Issue No 4 | November 2020

A&NZ JOURNAL

New Zealand Tunnelling Society

Journal of the Australian & New Zealand Tunnelling Societies

Australian Tunnelling Society

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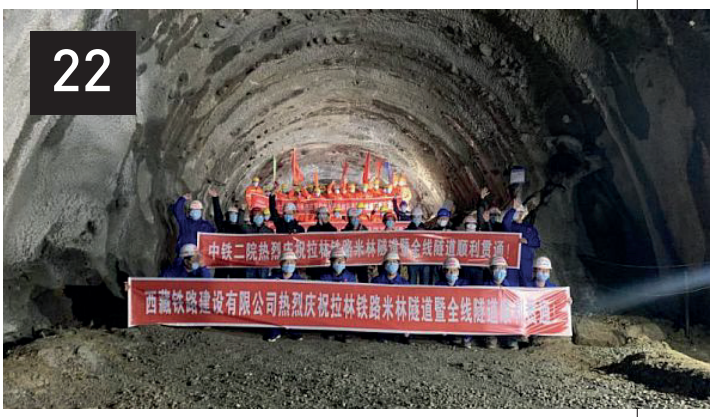

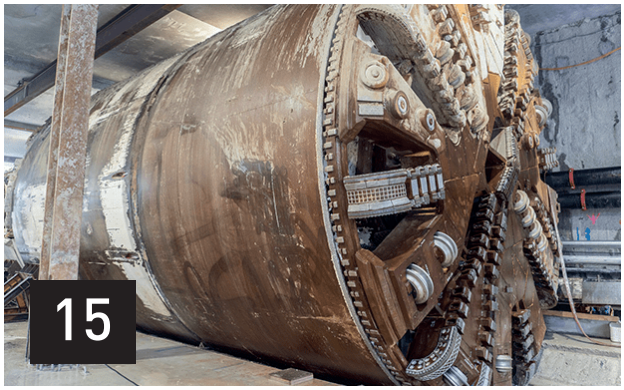

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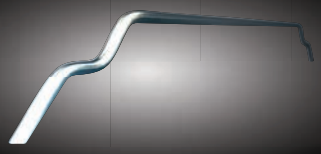

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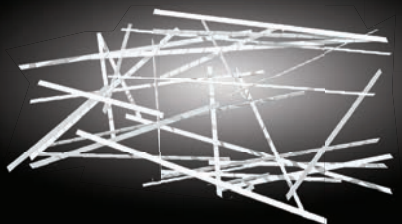

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Cover photo:
Sharon Hosseni, CRRDA's Area Engineer for the Roma St station site – photo curtesy of CrossRiver Rail

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President's foreword

Dear fellow ATS members, I hope that you are remaining safe and healthy through these difficult times. Generally, it seems that the Australian tunnelling industry is doing well, and tunnelling projects seem to benefit from the infrastructure stimulus that our governments have introduced. In fact I saw recently that the general concept of infrastructure projects was graphically represented as a TBM in a recent publication.

Nevertheless, it is clear that some members may be experiencing hardship in these times and we have instituted a process where hardship cases can be considered. If you would like to discuss how we can assist you, please contact Narelle via email societies@engineersaustralia.org.au. We value our members and would rather that they stayed on in the difficult times.

ATS has adapted to the new way of working and meeting socially and we have had a number of very successful online presentations, with attendances of more than 400 people each time. We are experimenting and expanding this program and it would seem that online gatherings will become routine.

Unfortunately it has been necessary to postpone the Melbourne 2020 ATS conference until the 10th - 13th May 2021 at the Melbourne Convention & Exhibition Centre.

In other initiatives, we are publishing our Design Guide, written by a very enthusiastic team of Young Members. Please go to the website members area to download this. We are also working to improve our services to our sponsors and members. As part of this we are seeking your feedback through a survey of members. The survey will be as concise as possible but we would appreciate your timely feedback so the committee can drive the issues that matter to members. The survey should hit your Inbox in the next couple of months. We are also looking to improve our relations with some of the international associations that we are close to and hope to have in place some key reciprocal agreements soon.

Our thoughts and good wishes are with you and your families as we all navigate through an extraordinary period in our lives. Take care, stay safe and if the ATS can be of assistance please don't hesitate to contact us.

Harry Asche,
President
Australasian Tunnelling Society

EDITOR'S NOTE

In the last journal we had details about how the tunnelling and underground mining industry had been affected by drought and bushfire, this journal focusses on how we have dealt with Covid-19.

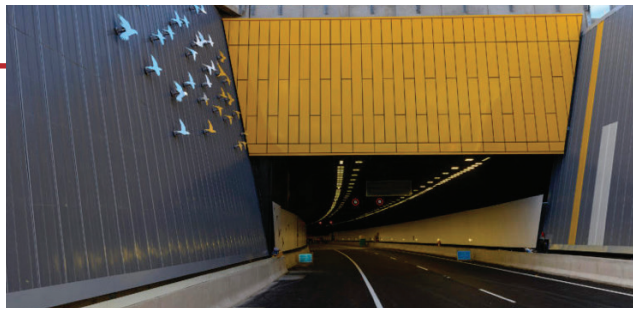
Whilst the industry has been fortunate in general there are still many difficulties to be overcome to keep the work going.

What is clear is that many consultants have developed working from home environments and the pandemic has also increased the development of remote controlled equipment.

I am also pleased to publish this year's winner of the David Sugden Award, and would encourage all young members to enter next year's contest.

David Lees
ATS Editor

NorthConnex opened to motorists on October 31



After months of waiting, commuters heading south were relieved when time saving Northconnex tunnel opened to drivers on October 31.

Commuters had been anxiously awaiting the opening of the $3B mega-project which will reduce travel times to Sydney by up to 15 minutes and allow them to avoid 21 sets of traffic lights along Pennant Hills Rd.

More than 17,000 people have been involved in delivering NorthConnex since major construction began. Member for Robertson, Lucy Wicks, said NorthConnex is designed to the highest safety standards, built and fitted with the latest technology to keep drivers safe. NorthConnex is Australia's deepest road tunnel, reaching 90 metres underground at its lowest point," she said.

Commissioning included more than 50,000 tests and checks to ensure that the motorway was ready to open.

NorthConnex will be the first road tunnel in Australia to include innovative lighting features, including trees, starscapes and birds, aimed at keeping drivers engaged.

The opening will see up to 5,000 trucks a day removed from Pennant Hills Rd, regularly voted one of the most congested roads in NSW.

"This is one of the most significant and eagerly anticipated road infrastructure projects ever delivered in Australia. It has not only provided thousands of jobs during construction, but it will change the way people commute to and from work each day", Wicks said.

Sydney's growing toll network is the most extensive and expensive in the world.

Sydney's new M8 tunnel open

The $944 million Brisbane Metro bus project includes a new underground station at the Cultural Centre and a tunnel along Adelaide St in the CBD.

It's been four years in the making, but the latest stage of WestConnex, the $4.3bn M8 tunnel that runs between St Peters and Kingsgrove, is open.

The 9km tunnel was originally referred to as the new M5 until today. The tunnels cost S$6.95 to use and run parallel with the existing M5 East route, which links Sydney's central business district with the international airport as well as Port Botany and the south-western suburbs. The new tunnels connect Kingsgrove with the newly constructed interchange at St Peters.

It is estimated there will be an estimated 43 per cent drop in trucks using the M5 tunnel thanks to the new WestConnex M8 build.

In a nod to the environment, the tunnel features 7400 LED lights. An 80km/h speed limit is in place in main-line areas and 60km/h on ramps.

The motorway tunnel is 5.1m tall, significantly taller than the average 4.2m for other tunnels in order to service the evolvement of freight.

It's expected to take less than 10 minutes to travel between St Peters and Beverly Hills, and there are dual lanes in either direction with room for a third depending on user numbers.

The new tunnels form the second phase of the massive WestConnex project, which is costing some A$16.8bn in all. WestConnex is being delivered in four major stages including the new M4 tunnel (which is open), the new M5 tunnels, the M4-5 link tunnels and the Rozelle interchange, which is scheduled to open in 2023.

The first stage of the WestConnex project included the opening of the M4 tunnels and a widened stretch of motorway. Future stages of the project will see the M8 linked with the M4 by further tunnel sections as well as to other new routes still being planned.

- More than 18,000 workers were involved in the project, with more than 20M hours worked
- The project used more than 723,000 cubic metres of concrete
- More than 7.9M tonnes of soil was excavated
- It features 7400 lights, more than 2500 information signs and more than 850 CCTV cameras with 24/7 monitoring

Replacing water with air

An innovative new technology which uses air instead of water in sprinkler systems is set to turn the infrastructure industry on its head - as well as creating far-reaching environmental benefits.

The technology, called Dry-Flo® has been implemented under exclusive license by pre-commissioning and commissioning service provider, EFTECH International, on Sydney's New M5 (M8) WestConnex tunnel.

EFTECH Managing Director Andrew Manning says by using state of art Dry-Flo® software to simulate wet flow testing, and by pumping air instead of water through sprinklers and deluge systems*, millions of litres of water and thousands of kilowatts of energy are being saved.

Additionally, systems which normally clog or rust as a result of using conventional water for wet testing will last longer.

"This is a breakthrough technology that creates enormous benefits to cost, time and the environment and we are confident it will become the industry standard going forward," Mr Manning said.

Mr Manning says Dry-Flo® has been successfully used to commission more than 10,000 sprinkler nozzles covering 678 deluge zones throughout the twin nine kilometre tunnels. This has been achieved in three months without using a single drop of water.

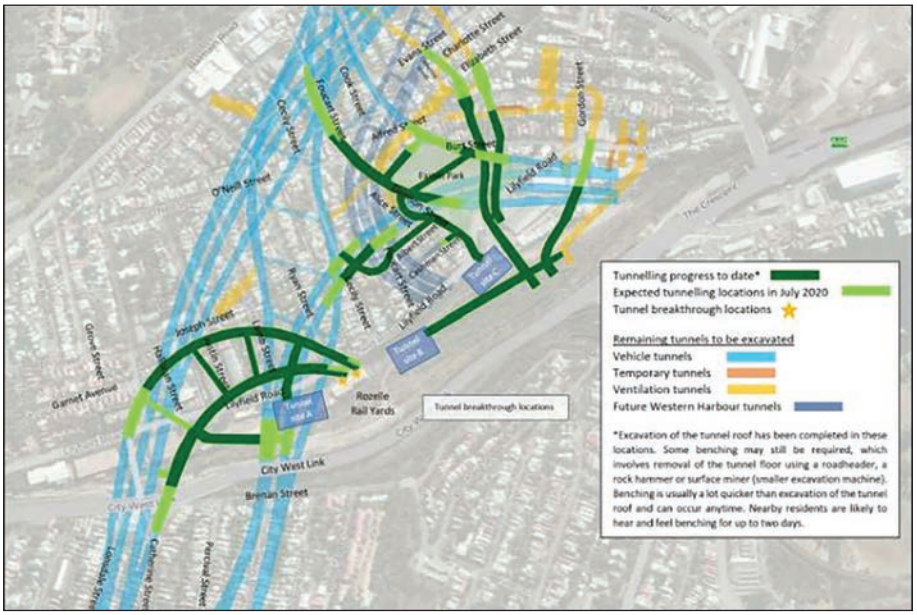
The benefits of keeping an entire section of tunnel dry during the commissioning allows other activities to progress unimpeded. The software accurately simulates wet flow testing in virtual litres and is able to detect various types of debris with absolute accuracy and rectify issues.

M4-M5 Link Tunnels

With just over a third of tunnel heading excavation now complete, the M4-M5 Link Tunnels project has entered peak excavation with all 28 roadheaders now operational. In-tunnel civil work such as installation of drainage channels and placement of the lower concrete layer called 'no fines' has also recently started from all three sites while final preparations are under way for the Mechanical and Electrical (M&E) team to start their in-tunnel work over the coming months. The important surface grouting work on either side of Hawthorne Canal in Haberfield started in March and will continue over the coming months. In late March, the project responded to the rapidly evolving COVID-19 situation in order to ensure the safety of our workers, their families and the communities in which we work. Therefore, until further notice from the NSW Government on restrictions for essential gatherings, our Community Information Centre remains closed with communications prioritised via direct mail, notification flyers, email and phone. Procedures have been implemented to ensure workers adhere to applicable social distancing and hygiene guidelines which include specific measures such as daily temperature checks, limiting the number of people in rooms, regular cleaning of equipment and common areas, online inductions and staggering lunch breaks.

Tunnel excavation is currently at peak production with 28 roadheaders working around the clock to remove around 10,000 tonnes of spoil every day. Over 33% of the total excavation is now complete. You can follow the progress of the tunnel excavation at www.westconnex.com.au/tunnelling. Construction of the new road surface within the tunnel has now started across all three tunnelling sites. The road surface, called pavement, is built in several layers. Work has started on the first layer of the pavement and will continue until mid-2022. The final road surface will be consistent with the road surface in the New M4 Tunnels. Work is also underway on the new ventilation facility at St Peters. Surface grouting work to improve the ground conditions prior to tunnelling below Hawthorne Canal is ongoing and is on track for completion in September 2020.

