, the famous Getreidegasse and many museums and landmarks.

Salzburg calls itself 'Austria's secret beer metropolis' with a 500-year history of brewing and multiple breweries and brew pubs to visits. Prost.

Schedule

Date	Programme
Wednesday, 9 October 2013	Workshop "Characterization of fault zones" Workshop "Failure prediction in geotechnics"
Thursday, 10 October 2013	8:30 Welcome by W. Schubert, president of the Austrian Society for Geomechanics 8:45 Power water conduits 10:15 Coffee break 12:15 Lunch break 13:45 Leopold-Müller Award 14:15 Special measures in soft ground 15:45 Coffee break 19:00 Congress dinner at Stieglkeller 20:00 Chamber concert in the Grosse Aula at the University of Salzburg
Friday, 11 October 2013	9:00 International large projects 10:30 Coffee break 12:00 Lunch break 13:30 Challenge shaft 16:30 Closing words by W. Schubert
Saturday, 12 October 2013	Excursion to the S10 Mühlviertler Highway

Who's on show

Company	Location	Company	Location
3GSM GmbH	1st floor, booth 06	ITA Croatia	1st floor, booth 14
AGRU Kunststofftechnik GmbH	1st floor, booth 24	KOPA Korschinek & Partner Vermessung ZT-GmbH	Ground floor, booth E8
Atlas Copco GmbH	1st floor, booth 35	KrampeHarex FIBRIN GmbH	1st floor, booth 19
Austin Powder GmbH	2nd floor, booth PS1	MACCAFERRI Deutschland GmbH	Ground floor, booth E1
BASF Performance Products GmbH	1st floor, booth 01	MAPEI GesmbH	1st floor, booth 18
Desoi GmbH	1st floor, booth 30	MAXAM Österreich GmbH	1st floor, booth 03
DIBIT Messtechnik GmbH	1st floor, booth 13	MC Bauchemie Müller GmbH	1st floor, booth 14
DMT-Deutsch Montan Technologie GmbH & Co. KG	1st floor, booth 05	Minova MAI GmbH	1st floor, booth 10, 11
Durstmüller GmbH	1st floor, booth 08	Mooser Schwingungstechnik GmbH	1st floor, booth 40
Dywidag-Systems International GmbH	1st floor, booth 09a	ÖSTU-STETTIN Hoch- und Tiefbau GmbH	1st floor, booth 02
Erkat Spezialmaschinen und Service GmbH	1st floor, booth 37	Pöyry Infra GmbH	1st floor, booth 07
Ernst & Sohn Verlag für Arch. und tech. Wiss. GmbH & Co. KG	1st floor, booth 36	Rockmore International GmbH	1st floor, booth 16
Fugro Austria GmbH	1st floor, booth 27	Rowa Tunnelling Logistics AG	1st floor, booth 15
Geoconsult ZT GmbH	Ground floor, booth E13	S & B Industrial Minerals GmbH, BU IBECO Bentonite	1st floor, booth 34
Geodata ZT GmbH	1st floor, booth 09b	SANDVIK Construction	2nd floor, booth PS1
germanBelt Systems GmbH & Co. KG	1st floor, booth 25	SIKA Österreich GmbH	1st floor, booth 12
Ha-Be Betonchemie GmbH & Co. KG, BK Giullini	1st floor, booth 20, 21	TPH Bausysteme GmbH	1st floor, booth 28a
Handelsvertretung Stefan Heibel	1st floor, booth 29	Universitätsinstitute Österreichs	2nd floor, booth PS4
Herrenknecht AG	1st floor, booth 31	VÖBU Vereinigung Österr. Bohr- und Spezialtiefbauuntern.	1st floor, booth 39
iC Consulente Ziviltchniker GmbH	1st floor, booth 17	VSV Engineering GmbH	2nd floor, booth PS1
IGT Ziviltchniker GmbH	1st floor, booth 04	Wacker Chemie AG	1st floor, booth 28
ILF Beratende Ingenieure ZT GesmbH	1st floor, booth 22	WEBAC-Chemie GmbH	1st floor, booth 33

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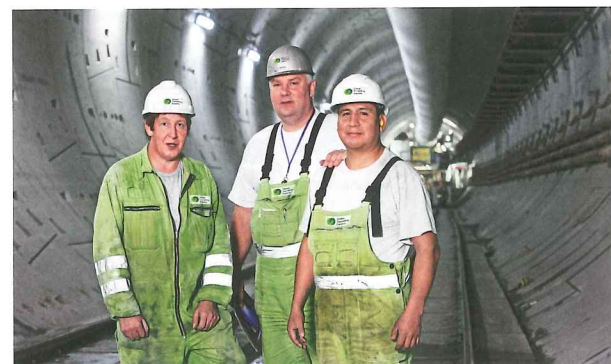
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Barcelona, Spain
The Symposium, celebrating its 40th year, is focused towards knowledge transfer on aerodynamics, ventilation and fire in tunnels.
www.bhrconferences.com