In June 2020, the project completed its first two breakthroughs with roadheader tunnelling machines reaching the surface inside the Rozelle Rail Yards, opposite Ryan Street. The locations are marked with a star on the map below and in final state, these will become the tunnel entry and exit portals connecting City West Link with the New M5. We also completed rock hammer excavation under Cashman Street for a section of tunnel that was too narrow to be excavated using a roadheader. We'd like to take this opportunity to thank all nearby residents for their continued patience as tunnelling for the future interchange progresses. We currently have 12 roadheader tunnelling machines in operation and expect the arrival of 5 more machines in July. Tunnel excavation and support activities on the surface (maintenance work, spoil handling etc) will continue 24 hours a day, 7 days a week with the expected tunnelling progress for July shown below.



M6

M6 Stage 1 Motorway is a 4km tunnel connecting the New M5 Motorway at Arncliffe to President Ave in Kogarah. Key components of the project will include:

- An underground connection to the existing stub tunnels at the New M5 at Arncliffe
- Twin motorway tunnels (around 4km in length) between the New M5 at Arncliffe and President Avenue, Kogarah
- A tunnel portal and entry and exit ramps connecting the tunnels to the surface with an intersection with President Avenue, including widening and raising of President Avenue and intersection upgrade of Princes Highway
- Mainline tunnel stubs to allow for connections to future stages of the F6 Extension (ultimately to Heathcote as subsequent phases).
- Shared cycle and pedestrian pathways connecting Bestic Avenue, Rockdale to Civic Avenue, Kogarah via Rockdale Bicentennial Park (including an on-road cycleway)
- An Operational Motorway Control Centre to be located off West Botany Street, Rockdale
- Ancillary infrastructure and operational facilities for signage (including electronic signage), ventilation structures and systems at Rockdale, fire and safety systems, and emergency evacuation and smoke extraction infrastructure
- A permanent power supply connection from the Ausgrid Canterbury sub transmission substation to the operational facility at West Botany Street
- Temporary construction ancillary facilities and temporary works to facilitate the construction of the project.

Project benefits include:

- Bypass up to 23 sets of traffic lights on the Princes Highway between St Peters and Kogarah
- Less stop-start, more reliable travel times
- Travel times savings between southern Sydney and the Sydney CBD
- Reduce the number of heavy vehicles on surface roads by over 2,000 per day
- Improve the amenity of the foreshore precinct at Brighton-Le-Sands and the Grand Parade through a reduction in traffic

TfNSW shortlisted three consortia to tender for the project with tender planned to run from late April-July 2020. Competitors include Arcadis with Jacobs and Acciona, CPB/Ghella with WSP and Gamuda/BMD with Arup as designers.

NSW Government Seeks Western Harbour Tunnel Partner

Transport for NSW (New South Wales) will soon seek expressions of interest for a potential Development Partner to assist with procurement and delivery for Sydney's 6.5km long Western Harbour Tunnel project. The alignment stretches from the Warringah Freeway at Cammeray, across Sydney Harbour, to the WestConnex interchange at Rozelle.

"The process is focused on achieving the best outcomes for NSW, similar to other complex road infrastructure projects such as the Woolgoolga to Ballina Pacific Highway Upgrade," the spokesperson said.

"We'll be seeking expressions of interest from industry to leverage private sector expertise such as innovative ideas and approaches to procurement and delivery.

"By creating a western bypass of Sydney CBD, the Western Harbour Tunnel is a nationally significant project to transform the way motorists move around our city."

The spokesperson said after engagement with industry the NSW Government decided on a State-led procurement and delivery process.

"We've been working closely with local communities on this vital program, which will support around 7,500 full-time equivalent jobs and deliver faster and more reliable journeys under Sydney's famous harbour," the spokesperson said.

"It's also important we keep stakeholders and industry informed on what will become a major social and economic driver that helps to re-boot the State's economy.

"The potential involvement of a development partner will focus on procurement and delivery structures and not the financing of the project. Project costs will only be finalised when construction contracts have been awarded."

Separately, Transport for NSW is seeking expressions of interest for the Warringah Freeway Upgrade, one of Sydney's busiest roads.

The upgrade will increase safety for motorists, make public transport more reliable and deliver better active transport links along four kilometres of the Warringah Freeway, and provide seamless connections to the future Western Harbour Tunnel and Beaches Link.

Sydney Metro

Sydney Metro workers have completed digging a 19m long escalator tunnel for the new Martin Place metro station, revealing a first glimpse at a new view of Sydney. The milestone has exposed a never-before-seen view of Sydney Tower and the MLC Centre – from 19m deep under Martin Place.

It took about seven weeks to excavate the tunnel, which will house four escalators as customers travel to the new underground metro station. The tunnel was built under the historic 50 Martin Place building, navigating the basement of the heritage-listed structure. More than 2,000 tonnes of crushed rock was removed, and 700 tonnes of shotcrete used to line the tunnel. The tunnel will now be waterproofed and concrete lined.

The Martin Place's metro station will be an "integrated transport precinct", said to be influenced by New York's World Trade Centre station and Hong Kong's International Finance Centre. It will feature shopping below ground and development above under a multimillion-dollar project from Macquarie Group, which bought air rights for the site for $355M. The station will form part of a $16bn new train line running from Sydney's north shore to its southwestern suburbs.

In total, 19 new and upgraded stations will make up the 30km project between Chatswood and Bankstown. The project, previously slated to cost between $11-12bn, is scheduled to open in 2024.

Sydney west metro

Construction of the Sydney Metro West, from Greater Parramatta to the CBD, is another step closer with the NSW Government shortlisting three consortia to deliver the mega project's first two major tunnelling packages.

Due to the scale of this city-shaping mega project the tunnelling and excavation works have been separated into geographically-specific contract packages between Westmead and the Sydney CBD.

The following consortia have been shortlisted for two packages:

- John Holland, CPB Contractors and Ghella Australia Joint Venture (JHCPBG JV)
- Gamuda and Laing O'Rourke Australia Joint Venture (GALC JV)
- Acciona Australia and Ferrovial Australia Joint Venture (AF JV)

They will firstly participate in the Central Tunnelling Package, with the successful tenderer awarded a contract to build 11km of twin tunnels from The Bays to Sydney Olympic Park. The remaining two tenderers will then bid for the Western Tunnelling Package, with the successful tenderer awarded a contract to build 9 kilometres of twin tunnels from Westmead to Sydney Olympic Park. The successful tenderer for the Central Tunnelling Package will not be eligible to be awarded the Western Tunnelling Package, driving greater competition in the delivery of Australian tunnelling infrastructure.

The planning process for the Sydney Metro West project is progressing with Sydney Metro currently addressing community feedback raised as part of the project's first Environmental Impact Statement.

Subject to planning approval, work on the project is expected to start in The Bays later this year, with the first of four mega tunnel boring machines expected to be in the ground before the end of 2022.

The Sydney Metro West project will deliver a new underground driverless metro railway from Westmead to the city, doubling the rail capacity of the corridor and cutting travel times to around 20 minutes between Parramatta and the city.

- A **fully underground** main line including approximately **24km of twin tunnels**.
- **8 Stations**
- Travel time target of around **20 minutes** between Parramatta and the Sydney CBD.
- Single deck, **driverless** trains (GoA4).
- Capability for a peak operating frequency of up to **30 trains per hour** each direction.
- 25kV AC traction system via **overhead conductor rail**.
- A combined maintenance and stabling facility and Operations Control Centre at Clyde.
- Safeguarded for **future East and West extensions**.

Latest cost estimate. **$20Bn +**

Melbourne Metro

Construction on the Metro Tunnel Project has continued, with workers adhering to strict COVID-19 safety measures in line with the Victorian Government's Stage 4 restrictions in August 2020.

The last two TBMs on the Metro Tunnel Project are now in the ground. The third TBM, Millie – named after Victoria's first female MP Millie Peacock – is digging the first 1.7km tunnel between Anzac Station and the Metro Tunnel's eastern entrance at South Yarra. The fourth TBM, Alice, is named after wartime medical hero Alice Appleford and is working on the second tunnel from the site under St Kilda Road.

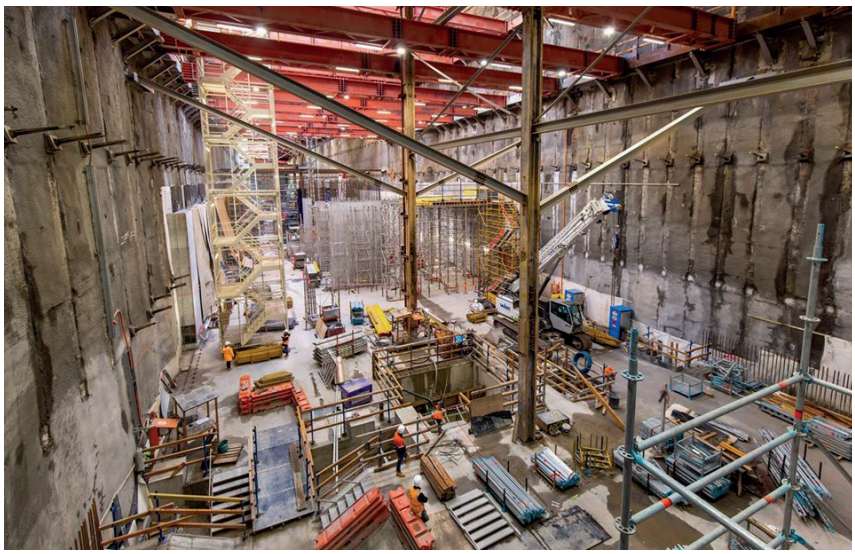
Creating some 7000 jobs over the life of the project, the Metro Tunnel is a critical piece of the puzzle in keeping Victorians in work and our state on-track for recovery. The Metro Tunnel Project has strict protocols in place for the safety of workers, allowing these vital works to continue and protecting thousands of jobs.

The components of TBMs Millie and Alice began arriving onsite in late 2019. Assembly started in January and both have undergone comprehensive commissioning and testing.

Construction on Anzac Station, which will be 300m long and sit 22m below St Kilda Road, is continuing. The first two TBMs, Joan and Meg, broke through at the western tunnel entrance in February 2020. After tunnelling under rail lines, CityLink, Moonee Ponds Creek, North Yarra Main Sewer and the West Melbourne Terminal Station, Joan and Meg has now broken through a 13m deep shaft at Childers Street, Kensington. The TBMs have travelled 1.2km and installed 4,200 curved concrete segments to create 700 rings lining the walls of the twin tunnels. The segments, each weighing 4.5t, are among 56,000 being manufactured by 70 workers at a purpose-built concrete manufacturing plant in Deer Park.

The TBMs were then returned to Arden Station by trucking parts back to the site and pulling the gantries through the tunnel, where they began their journey to Parkville Station. TBM Joan – named in honour of Victoria's first female Premier Joan Kirner – bored into the station box 20m under Grattan Street on 28th August, after tunnelling 1.4km from the Arden Station site.

The machine will now be moved through the Parkville station box under Grattan Street and relaunched towards the new State Library Station site in about a month, after the TBM is cleaned and recommissioned. The project's TBM Meg, which is tunnelling parallel to Joan from Arden to Parkville is expected to arrive at the station a few weeks after Joan.



Three roadheaders are excavating deep under Swanston and Flinders streets to construct the central cavern of Town Hall Station. Tunnelling of the twin tunnels in the CBD – at the site of the new State Library Station will start soon.

Lots of progress is happening across all sites, with the excavation of the station box at Parkville completed in April. The new Parkville Station is taking shape below Grattan Street as work on the permanent structure continues. Crews are also working on two of the station's entrances – one on Grattan Street West, near the Peter MacCallum Cancer Centre, and one on Royal Parade.

As noted by Minister for Transport Infrastructure Jacinta Allan: "Just as we're facing an unprecedented health challenge, we're facing an unprecedented economic challenge too. Our Big Build will be vital as we recover after the pandemic has passed. The Metro Tunnel team are doing an amazing job finding practical, safe ways of working, so we can continue building this urgently needed project in challenging circumstances. "We'll keep working closely with our workforce, construction partners and unions to protect the safety of workers – and project jobs."

Meanwhile the $11bn Metro Tunnel's independent cost advisers have warned its financial backers the project could face many millions of dollars in extra costs and months of delays due to the COVID-19 pandemic.

The Andrews government's flagship rail project has already blown out by up to $3bn, but leading quantity surveying and construction cost management consultancy WT Partnership has told the project's financiers to expect new coronavirus-related costs and delays.

The Town Hall site of the Metro Tunnel, which was connected to the Federation Square site in June 2020, was shut down after two workers tested positive to COVID-19.

Melbourne Airport rail tunnel

The giant investment fund offering $7bn to build Melbourne's airport rail link is urging state and federal support for a project that would create thousands of jobs amid warnings COVID-19 has impacted the project's timeline.