Bauma Africa
18-21 September 2013
Johannesburg, Africa
The massive construction show holds its first event in the African continent, focusing on all sectors and facets of the construction industry.
www.bauma-africa.com

SITCE 2013
7-10 October 2013
Singapore
The inaugural SITCE is a platform for urban land transport professionals worldwide to meet and discuss ways to shift the transport focus to people. The biennial SITCE is one of the first initiatives by the UITP Centre for Transport Excellence for the Asia-Pacific region.
www.sitce.org

62nd Geomechanics Colloquy
9-11 October 2013
Salzburg, Austria
The annual Colloquium of the OeGG. This year's topics include: power water conduits, special measures in soft ground, and international large projects.
www.oegg.at

ExpoTunnel
17-19 October 2013
Bologna, Italy
The newly-established exhibition will also host the Italian Tunnelling Society congress entitled "Tunnelling and Underground Space for European Development."
www.expotunnel.it

Southern Railway Link Conference Koralm and Semmering tunnels
21 November 2013
Leoben, Austria
The Southern Railway SESSION is a

forum to present experiences and discuss case studies to the above tunnels major projects and other projects along the Southern Railway.
www.suedbahntagung.at/index.php

Stuva Conference
27-29 November 2013
Stuttgart, Germany
The bi-annual confereency of the Stuva organisation heads to Stuttgart.
www.stuva.de/en

2014

CONEXPO
4-8 March 2014
Las Vegas, USA
Held every three years, the exposition showcases the latest construction equipment, products, services and technologies. The show will be held at the Las Vegas convention centre.
www.conexpoconagg.com

Eurasia Rail
6-8 March 2014
Istanbul, Turkey
The 4th International Rolling Stock, Infrastructure and Logistics Expo features a tunnel construction section. By 2023, Turkey's Ministry of Transport is planning to build more than 11,00 km of rail track. International pavilions are on show from Poland, France, Germany, Russian Federation, Czech Republic, the United Kingdom and Republic of China.
www.eurasiarail.eu

ISTSS
12-14 March 2014
Marseille, France
The 6th International Symposium on Tunnel Safety and Security will discuss current practice and emerging trends and research in the field of tunnel safety and security.
www.istss.se

Samoter
8-11 May 2014
Verona, Italy
This trade show dedicated to earth moving, site and construction machinery is held every three years. In 2011, the exhibition attracted 98,000 visitors and more than 900 exhibitors (of which almost 30 per cent were international).
www.samoter.it

World Tunnel Congress
9-15 May 2014
Iguassu Falls, Brazil
Organized by the Brazilian Tunnelling Committee (CBT) of the ABMS (Brazilian Association of Soil Mechanics and Geotechnical Engineering) and ITA, the congress will be paired with the 40th ITA-AITES General Assembly. Focusing on "Tunnels for Better Living", WTC 2014 will discuss and illustrate the importance of tunnels, especially in big cities. The congress will include a sold out technical exhibit. Online registration is expected to open this month.
www.wtc2014.com.br

North American Tunneling Conference
22-25 June 2014
Los Angeles, California
The Underground Construction Association's (UCA) biennial tunnelling conferece. UCA is a division of SME
www.smenet.org

British Tunnelling Society

The BTS has a membership of almost 700 individual and 60 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Events are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month.

Thames Tideway Tunnels
19 September 2013
After more than two years of public consultation on Thames Water's proposals, the development consent application was submitted to the Planning Inspectorate on 28 February. The presentation will include background on the sewage problems and the proposed solution; an update on the project development and design for tender; progress on the development consent application; an outline of the technical challenges faced; the proposed delivery route for the construction; and the latest situation on procurement.

London Underground turns 150
23 October 2013
A special presentation in honour of the 150th anniversary of LU operations.

National grid cable tunnels
21 November 2013
A report on the project, which comprises 33km of 3m and 4m diameter tunnels across London. John Trounson, National Grid Stephen Meadowcroft, Costain.

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Subscription prices for 12 (24) months:
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 Rest of the world \$316 (\$553).
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 Stephens & George Print Group, Merthyr Tydfil.