Prime Minister Scott Morrison and Premier Daniel Andrews were close to securing a deal on the $8bn-$13bn project before the coronavirus crisis hit and were poised to make an announcement.

IFM Investors, which leads the AirRail consortium including Melbourne Airport, Southern Cross Station and Metro Trains, has called on the state and federal governments to consider its proposal to build a 7km tunnel between the city and Sunshine, arguing it would "super-charge" the Victorian economy in the face of a devastating pandemic.

If built, the tunnel option would "generate 13,000 jobs, super-charge the local economies of the western suburbs and regional Victoria, and boost the tourism sector as the state emerges from the COVID-19 pandemic" executive director of global asset management Danny Elia said.

"IFM Investors' Melbourne AirRail proposal will be a strong investment for millions of Australians. It will enhance Melbourne's standing as a world-leading place to live and visit. Industry super funds stand ready to work with state and federal government to get going as soon as we can."

The state and federal governments — each stumping up $5bn — are understood to prefer a cheaper option that would see airport trains run along existing tracks from the city to Sunshine and a new link to Tullamarine.

A full business case for airport rail is still under way, despite government websites promising to complete the economic analysis by this year. Mr Tudge said the federal government was firmly committed to the project, but warned of a slight lag due to COVID-19.

Cross River Rail

The A$5.4bn ($3.84bn) Cross River Rail is a proposed rail line between Dutton Park and Bowen Hills, two major suburbs of Brisbane.

It includes the construction of 5.9km twin tunnels under the Brisbane River and CBD and four new underground stations. It also covers the refurbishment of existing stations.

Two massive TBMs have arrived in Queensland to be fitted out and deployed to dig Cross River Rail's twin tunnels under the river in early 2021. They are the same machines that dug the Sydney Metro. Now they'll get a full refit and refurbishment at Herrenknecht's north-side facility, to prepare them to dig Brisbane's first underground.

State Development Minister Kate Jones said the TBMs will be launched from the Woolloongabba Station site and will each dig a tunnel under the Brisbane River to the Albert Street Station. They will then continue to the new Roma Street Station before emerging at the project's northern portal at Normanby.

Currently 16 Herrenknecht workers are refitting the TBMs at Pinkenba.

Wagners Precast has commenced the manufacture of 25,000 concrete segments for the twin tunnels of the underground portion of Cross River Rail. The work is being carried out at the Wacol facility of the company, which is completely Queensland-owned.

Last December, Wagners received the A$40m ($27.5m) contract to provide precast concrete tunnel segments.

Due to the Cross River Rail, the workforce at the facility will increase to 70 from the previous 15 as the segments are delivered over the next ten months. The facility is spread across 70,000m² and has a 28,000m² storage area.

Six concrete segments will be used for the creation of one tunnel ring and a total of 4,157 tunnel rings are needed to line the twin tunnels. The 27cm thick, 1.7m long segments are produced at Walcol, which aims to develop 140 segments a day.

West Gate Tunnel

In May 2020, the Victorian government advised that the $6.7bn West Gate Tunnel project would not be completed in 2022 as originally intended, instead pushing the project back to 2023 over a dispute around the disposal of contaminated soil,

Hundreds of workers on the project are now facing the sack amid landfill cost increases.

Tunnelling was due to start about nine months ago but has not yet begun after an impasse over how to process and dispose of soil contaminated with the toxic chemical PFAS.

The Supreme Court case involves Transurban and the builders, but Justice Kevin Lyons has said that the state government must be brought into the case because they were part of the project's design and construction contract and would be bound by the court's findings. The government is now considering its position on the case.

Court documents reveal Transurban came to the state government on several occasions with compensation claims that had been originally put to the company by the builders, but they have been rejected by the state. The project's builders also allegedly accused Transurban of being dishonest about the extent of PFAS contamination.

A spokeswoman for the government said it would not back down from the terms of its agreement with Transurban. "It's time for Transurban and its builder CPB-John Holland to get on with the West Gate Tunnel and the government will be holding Transurban to its contract," she said. l

Moorabool Shire Council is considering launching legal action that may further delay tunnelling on Transurban's new toll road, as Bacchus Marsh residents weigh up a separate legal bid to stop PFAS soil getting dumped at the Maddingley Brown Coal landfill site, which is located hundreds of metres from homes and schools.

It comes as Maddingley, shortlisted to accept the project's 1.2M cubic metres of soil, lodged an application with Planning Minister Richard Wynne to use special powers to intervene and replace the council as the planning authority.

Brisbane Metro

QMCA has welcomed Lord Mayor Adrian Schrinner's announcement regarding the selection of the Acciona-Arup Brisbane Move Consortium as the preferred contractor chosen to deliver the Brisbane Metro project.

CEO, Jon Davies congratulated Council and the winning contractor "We are delighted that the Lord Mayor and Council have reached this important project milestone and congratulate QCMA member Acciona on their successful bid as part of the Acciona-Arup Brisbane Move Consortium."

"We are particularly pleased that the Council listened to industry advice and is using a collaborative procurement/delivery model for this project. There are many risks involved with constructing a major infrastructure project in the heart of a city, and collaborative contracts enable a partnership-based approach to the management of those risks, resulting in improved project outcomes.

'The use of collaborative contracts is also proven to reduce project costs, improve value and provide a platform for investment in people and productivity-enhancing tools and processes.

"The announcement will provide certainty regarding the project, which will see considerable investment made in employment, training and materials across the sector which will directly assist in kick-starting Brisbane's economy post-COVID-19.

"Brisbane Metro is a critical project for Brisbane and will play a vital role in the city's future transport infrastructure, further enhancing the liveability and connectivity of our city. Today is a significant milestone for the project, and we look forward to seeing Brisbane Metro take shape over the coming years with services commencing in 2023," said Mr Davies.

Snowy 2.0 tunnel from Tantangara Reservoir

The next stage of the Snowy 2.0 expansion will see a Herrenknecht TBM excavate a 27km tunnel that will connect the Tantangara Reservoir to an underground power station for the Snowy Hydro project.

The crucial stage of the Snowy 2.0 expansion can begin after the NSW Government approved the Polo Flat segment factory on 6 April 2020.

To build the tunnel, the German boring machine will drill the 27km, 11m-wide tunnel up to 400m below surface.

The Polo Flat segment factory, 5km from Cooma, will produce 130,000 segments that make up the concrete rings that will line the Snowy 2.0 tunnel.

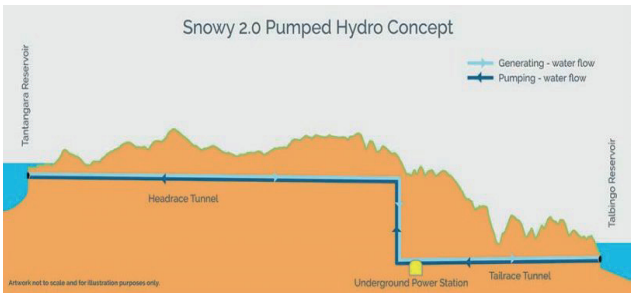
The development is creating lots of local jobs which is very welcome following the past summer's devastating bushfires and during the current COVID-19 pandemic. About 500 people are already working on Snowy 2.0, and at its peak the workforce will comprise around 2000 people.

The environmental impact assessment for the Polo Flat segment factory focused on sections of the Snowy Mountains Highway and Monaro Highway, as well as the connecting local road network between the site of the factory and construction sites within Kosciusko National Park.

Mitigation measures include reduced speed areas, intersection improvements in Cooma and upgrades to accommodate the combined impact of assumed traffic volumes in 2022 and estimated traffic associated with the usual winter peak period.

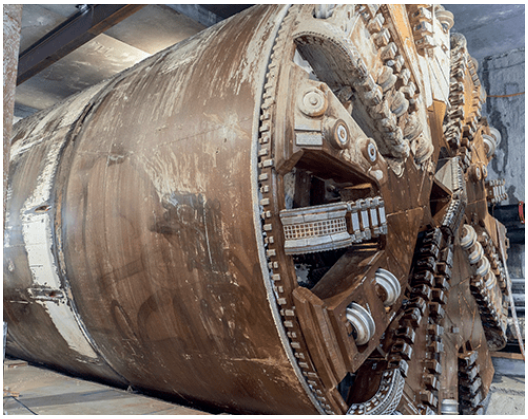
Further road maintenance will also be undertaken along with community consultation.

The Herrenknecht TBM that will connect Tantangara Reservoir to the new Snowy 2.0 underground power station.



Snowy 2.0 will generate pumped hydro by linking the Tantangara and Talbingo reservoirs.

Breakthrough for Perth Airport-Link



Tunnelling on METRONET's is now complete after the TBM broke through the dive structure. The 130m, 600t machine has spent more than 900 days tunnelling through varying and challenging conditions, including under Perth Airport and the Swan River.

Arriving at the Bayswater dive structure at the end of April, the TBM completed a total of 16km for the project comprising twin bored tunnels of 8km each, which will link three new rail stations at Forrestfield, Airport Central and Redcliffe to the existing network.

The breakthrough comes just nine weeks after the project's other TBM arrived at the same location on 18 February 2020.

The end of tunnelling will bring a new phase for the project with the focus now shifted to tunnel fit-out and civil construction.

To date, 50 per cent of the first stage of the track slab has been constructed within the tunnels, while 35 per cent of TBM support pipes have been removed.

Track laying is expected to commence, subject to construction regulations during the COVID-19 pandemic.

GHD completes borehole to 2000m

Leading professional services company, GHD has achieved a major milestone drilling to a borehole depth of 2000m, as part of its geotechnical investigations on Snowy 2.0.

The GHD and Deepcore Drilling team drilled to a depth of 2000m - not only did this milestone exceed Deepcore's previous depth record by 650m, the borehole also had an extremely shallow angle starting at 32 degrees and finishing at 16 degrees.

The core was logged, sampled and tested for geotechnical and specific tunnelling parameters. The core sample results are a critical component of Snowy 2.0 and add to the information collected over the last two years of the project's geological investigation program.

GHD is carrying out the geological testing for Future Generation, a joint venture created specifically to build Snowy 2.0 on behalf of SHL.

GHD's team has been working closely with Future Generation and Snowy Hydro throughout the project, providing geotechnical data to inform decisions on the placement and location of key structures.

Townsville microtunnel

Microtunnelling of a 2.5m diameter concrete jacking pipe installation has been completed for the Haughton Water Pipeline Project.

As part of the Water Security Infrastructure – Stage I Project for the Haughton Pipeline Duplication, the City of Townsville required a pipe installation comprising of 35.6 km of DN1800 GRP pipeline.

The pipeline alignment included microtunnelling under the Flinders Highway and between rail lines and rail corridors, requiring a 2.5m outside diameter enveloper pipe to be installed 120m in length by pipejacking.

To undertake the project, D.J. Mac Cormick Contractors selected one of its Herrenknecht tunnelling systems with a mixed cutting wheel, which was chosen as ground conditions ranged from stiff sand and clay to granodiorite rock.

A detailed temporary design was completed for the launch shaft shoring, thrust block, concrete pad, entrance wall and receival shaft for tunnel boring machine removal, while the chosen jacking system is capable of up to an 850t safe jacking load.

The DN1800 GRP carrier pipe was installed inside the 2.1m, 12.2t jacking pipe – supplied by Humes – following the grouting of annulus outside of pipe.

Using trenchless construction, the pipe was installed in 11 days, with a total tunnelling drive length of 120m.

Auckland's City Rail Link US$9M TBM Arrives

Auckland's City Rail Link US$9M TBM, known as Dame Whina Cooper, has arrived from its factory in southern China. The 7.15m diameter Herrenknecht EPBM that will be used to excavate the rail tunnels for New Zealand's largest ever transport infrastructure project arrived in sections on board the BBC Orion and will now be trucked to the City Rail Link site in Mt Eden for reassembly.

Joint Venture City Rail Link Ltd's (CRL Ltd) Chief Executive, Dr Sean Sweeney, says the TBM's arrival signals an important transition for the project. "A lot of our work until now has focussed on getting ready for the heavy work ahead. The building blocks are in place and the arrival of Dame Whina Cooper marks a symbolic crossover from those enabling works to the complex and hefty job of finishing our tunnels and stations – construction is ramping up quickly," Dr Sweeney says. CRL comprises Vinci Construction Grands Projets S.A.S., Downer NZ Ltd, Soletanche Bachy International NZ Limited, WSP Opus (NZ) Limited, AECOM New Zealand Limited and Tonkin + Taylor Limited.

Over the next few days a small convoy of trucks will transport the TBM from the port to Mt Eden, where it will be reassembled and retested before it starts tunnelling next year.

"The TBM was thoroughly tested before leaving China, but there will be further checks on site. It is very advanced technologically and we want to make sure we have a concrete-solid machine in place and ready to do the job it has been specifically designed for – operating in Auckland's unique soil conditions to build CRL's rail tunnels," says Francois Dudouit, Project Director for CRL's Link Alliance.

The Link Alliance – the group of New Zealand and international companies building the substantive tunnels and stations contract for CRL Ltd – will use the TBM to excavate two 1.6km-long tunnels from Mt Eden to the CBD to link with the tunnels already dug from Britomart Station.

Work will start later this week on the excavation of the first 51m of the tunnel at Mt Eden. The excavation of the cavern and trench provides room for the TBM to be fitted into position to take over mining. TBM tunnelling is due to start next April, with excavation of the second tunnel planned to start in March 2022. Each tunnel is scheduled to take 9 months to excavate at top rates of 32m per day.

Mt Albert sewer tunnel collapse

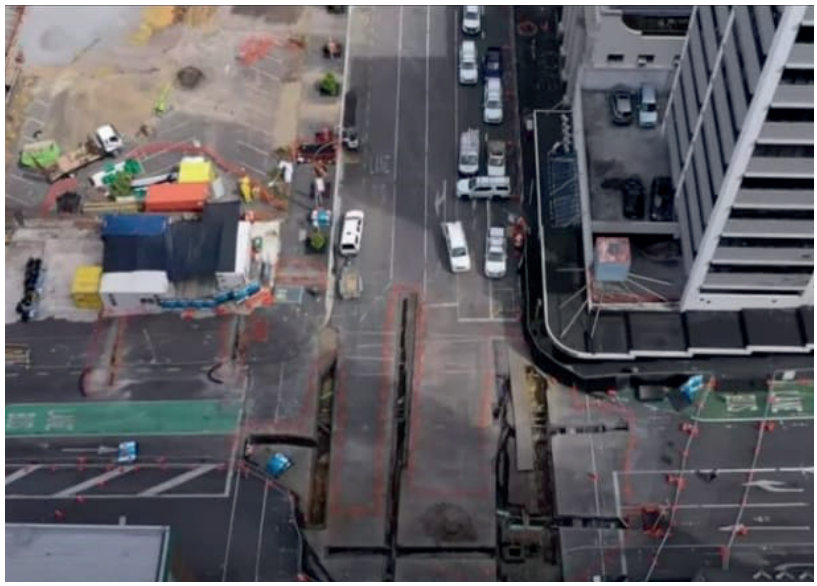
In December 2019, a wastewater pipe collapsed in Wellington CBD, which caused more than five million litres of sewage to spill into the harbour. The Mt Albert tunnel takes all the wastewater from Island Bay - about 100 litres per second of wastewater.

The failure in the Mt Albert sewer tunnel - part of a 9km pipeline that carries sewage from Moa Point on the city's south coast required trucks to carry millions of litres of sludge to the Southern Landfill in an attempt to prevent wastewater having to be discharged into the harbour.

It is suspected an installation fault was to blame, as this particular system was only installed in 1998 and was meant to last at least 80 years. The network was built as a dual-pipe system that was meant to account for failures and maintenance but, in a "highly unusual" situation, both failed.

Several options were explored including repairs, having the pipe out of the tunnel, or bypassing the pipe altogether. A similar repair, also due to a defect in the concrete in which the pipes are embedded, was carried out in 2013 and took about five weeks to complete.

Initially an above-ground black plastic pipe was working in place of the broken sewer, while plans were put into action to put a "slightly larger, slightly deeper" pipe underground in its place. But this meant pulling up an old 1890s pipe, which was wedged in among the extensive network of power and gas pipes beneath the city's narrow streets.



The plan was to divert waste from the broken pipe near the intersection of Willis and Dixon Streets in the central city to the next pipe that feeds the main tunnel - about 200m away near Ghuznee Street.

It was hard to determine what caused the collapse of the 1.3m high tunnel, but other parts of the system were also checked where similar vulnerabilities could be.

Fixing the collapsed tunnel was complex requiring digging down to find out what was going on properly and fix it, but without allowing any of the collapsed material to wash into the main tunnel.

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Tunnelling for Another Trenchless World Record

In 2018, McConnell Dowell set a world record for the longest Direct Pipe® drive on the Army Bay Ocean Outfall project for Watercare Services Ltd (Watercare) in Auckland, New Zealand. Striving for continual advancement, McConnell Dowell has now broken their previous record on the Snells Algies Outfall Pipeline with the world's newest longest Direct Pipe® drive at 2021m.

Warkworth, a town approximately 50Km north of Auckland, New Zealand, is undergoing population growth that necessitates the expansion and upgrade of the local wastewater system.

Currently the wastewater is treated in Warkworth and discharged into the local river. The upgrade scheme, as well as dealing with the local low pressure network also encompasses the construction of a new main from Warkworth to a new treatment plant at Snells Algies and a new marine outfall for treated effluent discharge to replace the aging system.

This scheme upgrade is also part of Watercare's overall strategy to provide cleaner discharges and improve the overall environment around the area.

McConnell Dowell were awarded the contract for the outfall portion of the overall scheme which consists of 4km of trenched pipeline installation from the new treatment works at Snells and an offshore pipeline section.

The reference design for the outfall section consisted of a trenched solution across farmland followed by a trenchless section beneath the cliffs linking to a seabed laid pipeline complete with diffusers.

McConnell Dowell, through discussions with Watercare, proposed a single trenchless alternative linking to the seabed pipeline to minimise disruption to the farmland and local environment. This revised design focused on meeting Watercare's three key criteria;

- Providing an efficient design with respect to whole of life cost
- Minimising risks to health and safety through application of Safety in Design principles, combined with construction methodologies with risk mitigation at their core
- Minimising disruption to Watercare's operations and landowners

Piper setting off on her journey to break the world record for Direct Pipe® set by McConnell Dowell

The project is split into three distinct operations involving a trenched dig and lay section, a Direct Pipe® drive, and marine dredging for the final marine pipeline.

Retrieval of the MTBM at the Army Bay Ocean Outfall project

Over 4.4km of DN630 HDPE pipe has been laid through traditional trenched dig and lay, primarily along public roads and the design incorporated six air valves and seven scour valve chambers.

The outfall section consists of 2021m of trenchless installation of a 1220mm OD steel pipe which is linked to the seabed section of 258m of DN 335 HDPE pipeline.

The layout of the scheme requires a seabed recovery of the Micro Tunnel Boring Machine (MTBM) and this operation will be a repeat of the previous MTBM recovery operation on the Army Bay project.

The original team and the same Direct Pipe® equipment from Watercare's Army Bay Ocean Outfall project was reused for this project, with a new separation plant added to process the excavated spoil. As per tradition, the MTBM was named with the help of the local school children, Piper.

Lessons learnt from the Army Bay project were also incorporated into the planning and operation of the Snells project to improve safety and operational efficiency including changes to the pipe handling systems.

The launch trench for the Direct Pipe® MTBM, was constructed using pre-drilled king piles embedded to the required depth with sheet pile lagging supporting the trench excavation. Multiple ground anchors provide the vertical restraint for the pipe thruster, whilst the horizontal restraint is provided by tying into the launch trench structure. Piper was launched through a launch eye seal which stops any of the annulus lubrication fluids or groundwater migrating into the launch trench.

The overall length of the single trenchless drive itself was one of the biggest challenges as the preparation and planning needed to be extensive and make allowance for extremely limited access within the pipe and to the MTBM. Cutter tool changes, for example,

could not be undertaken with the machine underground, so tools and wear parts needed to be specified and monitored closely, with specific maintenance opportunities planned to allow early intervention. The effects of forces within the pipe walls themselves over this extensive single pipe length also becomes significant. Whilst 1929m had been previously achieved at Army Bay, it was not without its challenges too, being already 432m longer than the previous record - Snells Algies at 2021m is another 92m longer.

The Army Bay Ocean Outfall project provided McConnell Dowell with a range of lessons learnt which they were able to incorporate into the Snells Algies Outfall project. However, the team encountered several key challenges that they did not experience on Army Bay. As an example, the geological conditions of the Pakiri sedimentary rock was expected to be similar to the East Coast Bays Formation sandstone and siltstones encountered at Army Bay. This has proven to be not the case and the differences between the geological formations required changes to the slurry management systems and maintenance regime.

The New Zealand Government considered this project 'essential' during the COVID-19 Lockdown, supporting the need to keep the MTBM moving. This provided the Team with opportunity to implement, ahead of the rest of the country, Level 4 COVID-19 Health and Safety practices and procedures, which was rolled out to the rest of the projects when the country shifted back to Level 3 and projects remobilised.

McConnell Dowell have a long history of marine recovery operations for MTBM from the Tahuna Outfall in 2008 with three others since then and a further two in the planning stages in addition to the Snells project.

The MTBM has been driven into a pre-dredged trench and will be shortly separated from the main steel pipe and lifted to the water's surface using an in-house designed pontoon that will also be used to transport the MTBM to a local harbour where it will be lifted out using a straddle carrier.

"In this tunnelling drive the TBM bored through more than a kilometre of basalt rock, and curves with a radius of 750m, which placed pressure on the interjacking stations," said McConnell Dowell Project Manager Richard Atkin.

There is one more drive to go in the final section of the watermain project, which will see a new record set once again at 1296m long.

The watermain project will cater for Auckland's growing population and add resilience to its water network, with construction aiming to be finished next year.

National in $4bn Wellington transport policy

Bringing forward the construction of a second Mt. Victoria tunnel, building a second Terrace tunnel, and a series of new roads in the Hutt Valley are part of National's $4bn transport policy for Wellington.

State Highway 1 through Wellington is a big beneficiary, with the route from the city to the airport getting major improvements, including two new tunnels. National is promising to build a second Mt. Victoria tunnel, costing $700M, with work beginning by 2023/24. The party also promises to build a second tunnel under the Terrace, costing $400M, with work beginning by 2027/28.

The route through Te Aro and around the Basin Reserve would also be upgraded. National wants to put State Highway 1 underground as it goes through Te Aro, separating the highway from traffic going through the city. Bishop thinks that will cost $1.1bn with work beginning by 2029/30.

He also wants to separate north-south traffic going around the Basin Reserve from east-west traffic, to ease congestion. Collins said she wants this to be done by 2024.

The current Government has promised a $6.4bn Wellington Transport package, Let's Get Wellington Moving, with the cost split 60-40 between central government and the Wellington City and Regional councils.

Let's Get Wellington Moving has been controversial for the fact that the Government's proposed sequencing of projects stated the second Mt. Victoria tunnel would be built late in the 2020s, and large projects recommended by the working group were absent from the package announced by the Government.

National promises to pick up and fund those projects, the second Terrace tunnel, and putting State Highway 1 underground through Te Aro.

Mumbai Metro Sees 33rd Breakthrough

Mumbai Metro Rail Corporation (MMRC) has achieved its 33rd breakthrough, with the completion of a 653m long tunnel from Churchgate to Hutatma Chowk station.

It is the first TBM breakthrough inside a NATM tunnel bored using a Robbins-made Dual mode hard rock TBM. Surya-2 has completed this downline stretch in 275 days using 502 rings.

"The presence of iconic Flora Fountain and various heritage buildings made out task a bit challenging. However, this unique station, in the vicinity of Hutatma Chowk, is being built by using a combination of Cut-and-Cover and NATM. This station will provide accessibility to the business centres of South Mumbai", said Mr. Ranjit Singh Deol, Managing Director, MMRC.

The overall progress of Hutatma Chowk station is 53%. Package-1, which consists of Cuffe Parade, Vidhan Bhavan, Churchgate and Hutatma Chowk stations, stands at 80% tunnel completion and 68% station work progress.

The total tunnelling on the entire Mumbai Metro project completed is 88% and civil work is 60%.

Mumbai's water tunnel project TBM passes FAT

A 3.2m diameter TERRATEC Open TBM for use on the Municipal Corporation of Greater Mumbai's (MCGM) Amar Mahal II Tunnel Project in Maharashtra, has passed the Factory Acceptance Test (FAT), making it ready to be shipped to the site where contractor Patel Engineering Limited will complete a water transfer tunnel.

This TBM is designed to work effectively in the geology expected along the project alignment. The project requires the TBM to have a modular design that allows it to be launched and potentially received via shafts (or alternately disassembled inside the tunnel). The Cutterhead is equipped with 18 heavy-duty back-loading disc cutters. The VFD controlled electric motors enabling the cutter head to rotate at over 10rpm with optimum torque.

To allow safe tunnelling through all the sections of the alignment, the machine has been designed with ground supporting equipment which includes a fixed probe drilling unit, two rock bolting drills and a steel arches erector.

The TBM will be deployed by contractor Patel Engineering Limited, on the AMT-II tunnel which is one of a number of projects presently being carried out by MCGM to augment and improve its water distribution system in order to meet increased demand and ensure reliable supply.

The project will consist of two TBM drives totalling 5,350m in length between three shafts of depth up to 105m. The finished 2.5m diameter tunnel contract from Amar Mahal (Hedgewar Udyan) to Trombay Low-Level Reservoir (TLLR) and further up to Trombay High-Level Reservoir (THLR) at an average depth of 80 to 90m is for water transfer.