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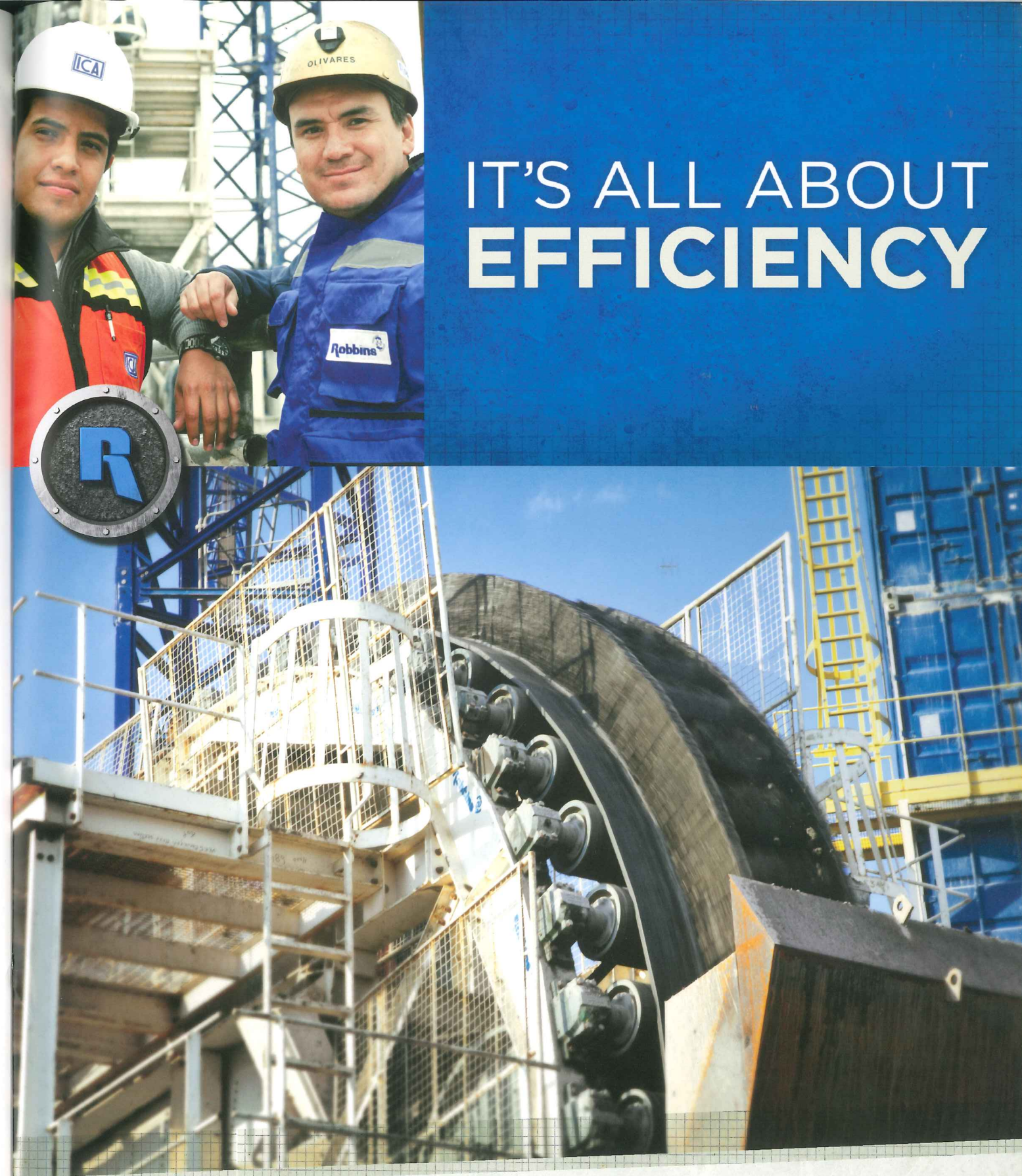
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Tunnels & Tunnelling International ISSN 1369-3999 is published monthly by Global Trade Media, John Carpenter House, John Carpenter Street, London EC4Y 0AN, UK. The 2012 US annual subscription price is \$ 226 Airfreight and mailing in the USA by agent named Air Business, C/O WorldNet Shipping Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, New York NY 11434 USA. Periodicals postage pending at Jamaica NY 11431.

US Postmaster: Send address changes to *Tunnels & Tunnelling International* C/O Air Business, C/O WorldNet Shipping Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, New York NY 11434 USA.

Subscription records are maintained at Global Trade Media, John Carpenter House, John Carpenter Street, London EC4Y 0AN, UK. Air Business Ltd is acting as our mailing agent.

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