Biggest Underwater Road Tunnel in China Complete

A giant TBM broke through in May 2020 on one of the major sections of the Nanjing Number 5 Bridge. For 5 months, the shield machine "New Era" had been digging its way under the Yangtze River, at depths of up to 70m, having begun its journey on the isle of Jiangxinzhou.

Many difficulties were overcome during the tunnelling including when the TBM passing within 81cm of the foundations of the Nanjing Eye observation platform.

The Jiajiang Tunnel takes its name from the river under which it passes, that slim portion of the Yangtze, between Hexi and Jiangxinzhou.

Overall, the gigantic project consists of the main bridge across the river, the Jiajiang Tunnel on the southern side and the connection in Jiangbei New Area to the north. The total length of the project is 10.335km, including the 1,159m shield tunnel - its 15m diameter making it the largest underwater shield road tunnel under construction in China.

TBM launch on Chouer to Liao River Diversion Project

September 10, 2020, saw the successful launch of the 5.2m diameter CREC667 TBM, named Peaceful Grassland, which will be used to construct 18.8km of the 58.5km long second lot – No. 2 tunnel – on the Inner Mongolia Chouer to Liao River Diversion Project. The event sees the largest water conservancy project in the Inner Mongolia Autonomous Region (Chouer River into the West Liao River) enter full-scale construction.

The entire No.2 tunnel is a critical section of the Chouer to Liao River Diversion Project and is characterised by its long excavation distance, small tunnel diameter, shallow cover, fault-fracture zone, and water-rich formation. The tunnel will be constructed by a combination of D&B and two 5.2m diameter hard rock CREG TBMs, including CREC667, which will carry out the long-distance tunnelling.

China Railway Engineering Equipment Group Co., Ltd. (CREG) has implemented a series of targeted designs such as a high-strength cutterhead, suitable cutter spacing, large breakout torque, and an optimized working space for the challenging drive.

The total length of the Chouer to Liao River Diversion project alignment is 390.26km, which passes through the Tao'er River and Huolin River from north to south. To optimize a gravitational water delivery, the project begins from the Hinggan League to Tongliao city, and finally reaches the Molimiao Reservoir at the mainstream of the West Liao River. It is one of 172 major water conservancy projects stipulated by China State Council during the "13th Five-Year Plan" period. After the completion of the project, it can effectively alleviate the severe water shortage in the West Liao River Basin in the eastern part of the Inner Mongolia Autonomous Region.

Balfour Beatty JV Awarded Major Hong Kong Tunnel Project

Balfour Beatty with Gammon Construction, has been awarded a HK$7.2bn (~US$950M) contract to deliver tunnels and associated works for an automatic people mover (APM) and baggage handling system (BHS) at Hong Kong International Airport on behalf of Airport Authority Hong Kong.

The contract will see Gammon deliver two 1,800m long 8-cell tunnel structures for the APM and BHS systems as well as all electrical and mechanical works for the tunnels. Additionally, Gammon will construct several support buildings including pumping stations, a data centre and security facilities.

The APM and BHS tunnels and the associated works form a major part of the Three Runway System (3RS) project at the airport and will ultimately allow travellers to move between the new Third Runway Concourse and the expanded Terminal 2.

To ensure the project's safe and efficient delivery, Gammon will deploy modular solutions for 75% of the electrical and mechanical works for the tunnels. In line with Balfour Beatty's commitment to reducing onsite activity by 25% by 2025, this approach will see activities carried out off site to ensure enhanced health and safety, increased productivity and reduce the duration of the works.

In addition, all offsite activities will be monitored with the use of the real-time technology system, STAMP, throughout the build process to further enhance the quality and production of works, as well as enhancing the safe and efficient delivery of products to site.

Kolkata metro

Kolkata's East-West Metro project reached a milestone in June 2020 as the TBM reached BB Ganguly Street, after covering the stretch that housed most of the old and dilapidated buildings.

"We are relieved that the TBM has safely reached the main road," said an engineer. The tunnelling will now take place below the thoroughfare, but engineers involved in the project said they would be able to heave a sigh of relief only after passing the Bank of India building at the Amherst Street crossing. The agencies involved in the project, KMRC and contractors ITD-Cementation have their fingers crossed. TBM Urvi is now below a jewellery shop at 106, BB Ganguly Street. It will take another fortnight to dig 200m to reach the Bank of India building and another month to cover around 400m from there to Sealdah station. An East-West station is currently under construction inside the Sealdah station complex.

The 2.45km journey for the twin East-West Metro tunnels from Esplanade to Sealdah involved passing below nearly 700 century-old houses, many of which were dilapidated. More than halfway into the zig-zag route, the first machine (TBM Chundee), which was digging the west-bound tunnel, hit an aquifer on August 31, 2019, causing largescale subsidence in Bowbazar. Since TBM Chundee was damaged during grouting, Urvi will make a turnaround at Sealdah station and return to complete the rest of the west-bound tunnel up to Durga Pituri Lane in Bowbazar. Engineers will once again have to be careful during this return journey below the 'danger' stretch.

Mumbai coast road tunnel

The Brihanmumbai Municipal Corporation (BMC) has decided not to take assistance from China to assemble the TBM that will be used for the construction of a 3km tunnel between Chowpatty and Malabar, a part of the 9km coastal road between Princess Street flyover and Worli.

The 12.9m diameter TBM was imported from China a month ago, and BMC were to take assistance from the Chinese manufacturer to assemble it in the TBM shaft. This would have involved the TBM manufacturer's company representatives flying to Mumbai. However, it has now been decided to take assistance from Indian experts, and if required, experts from Singapore.

BMC claims this decision has nothing to do with the Indo-China clash at the border in Ladakh and was planned a few days before the conflict. According to BMC officials, the decision was taken due to the international travel difficulties owing to the Covid-19 crisis.

"We are yet not in the stage to start tunnelling work. Due to delays in the schedule, owing to the outbreak of Covid-19, we are running around two months behind. The actual work of tunnelling will now start in October," said a BMC official.

The coastal road project is already running behind schedule after the Bombay high court stayed the work in July 2019 for want of environment clearances. After BMC challenged the stay in the Supreme Court, pointing out that the project was exempted from the clearance and environment assessment as it had been completed, the Apex court stayed the HC order in December 2019. The coastal road project's completion has also been postponed to mid-2023 from the earlier deadline of end-2022 and may now be delayed further.

Milin tunnel holed through

The 11.56km Milin tunnel has holed through on the 435km Sichuan-Tibet railway which will connect Lhasa with Nyingchi in southeast Tibet.

The tunnel is one of six 10km tunnels being constructed on the most difficult stretch of the 160km/h line. The Milin tunnel is about 1200m below the surface and has an average altitude of 3100m.

The Lhasa – Nyingchi section of the Sichuan-Tibet Railway will be the first electrified railway in Tibet. It is located in the southeast of the Qinghai-Tibet Plateau, one of the regions with the strongest movement of the earth's crust in China. Workers face altitude sickness, bad weather and a problematic environment.

China Rail says experience gained during the construction of the line has furthered scientific and technological research, and produced innovative techniques to overcome aeolian sand, toxic and harmful gases, high ground stress, high ground temperatures and moraine layers. Tunnel construction challenges have been overcome and several new techniques applied such as wind and sand fixation, comprehensive cooling, water and mud inrush prevention and control, and rock burst control, resulting in 32 patents.

So far, 47 tunnels and 120 bridges have been built, and track laying has been completed on 115.11km of the line. CR expects to complete the line by the end of 2020 ahead of opening in 2021.

Sri Lanka's flood prevention tunnel breakthrough

Construction of the New Mutwal Tunnel in northern Colombo was completed on August 21 by the China Petroleum Pipeline Engineering Company Limited in a breakthrough ceremony attended by State Minister of Urban Development, Coast Conservation, Waste Disposal, and Public Sanitization Nalaka Godahewa and Charge d'affaires of the embassy of China in Sri Lanka Hu Wei.

The storm water drainage tunnel will alleviate flooding in Sri Lanka's capital city, Colombo.

Speaking at the opening ceremony, State Minister Godahewa thanked the Chinese contractor for working through difficulties posed by the COVID-19 pandemic in order to deliver infrastructure that would benefit more than 50,000 people living in the capital.

A statement from the Ministry of Urban Development and Housing said the tunnel was built, "with the objective of mitigating the adverse physical, social, and economic effects caused by the constant flooding experienced in the Colombo Metropolitan Region."

The 778m long tunnel will carry flood water at a capacity of 15,000 litres per second from a canal in the Colombo neighbourhood of Aluthmawatha, under the town of New Mutwal, and out to sea from an opening at the Mutwal Fisheries Harbor.

The project was first proposed in 2010, after which a feasibility study was conducted in 2013 and construction began in 2019.

The New Mutwal Tunnel is part of the Sri Lankan government's Metro Colombo Urban Development Project.

Zojila tunnel

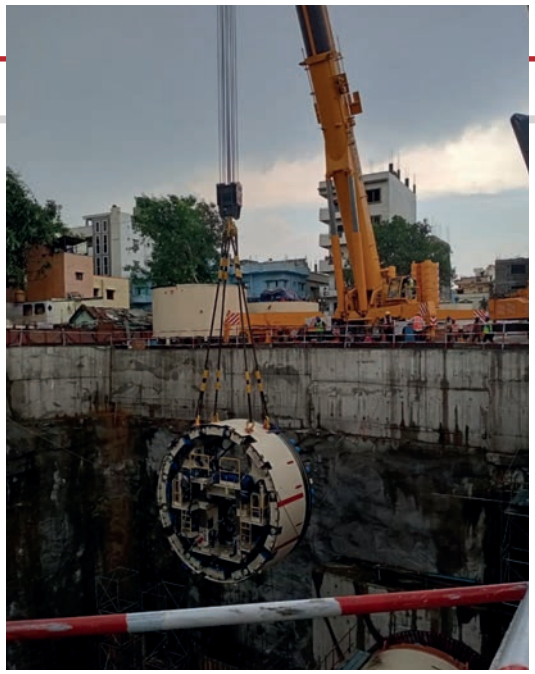
Megha Engineering & Infrastructure Ltd (MEIL) has emerged as the lowest bidder for the prestigious Zojila Pass tunnel project running through the Jammu and Kashmir and Ladakh union territories, according to the National Highways and Infrastructure Development Corporation Ltd (NHIDCL).

The company was among the three bidders in the race, including Larsen & Toubro and Ircon International JV. Megha, however, had the lowest quote at Rs4,509.5 crore for the tunnel project, which has remained in limbo for over six years now.

The project holds strategic significance as Zojila Pass is situated at an altitude of 11,578 feet on the Srinagar-Kargil-Leh National Highway and remains closed during winters due to heavy snowfall.

This whole project has to executed in two parts, firstly as 18.5km of road, and then secondly as 14.15km of tunnel. Prime Minister Narendra Modi laid the foundation stone for the Rs6,800 crore project in May 2018.

Bangalore Metro



One month after resuming the work on the 13.9km underground metro line from Shivajinagar on the Bangalore Metro, the Bangalore Metro Rail Corporation Limited (BMRCL) lowered the second TBM at Cantonment station. The machine's middle and front shields were lowered by a giant crane at the end of May 2020.

Officials in the BMRCL said they were trying to speed up the pending work to ensure minimum cost escalations in the project caused by delays due to the Covid-19 lockdown.

The 13.9km tunnel section, part of the 21km Gottigere-Nagawara line, also faced delays during the tendering process over the past two years. The work was finally awarded in the first quarter of 2019.

Larsen and Toubro Limited has bagged two of the four packages: Shivajinagar-Tannery Road and Vellara Junction-Shivajinagar, which have a deadline of 42 months for completion.

Underwater tunnel in Assam

The Indian government has given in-principle approval for the construction of a underwater tunnel at the Brahmaputra river in Assam. The tunnel will be strategic importance as it will provide round the year connectivity between the North-Eastern states of Assam and Arunchal Pradesh.

Hindustan has quoted a senior official who said construction of the tunnel is expected to start in December this year. The tunnel will be built in three phases and its total length will be 14.85km.

The report also said that the tunnel will be longer than the underwater tunnel being built by China below the Taihu Lake in Jiangsu province. The underwater tunnel built by China below the Taihu Lake is 10.79km long.

Namma Metro tunnel boring begins

After a host of delays, tunnel boring works under Phase II of the Namma Metro began at the end of July 2020. Bangalore Metro Rail Corporation Limited (BMRCL) said TBM 'Urja' will bore from the proposed Cantonment metro station towards Shivajinagar.

In May 2020, the BMRCL started lowering four TBM called Avani, Urja, Lavi and Vindhya, all imported from China. Two machines will dig towards Shivajinagar and the other two towards Vellara junction.

Under Phase II, the BMRCL will build a tunnel network from Dairy Circle to Nagawara stretching close to 14km.

Wuhan begins construction of tunnel-crossing beneath lakes

At the beginning of August 2020, Wuhan began the construction of a lake-crossing tunnel project, as life and work gradually return to normal in the virus-ravaged Chinese city.

The crossing will include two double-deck tunnels under the Donghu and Nanhu lakes. With 13.3km dug by TBMs and a maximum boring diameter of 15.5m, it is expected to be the largest tunnel-crossing beneath a city lake in China.

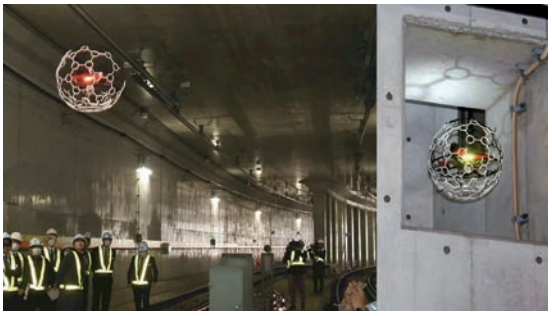
The project is expected to be an engineering challenge, as it will cross highly complicated sub-lake strata, according to Wuhan Urban Construction Investment & Development Group, the company in charge of construction.

The project will take four years to finish. Upon completion, it is expected to ease traffic congestion in Wuchang District.

The company said it will implement a series of precautions to minimize the project's environmental impact on the lakes.

Drones used to inspect Tokyo's subway tunnels

Tokyo Metro Co. has implemented drones to complete inspections in an effort to improve tunnel safety and to reduce the need for scaffolding and heavy equipment. Both are currently used when inspecting the almost 200km of tunnels that run under Tokyo.



The inspection drone has a cage surrounding it, along with a camera, and a bright LED light attached to it. The drone has a diameter of 22cm, weighs 1.15kg and can fly for up to five minutes at up to a height of 50m.

The drone also takes photos for later inspection if anything of concern was found by the drone. The company plans to roll out drone inspections throughout the whole tunnel network in the next few years, with the Marunouchi line being added to the list before the end of the year.

Indonesia's Jakarta-Bandung high speed railway

Tunnel 3 of the Jakarta-Bandung high speed railway (JBHSR) drilled through in April 2020 - the project's third drilled-through tunnel after the Walini Tunnel and Tunnel 5.

Tunnel 3 project has been delivered by the Power Construction Corporation of China JBHSR Project Team, which started work on April 13 last year. The bore is 735m long, with a 5.8m minimal cover, and 60m maximum depth.

During construction, the project team dealt with a collapse resulting from unfavourable geologic conditions and tropical rainforest climate.

Jakarta-Bandung HSR has a total length of 142.3km with 13 tunnels, and a designed speed of 350km/h. When it is put into operation, the commute time from Jakarta to Bandung will be decreased from over three hours to 40 minutes.

Workers celebrate the breakthrough of the No. 3 tunnel of the Jakarta-Bandung high-speed railway.

Coronavirus prompts mining companies to implement new procedures

Fly-in fly-out (FIFO) work presents a unique set of challenges when it comes to avoiding the spread of COVID-19. The flights, on-the-ground transport, tight workspaces, and shared dining and leisure spaces all make physical distancing more difficult than many other workplaces.

The resources and energy sector employs about 120,000 workers in Western Australia alone, while the NSW mining workforce includes 40,000 workers.

State and Federal resources minsters agree that the resources sector is "essential in maintaining a strong Australian economy".

"It's in our best interests to stay in production, and that will only happen if there are no breakouts of COVID-19 in our industry," WA Chamber of Mining and Energy CEO Paul Everingham said. "So we're working our arses off to keep people healthy and safe."

After initial confusion, there is now more clarity about interstate travel for workers.

Western Australia, South Australia, Tasmania and the Northern Territory have effectively shut their borders, requiring anyone visiting to undertake a 14-day period of self-quarantine.

In Western Australia, workers in the energy and resources sector are exempt from these isolation periods but interstate flights and travel from FIFO workers are massively curtailed.

Workers flying into WA need to be greeted by their employer as they disembark and need to display photo identification on arrival. But some companies chose to shift or relocate workers to WA before the restrictions came into effect.

South Australia introduced restrictions on non-essential travel, but people required to maintain or service critical infrastructure, work in agriculture or those required to fly or drive into the state for jobs in mining and resources are exempt from those travel restrictions.

The South Australian Department for Energy and Mining has recommended employers provide their workers with an "authorisation letter stating their name, working dates, transit path, and work location to show to border control staff as required".

The Northern Territory has adopted a case-by-case approach, with authorities aiming to minimise contact with remote and isolated communities. FIFO workers must apply for an exemption from travel restrictions that require arrivals to isolate for 14 days, whether they are from another state flying into the Territory for work or returning home from work outside the Territory. Exemptions to the travel restrictions are granted on the grounds the person "is governed by a COVID-19 management plan, imposed by the employer of the person or class of persons, to prevent the transmission of COVID-19".

In Queensland, Minister for Natural Resources, Mines and Energy, Dr Anthony Lynham said "all mines in Queensland are being asked to provide a COVID plan that covers their workers", which included measures being undertaken to improve hygiene on site.

While interstate FIFO and DIDO workers are not required to undertake isolation periods, companies were being asked to "reduce FIFO and DIDO" to "minimise the mass movement of people".

Mental health concerns for mine workers on gruelling COVID-19 rosters

Australia's second-biggest gold miner has warned the industry to be on "red alert" for fatigue and mental health issues among workers after the introduction of longer rosters.

Northern Star Resources was among the first of Australia's major mining companies to introduce a new work schedule of two weeks on and two weeks off in late March.

Designed to limit exposure during the coronavirus outbreak, the system has become the industry standard — but Northern Star chairman Bill Beament says the change has raised potential safety issues. "The need to manage fatigue and safety will be crucial and costly, and as an industry we must also be on red alert for mental health issues," Mr Beament said. "One of our sites recently had more Emergency Assistance Provider (EAP) inquiries in one week than it did in the previous 12 months."

If you or anyone you know needs help:

- Lifeline on 13 11 14
- Kids Helpline on 1800 551 800
- MensLine Australia on 1300 789 978
- Suicide Call Back Service on 1300 659 467
- Beyond Blue on 1300 22 46 36
- Headspace on 1800 650 890
- SANE Australia on 1800 18 7263
- ReachOut at au.reachout.com

Newcrest gives $20M for COVID-19 care

NEWCREST Mining has stumped up $20M to work on a vaccine for COVID-19 and to boost Papua New Guinea's preparations for and management of the pandemic.

Through the $20M community support fund Newcrest will spend half on PNG efforts while a portion will go toward vaccine research.

Newcrest MD and CEO Sandeep Biswas said the health and safety of the company's people and host communities was its prime concern. "The community support fund will initially focus on increasing the availability of medical care and equipment to cope with the pandemic, as well as assisting in the provision of other essential goods and services, in the communities that host Newcrest's operations worldwide," he said.

Newcrest has operations at Telfer and Havieron in Western Australia, Cadia in New South Wales and Lihr in PNG.

Biswas said the company had no confirmed cases of COVID-19 at any of its operations or projects, all mines were continuing to operate and there was no change to the company's guidance for FY20. He said the limitations on the movement of people interstate and internationally was being managed effectively.

Passenger screening and health checks for all fly-in, fly-out employees, contractors and visitors to Newcrest sites are in place and all workers not required on site have been sent home.

Immuno-compromised workers or those undergoing medical treatment have also been told not to come to work.

At Telfer and Havieron, which is 45km from Telfer in WA's northwest, interstate FIFO travel has been suspended and rosters altered. Face -to-face meetings with the local Martu people have been banned.

Biswas said Newcrest recognised it had a responsibility to help protect people in remote and regional communities around

Telfer and was working with the Western Desert Lands Aboriginal Corporation to help the Martu through the crisis.

At Cadia work is continuing as most of the workforce is residential, he said, with the transportation of concentrate from Blayney to Port Kembla remaining open.

Biswas said at the Lihr gold mine on Niolam Island in PNG's northeast operations and maintenance cycles would continue in the near to medium term.

Ports are still open for essential supplies and Newcrest can continue shipping dore from Lihr to the Perth Mint.

Biswas said the company also sourced personal protective equipment for clinics run by the Lihir medical centre and was working with the local government and communities to support measures that reduced the risk of COVID-19transmission.

These are aimed at keeping local communities informed, limiting community gatherings and reducing travel between villages and islands.

While guidance remains unchanged for the year Newcrest told the Australian Securities Exchange the suspension of operations at the Fruta del Norte mine in Ecuador, where it held a 32% interest, placed about 20,000 ounces of gold at risk.

Amira seeks expressions of interest for new mining automation testing facility

Independent resources industry innovation and R&D organisation Amira Global has initiated an Enabling Futures Program to accelerate the adoption and implementation of the knowledge and technology outcomes from Amira's research and development, innovation, and implementation (R&D+I2) projects. Core to Amira's Enabling Futures Programs is access to physical and digital test facilities.

Amira is seeking expressions of interest to support a physical test facility at Neerabup, Perth, Western Australia. The purpose of the Neerabup Automation and Robotics Park (NARP) is to advance development and integration of technology in Automation, Robotics and Analytics by and for Amira's resources industry members. "NARP provides a physical testing facility to support a range of Amira's Futures Programs, which focus on addressing a suite of our members grand challenges."

In addition to site access, NARP will provide a stimulus for cluster development that will support the development of an Automation and Robotics service ecosystem, including advancing business capability and an associated sustained talent-pipeline development. This Expression of Interest proposes a staged development of test facilities at Neerabup, Perth, Western Australia, in concert with METS Ignited's proposal for the development of West Australian Cluster in Automation, Robotics and Analytics. Amira proposes accelerating the first stage of Neerabup to enable access during the COVID-19 crisis to help prepare mining companies for post-crisis recovery.

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Could Covid-19 spark an autonomous revolution in mining?

At the peak of the Covid-19 pandemic's worldwide economic and social disruption around early April, analysis by GlobalData showed that more than 1,600 mines worldwide had been temporarily suspended. While companies have remained coy on the extent to which this has affected production, the larger picture is slowly being filled in with an estimation that mining output in the country is likely to fall by around 17% in 2020;

Automation and remote mining are not new ideas – the first major foray into the technologies came with Rio Tinto's Mine of the Future project back in 2008 – but they are ideas that are likely to be accelerated in the mining industry's post-pandemic future. "Had these technologies been in place we may not have been required to close a mine as a result of the pandemic," said Gold Fields vice president of corporate affairs Sven Lunsche. "Operating machinery remotely is physical distancing at its most extreme, as it ensures that our people can operate machinery away from their colleagues and away from working areas where they are most at risk."

Resolute Mining, operators of the world's first fully autonomous gold mine – Syama, in Mali – confirmed that operations at the mine had been unaffected, and production was still in line with expectations.

In terms of technology, the Covid-19 crisis will undoubtedly help to accelerate mechanisation, automation, and digitisation of the mining industry, but new technologies will require new skill sets among the company's workforce and will undoubtedly lead to lower staffing levels at most mines.

Remote mining operations are perhaps most prominent in the Pilbara region of Australia, where companies including Rio Tinto and Fortescue Metals have implemented automated processes that are overseen at remote operations centres in Perth, around 1,200km away. Gold Fields has been in the process of implementing remote-control systems for its underground machinery across its Australian operations, operated at surface-level control centres.

Analytics technologies can be a boost to efficiency in mines, essentially digitising and automating various safety processes that would typically need to be manually monitored on location.

"Digitisation is also being implemented at our Australian mines," Lunsche said of Gold Fields' moves towards remote mining. "We use sensors and machinery to provide us with live data of the ore body we are mining. This, for example, allows us to place explosive charges in drill holes where they are most effective, rather than relying on the experience of a drill operator."

While the benefits of autonomous and remote mining technologies have perhaps never been more prescient than in 2020, when miners have been forced to sacrifice production output to curb the spread of a highly infectious disease, the benefits of these technologies are wide ranging.

Autonomous machinery can be programmed to complete certain processes, like driverless haul trucks moving material from one location to another. While activities such as these can be performed relatively safely by human operators, there always remains an element of human risk – a brief lapse in judgement could result in an accident. Machines are more predictable, and can repeat the same task identically. The predictability factor means hazards can be better identified and neutralised, but also means that the machines can operate with relatively little oversight.

Aside from the cost benefit, automation may also bring benefits to the workforce themselves. There is an improved work-life balance, improved diversity of hiring, for example the opportunity to hire people with disabilities or implement more family-oriented strategies. Mining companies may also be able to tap into a new resource pool of people who would be interested in working in the mining industry if it was environmentally cleaner.

Most mines are retrofitted to use automated technologies but as the equipment becomes more widespread, efficiencies may also be found in how mines are designed and built – much like the purpose-built autonomous mine at Syama. As Ahmed explains: "Automation enables more efficient mine design and processes such as more efficient scheduling and traffic management of both people and machines."

Bortana electric vehicle prototypes under test

Ten prototypes of the locally developed Bortana electric vehicle are making their way to minesites across Australia for testing underground and general mining. The Bortana, a battery powered vehicle fitted into a rugged utility vehicle by Victorian e-mobility group Safescape, has been in use on three sites for the past year. In total up to 20 prototypes are to be built.

Developed in a collaborative industry effort led by the Mets Ignited industry growth centre, the vehicle is based on the Agrale Marruá, a heavy-duty, corrosion resistant Brazilian vehicle. The vehicle was developed for the partners by e-mobility group 3ME Technology.

According to Safescape the benefits of a light battery EV include low maintenance costs, high up time, zero emissions, low heat generation and safer operational controls. Maintenance cost and up time benefit comes from the fact that EV system components are mainly solid state, and there are not many wear parts and even fewer moving parts.

The batteries and some other EV specific components are made in Australia by 3ME Technology. The smart lithium-ion batteries have been purpose designed for mining, are maintenance-free, able to support rapid charging and achieve impressive energy density.

Digital ‘canaries’ to monitor air quality in Australian-first mine trial

New technology to remotely detect toxic gases in underground mines, described as the modern equivalent of the canary in the coal mine, is being trialled in Western Australia.

In what is believed to be an Australian first and a sign of the advancement of mining technology, a new wi-fi system being trialled at the Mount Morgans operation in WA’s Goldfields allows workers to check air quality from the surface.

Known as Smart Gas, the system has been developed by Perth-based InSig Technologies and is being trialled by mining contractor RUC Cementation Mining, which owns a 30 per cent stake in its partner.

InSig Technologies managing director Marius van der Westhuizen said there were similar gas monitoring systems on the surface, but it was the first time the technology had been adapted for underground mining.

Mr Westhuizen, who co-founded the company with Paul Barisich, said Smart Gas tapped into fibre-optic cabling running throughout the mine and would significantly improve safety. “It is the caged canary — that’s spot on,” he said. “We can now measure the air quality from the surface and we can control fans to provide more or less oxygen as per the demands within

the mine. We can constantly monitor for things like methane gas and the system will automatically detect if there’s an issue and raise an alarm.”

The two most dangerous gases in an underground mine are nitrogen oxide, generated from explosive blasting, and carbon monoxide, from trucks and other mining equipment using internal combustion engines.

Remote drilling and wireless blasting at Cadia

A ‘safety driven initiative’ has been successfully trialled at Newcrest Mining’s Cadia Valley Operations site using remote drilling, loading and wireless blasting to remove the exposure of workers to major hazards associated with draw points at Cadia East.

The 30-day trial provided the opportunity to trial new technology from MacLean Engineering’s secondary break drill and blast system (Automated Explosive Charger) and Orica’s Wireless Blasting System (WebGen 100) in an isolated area.

Secondary breaking activities are utilised when oversized rocks require removal from the draw point as they are blocking the flow of material into a draw point or are deemed too large to pass through the jaws of the underground primary crusher. Many oversized rocks can be dealt with by preparation loaders

or rock breakers, however a number of rocks require explosives where workers need to access the area to perform the wiring up of each respective conventional explosive being used.

MacLean’s secondary breaking drill and blast system removes workers from secondary break activities through the development of a prototype ‘bolt on’ piece of equipment which is attached to existing secondary break drill rigs.

This Auto Explosive Loader (AEL) can drill a hole in a rock and push the wireless explosive inside the hole, without the operator leaving the cab of the drill rig. The operator can then remove the drill rig, leave the area and remotely detonate the explosive, using a wireless

device manufactured by Orica.

“The trial has demonstrated the opportunity for significant safety benefits, through eliminating human exposure to the major hazards associated with secondary break activities,” Cadia Acting General Manager, Aaron Brannigan said. “The partnership with MacLean and Orica has been mutually beneficial as it has enabled specialist contracting partners to bring together their devices to streamline an entire process in an underground mining environment.”

Dyno Nobel blasts EZshot into Australian mines

Underground miners can now take advantage of the best aspects of electronic and pyrotechnic blasting systems in the one solution ¬with Dyno Nobel's EZshot technology.

Making an electronic blasting system a worthy choice for underground perimeter blasting has been a long time coming for Dyno Nobel. As one of the world's leading commercial explosive providers, Dyno Nobel is now in a position where it can convince mining companies that an electronic system is just as easy to use as a traditional pyrotechnic system. After several years of development, Dyno Nobel has begun rolling out the EZshot electronic initiation system for underground perimeter blasting at mines on both sides of Australia in 2020.

EZshot lives up to the well-known benefits of electronic systems by delivering superior timing, both precision and accuracy, when compared with pyrotechnic alternatives. But importantly, EZshot also offers what electronic models have previously failed to ¬– the straightforward setup of a pyrotechnic system, known as NONEL in the industry. Driven by Dyno Nobel's industry recognised NONEL brand of shock tube, the technology brings the best of both worlds to the Australian and international mining industry.

EZshot was initially designed to help solve a major challenge underground mining companies and contractors face during perimeter development – overbreak.

Dyno Nobel vice president, product and applications technology David Gribble says EZshot trials have consistently returned reductions in overbreak, which is caused by unfavourable geological conditions, and inefficient or excessive drilling and blasting. "We've had customers say that the profiles of their blasts are a lot smoother than what they have seen before using EZshot," said Gribble.

Paul Klaric, technical manager at DynoConsult, Dyno Nobel's specialist consulting division, reinforces the promise of EZshot, saying there is evidence during early use that overbreak may be reduced by up to 12 per cent. He adds that feedback from EZshot users in Australia indicates that the product also delivers safer and more stable drive profiles. "All of the customers that are using the product have indicated increases in visible half barrels, which are a sign of well-controlled blasting in underground development mining," Klaric says. "This promotes ground stability and from an overall sense, means we are producing safer drives that will be there for longer as we are doing minimal damage to the surrounding rock mass."

Rhino raiseborer has Raising Australia reaming ahead

The arrival of the Rhino 100 mobile raiseborer has seen Raising Australia slash slot-raise production times, improve productivity for its customers and significantly increase its own revenue.

'Slot raises' play a crucial role in the development of many underground mines in Australia. These wide-diameter holes provide void spaces in the stope into which blasted ore can expand, improving fragmentation.

The problem is traditional raiseboring machines used to drill slot raises are cumbersome to transport and have high demands for labour and time taking two to three days of preparation before drilling begins.

Mounted on rubber tyres, the Rhino 100 travels under its own power within a mine, requires just one operator, and can begin boring within 45 minutes of arrival on site.

Raising Australia took delivery of its first Rhino in September 2017. That first Rhino went straight to Saracen's Carosue Dam Operation, near Kalgoorlie, and it's been there ever since. The previous contractors were drilling 150m/mth, and the Rhino has achieved more than 400m/mth, drilling just under 5,000m between October 2017 and December 2019.

After the initial success, Raising Australia ordered another two Rhino 100s. The first arrived in August 2018 and was sent to Northern Star's Jundee gold mine, in Wiluna, Western Australia. The next was delivered in October 2018 and has been a campaign machine, travelling to a range of customer sites. The company has since ordered a fourth and fifth machine.

In fact, so fast is the process with the Rhino 100, one of the biggest challenges for Raising Australia has been convincing clients that it will live up to its promises.

As well as slot raises, the Rhino 100 can be used to drill ventilation shafts, drainage shafts, escapeway shafts, ore passes and back fills.

Another key advantage of the Rhino 100 is safety. With older-style raiseborers, the operator is generally in the open less than 5m from the hole being drilled and must drill deep into the rock before erecting a muck chute. With the Rhino 100, the muck chute opens and closes. You open it up, push through the rod, and when you're ready to start drilling you can close the chute up. It covers the hole, stopping the dirt cuttings flying out and hitting the operator.

Historic Tunnel Hill railway tunnel for lease

The tunnel at Tunnel Hill near Hobart was built in 1891 as part of the Bellerive-Sorell train line, also known as the 'Idiotic Railway'. The railway operated until 1926, and was labelled idiotic after much debate about its viability — and some said it was faster to walk parts of the line.

A section of the 165m piece of rail history is being used to grow mushrooms, and its owner is searching for a neighbour with the tunnel up for lease.

"I wouldn't say it's a great place to live," owner Dean Smith said, "But it's a unique spot, and one of a kind really."

The tunnel is separated in two parts belonging to different owners and has had many uses over the years.

During World War II it was used by the Defence Department and a zinc company to store records. It was later used by the University of Tasmania for cosmic ray observations. Mr Smith has owned 90 m of the tunnel for 20 years. He initially used it for storage, before converting it to a mushroom operation.

"I currently use the first 35–40m of that space for growing," Mr Smith said. He said he was able to grow 100 kilograms of mushrooms in half the space each week, and does not need the rest of the tunnel. "We looked at the back half of the tunnel and that would probably get us half a tonne of mushrooms a week, which is pretty serious stuff — and I don't think we're at that level yet," Mr Smith said.

"So there's a good section of tunnel there if anyone out there can think of a quirky way to use it." Although due to its moist mushroom-growing conditions, the tunnel is no longer suitable for storage and would have limited uses.

Part of the tunnel is being used to grow mushrooms

The heritage-listed tunnel is 3m wide and 4m high. Located near Cambridge, it formed part of the railway line that ran from Kangaroo Bay in Bellerive, winding through Mornington to Cambridge and on to Sorell over a causeway at Pittwater. It reportedly took an hour to get from Bellerive to Sorell, despite being only a 20km journey. The tunnel sits 12m below ground and the floor is gravel, but there is power and light.

Mr Smith said the tunnel was naturally about 60% humidity, but since being set up for mushroom production it sits at 90%. "It's pretty cold and very hard to heat," he said.

Tickhole Tunnel

The 1887 Tickhole Tunnel has historical significance at a local level. The tunnel is one of the first significant features to be constructed as part of the railway line between Newcastle and the Hawkesbury River opened in 1888.

Tickhole Tunnel is a 153m long double track railway tunnel passing beneath Charlestown Road at Garden Suburb, NSW. The tunnel is of brick construction throughout and has a slight curve. Although originally built for double track service, the tunnel features one track and is used for the Down Line only. The brick tunnel entrances feature a sandstone string course and brick buttresses.

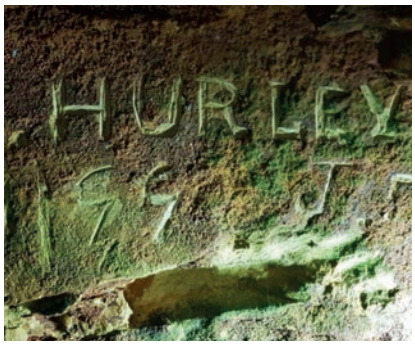
A second tunnel was built adjacent to the original Tickhole Tunnel in 1983 in order to ensure sufficient clearance for double decker suburban carriages. The 1983 tunnel is of concrete construction and is 205m long. The tunnel contains a single track and is used for the Up Line only. At the eastern end of the tunnel, the tunnel entrance abuts the original (1887) tunnel, whilst at the western end the tunnel entrances are separated by approximately 10m, with a rock cutting separating the tracks.

Gold tunnellers' handiwork discovered on South Gippsland farm

During COVID-19 restrictions Anne Roussac-Hoyne used her time to explore old gold prospecting tunnels on her farm, believed to be 119 years old. Inside one of the tunnels were the prospectors' names, T Hurley and J Thomas, alongside the date 21 November '99.

She is now searching for the descendants of gold prospectors who established two tunnels on her property at Foster in 1899. "As far as we know there was not any gold found here. They're small [the tunnels], I know there are much bigger ones in areas around here," she said.

From the outside, the larger of the two tunnels looks like a large wombat burrow surrounded by tree roots. Inside, the tunnel spans 15 metres, with an eight metre tunnel off to the right.



Alluvial gold was discovered at Stockyard Creek, now known as Foster, in the 1870s, and the tunnels are believed to be made by hopeful prospectors who remained in the area almost 30 years later. Pick marks remain preserved within the tunnel.

Mines of the Outback video shows Mount Isa in 1960

The Queensland State Archives has released a rare video showing Mount Isa as it was in 1960 as well as other inland places transformed by mining. The 17-minute video called Mines of the Outback was originally produced by the Department of Education to document mining activities across the arid regions of Australia, and Mount Isa features prominently.

It begins by talking about how John Campbell Miles found the first lead ore in the region in 1923.

Also featured is the Mary Kathleen Uranium Mine, whose rich ore was found just six years earlier and then contained a township of one thousand people, half way between Mount Isa and Cloncurry. The video also details the gold mines of Tennant Creek, as well as the Rum Jungle uranium mine.

ATSym Report

August 2020
Keith Bannerman | ATSym

The ATSym are proud to announce the launch of the ATS' Tunnel Design Guideline. This document was originated out of a discussion between the ATSym representatives in late 2018 as part of the ATS short course held in Melbourne. The discussion centred on sharing industry practice for the design of tunnels in a very practical sense.

A core working group addressed over 400 comments across a three-stage review process and negotiate copyright requirements for 170 separate sources. The document was improved by the 28 strong review team providing challenges and additional sources, whilst the ATS Review committee provided critical review and sage words of advice to the Working Group.

The contents of the guideline include the following key topics:

- General Approach – Design Methods in Tunnelling
- Rock Classification and Empirical Methods
- Semi-rigorous Method – Beam Springs
- Analytical Methods
- Numerical Methods
- Segmental Lining Design
- Ground Movements and Settlement Impact Assessment
- Constructability and Detailing
- Drawings and Documentation

Although the effort to-date has been significant, the Terms of Reference for the Working Group were focused to ensure a timely delivery of documentation. The intent is for a future edition of the guideline to deepen and broaden the guideline in future editions. Thanks to all who have been on the journey for Revision 1.0 of the ATS' Tunnel Design Guideline.

Working Group	Simon Brinkmann (WG Chair), Brodie Aitchison, Aaron Lippett, Carmen Hu, Chris Rees, Geoffery Chan, Jin Chong, Renee Shi, Senthilnath G.T., Rachel Wand and Ronald Li.
ATS Review Committee	Harry Asche (WG Tutor), Alex Gomes, David Oliveria and Diane Mather
Guideline Reviewers	Albrecht Muller, Alun Thomas, Andrew Harding, Andreas Raedle, Andrew Ridout, Arnold Dix, David Evans, David Lees, Daniel Bosco, Des Vliestra, Giordano Russo, Kate Cole, Leon Frylinck, Lorenzo Facibeni, Mahdi Zoorabadi, Morteza Ghamgosar, Olga Mikhaylova, Reza Osgoui, Rick Fox, Ruben Duhme, Saei Khazaei, Shannon Goff, Steve Macklin, Stuart Simmonds, Todd Clarke, Tony Peglas and Yunpeng Zhu.

The document will be available to all ATS members as a secure document via the "Members Section" of the ATS website. The team are looking forward to sharing the contents of the guideline across a series of technical presentations in coming months and welcome any constructive feedback for the Working Group.

Victorian Chapter Report

3rd Qtr 2020 (July)
Richard Buckingham – Chair Victorian ATS

Activity	Outcome/Report
Current ATS VIC Committee Grant**with roles – elected December 2019**	Chair: Richard Buckingham, Deputy Chair: Stephen Barrett, Secretary: Anthony Bennett, Treasurer: Bruce Young Member: Gerard Quigg, Events Coordinator: Jay Lee, Committee Members: Gerry Bertakis, John Main, Nadin Makin, Jawad Zeerak, Toby Shutler, Rachael McCarrison, David Grist, Siddharth Patel Working closely with the ATS Vic Committee is the specific ATS 2020 Conference Organising Committee. The conference organising committee is very active. The ATS2020 Organising Committee consists of. **ATS2020 Conference Organising Committee Members** Rob Muley (Chair), Richard Buckingham, Bruce Grant (Treasurer), Louise Telford (Event Manager), Andrew Kindred (technical program lead), Stephen Barrett, Lucie Missen, Gerard Quigg, Yuqi Tan, Tong Joo Sia, Jiang Aizezi, David Grist, Kristy Allen, Qian-Bing Zhang, Larissa Garvin
TECHNICAL SESSIONS 2019	**Technical Sessions held so far in 2020** 26th Feb 2020: Melbourne Metro Tunnel works update (attendance 150) 10th June 2020: Modelling for ground conditions and BIM tunnel design in the Melbourne Formation – Webex webinar (attendance approx. 305) 7th July 2020: Numerical Modelling of Shallow Tunnels to Mitigate Ground-borne Hazards - event link and running order(attendance approx. 220)
	A program for 2020 had been planned out at the start of the year through to the end of July. However, the introduction of covid-19 social gathering restrictions in March has significantly impacted the program. Events for March and April 2020 were cancelled, but the team was able to host an event for May, however due to webex demand this event got shunted into early June. We then were able to host another in early July. Both events were well attended, as the usual tyranny of distance did not get in the way allowing a good inter-state attendance. At this stage the Victorian does not have an event planned for August because of upcoming events hosted by other states. There is good coordination being carried out by the state chapters and EA national in order to ensure as good a spread of webinar sessions as possible. Going forward the team will assess the situation and guidelines issued by state or EA is terms of future gatherings. Feedback from the recent Vic PDAC meeting in mid-June suggested that EA are in no rush to go back to live sessions at Bourke St, essentially because lift logistics prevent large numbers.
YOUNG PROFESSIONALS	No update at this time
INDUSTRY	**Melbourne Metro Tunnel project ongoing** Both TBMs driven from the Arden site broke through to the West Portal in February and early March respectively. Both have now been relaunched and are currently tunnelling towards Parkville Both TBMs have now launched from the Domain site and are currently tunnelling towards the East Portal, with first breakthrough expected in a couple of months' time Mined station cavern excavation is going well at Town hall and State Library stations in the CBD
	Westgate Tunnel project – challenges exist around contamination for tunnelling works which is yet to commence. Other civils works are ongoing at the portals and the civil viaduct structures
	North East Link Project tender was submitted in June, with award now likely to be Q1 2021
GENERAL & ATS2020 CONFERENCE	**Planning continues for the 2020 ATS conference in Melbourne.** Unfortunately, due to the continuing disruption and uncertainty caused by the global covid-19 pandemic the ATS2020 Organising Committee has recently made the decision to postpone the event until May 2021 o Active committee meets fortnightly o Venue confirmed as the MCEC on Southbank o The conference website is live (ATS2020.com.au) o Technical paper authors have been notified, including those who have been offered poster spots o Technical paper reviews are ongoing within the national ATS community o Sponsorships continue to come in (slowly) o Delegate ticketing is up on the website • The conference workshop, to be held at the VTC, is under planning, with support from the industry to assist in classes • It has been acknowledged that there will be limited or no international attendance (hopefully NZ can be included) • The ITA Awards would only be a pre-recorded conference but actual awards are proposed to be live at the ATS dinner by an ITA Rep • The Holmsglen Victorian Tunnelling Centre construction is progressing well, due to complete in mid-May. A meeting was held on April 28th to discuss their plan going forward and involvement in ATS2020. The ATS does intend to support of the VTC going forward post ATTS2020 • New Neyland award medallions have now been produced and rock core cut to produce this year's award
STUDENT AND GRADUATE ENGAGMENT	• Need to continue working with local education institutions to spread the word of the ATS. Several Vic ATS committee members have ties with such institutions which is a good link • The ATS 2020 conference has engaged with Melbourne institutions to encourage student involvement
2020 VIC COMMITTEE	• Met via MS Teams on 24th June 2020, being the third meeting of the year. MS Teams seems to be a suitable platform for us

NSW Chapter Report

Q2 2020
Nigel Casey

Activity	Outcome/Report
Committee	**2020 NSW ATS Chapter Committee** Chair – Nigel Casey Vice Chair – Phil Clark Past Chair – Rob Nievergelt Treasurer – Hashim Mohammad Secretary – David Oliveira Young Members Rep – Aaron Lippett Golf Day – Brad Boardman Events Co-ordinator – Todd Clarke Committee Member – David Clague Committee Member – Alexandre Gomes
TECHNICAL SESSIONS & EVENTS	**Conferences** For the first time in a number of years there is currently no proposed tunnel related conference in Sydney for 2020. ATS NSW have volunteered some assistance in review of technical papers for the ATS2020 conference to be held in Melbourne in Nov/Dec 2020. **Technical Sessions 2020:** Technical Sessions of ATS NSW have been suspended due to the COVID-19 pandemic. ATS NSW have volunteered to present some webinars to the broader ATS community. July 21st 2020 – Recent Innovations in Ground Support in Sydney Tunnels (by David Oliveira of Jacobs and Mark Sheffield of Aurecon) Upcoming Webinar Technical Presentation Sessions in 2020: Date tbc – Use of Fibre Reinforced Concrete (FRC) in Precast Segmental Tunnel Linings in Asia (Focus on QA / QC) (by Gan Cheng Chian of Bekaert)
CHARITY GOLF DAY	In dialogue with Brad Boardman, it has been decided to postpone the ATS NSW Golf Day for 2020. The event, if held, would be unlikely to draw its usual level of support due to the COVID-19 pandemic. Brad has contacted Ryde Parramatta Golf club and requested that deposits for the 2020 event now be used in 2021.
YOUNG PROFESSIONALS	ATS NSW congratulates the Young Members group on their hard work to deliver a quality Tunnel Design Guidelines. We look forward to forthcoming seminars using the material.
DAVID SUGDEN AWARD	Daniel O'Kelly of TfNSW was awarded the David Sugden 2020 award for his paper *Implications of the Evolving Vehicle Fleet on Ventilation Energy Consumption in NSW Road Tunnels*. The judging panel noted the winning paper "an important paper that quantifies the current and future impact of policy in NSW and Australia".
INDUSTRY	Current tunnelling news in NSW relates to: • Opening of the M8 tunnel – the second tunnelled part of WestConnex • The NorthConnex is proposed to open later in 2020 • Announcement of short listed consortia bidding to deliver Sydney Metro West • The M6 Stage 1 project is currently in the tendering phase • WestConnex Stage 3A continuing in delivery • WestConnex Stage 3B continuing in delivery • Sydney Metro CBD and SouthWest continuing in delivery • Development work on the Western Sydney Airport Line is continuing • The EIS for Coffs Harbour Bypass includes three short tunnels
MEDIA	SBS are currently screening a documentary series of the delivery of Sydney Metro CBD and SouthWest called 'Sydney's Super tunnel'. There have been some media releases in NSW regarding the potential future trial of GNSS Repeaters in Tunnels.
ATS SHORTCOURSE	ATS NSW will hold the ATS shortcourse in 2021. This will be a three curated series of lectures on varying aspects of tunnel development, delivery and operation.

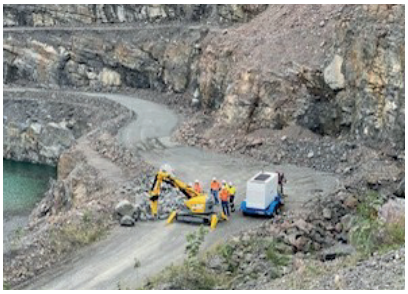
QLD Chapter Report

1st Quarter 2020
Mrs Diane Mather Chairperson Queensland ATS

Activity	Outcome/Report
Annual Meeting held Thursday 7th November 2019. The 2020 committee nominations were accepted.	**2020 QLD ATS Committee** *Chair – Diane Mather (Standards Australia Rep), *Immediate Past Chair National Chair- Dr Harry Asche, Vice Chair- Andrew Ridout, Secretary - Stuart Schmidt, Treasurer - *Jurij Karlovšek & Shotcrete Society Representative, Young Member Representatives – Monique Quirk, Brodie Aitcheson, Jiwoo Ahn (webmaster) Committee Members – Alan Robertson, Jeremy Kruger, Anthony Harding – CPD Co-ordinator, Brendan Henry, Tino Ferrero, Morteza Ghamgosar, Scott Keniston *National Treasurer - Geoff Archer * ATS National Austroads Representative – Tony Peglas *denotes role on National executive
TECHNICAL SESSIONS & EVENTS	**Technical Sessions & Events Dec 2019 to date:** December 4 2019 St Barbara Day Function Charming Squire South Brisbane – Mates in Construction Feb 13 2020 SNOWY Site investigation and 3D modelling March 12 One Day Workshop Mount Coo-tha Quarry **Upcoming 2020 Events:** TBC – National co-ordination with Engineers ongoing to determine ATS program for COVIS 19 lockdown Golf Day - TBC 4th December St Barbara Day Function TBC **Postponed:** Young Members Engineering Heroes at Milton Common **2020 Proposed Technical Sessions & Events:** Segmental Linings- What's new- Anthony Harding Jacobs David Sugden Paper- Sentinel GHD Sydney Metro Under Harbour TBM Crossing-PSM/JHG Westconnex 3A – David Oliveira Jacobs Westgate tunnel- Jack Muir Aurecon/ Ben Clarke JHG Sustainability in tunnelling – Andrew Ridout-ISCA Mel Metro JHG/WSP Annual Golf Day Support RBWHF
YOUNG PROFESSIONALS	Young members supported the QLD ATS St Barbara Day Function, in the Christmas spirit distributing gifts to members. (see write up and photos pages 2&3) Young members networking event Engineering Heroes at Milton Common 20th March 2020 postponed due to COV19 social distancing requirements will be rescheduled pending advise from EA.
INDUSTRY	Cross River Rail has been awarded Tunnel and Station and RIS awarded to CIMIC group CPB, BAM, GHELLA, UGL JV. Construction of shafts and declines have commenced. Brisbane Metro is on hold. Inland Rail PPP pending.
GENERAL	Stacey Rawlings General Manager for EA QLD has attended the QLD ATS committee meetings (2019/2020). QLD Committee and working closely with EA QLD Division for upcoming events. EA QLD relocated to new building December 2019, First technical session (Feb20) held at new venue.
STUDENT AND GRADUATE ENGAGEMENT	QLD ATS Chapter are working closely with EA and CSIRO promoting "The STEM Professionals in Schools" initiative. Further info can be accessed through the following CSIRO website: https://education.csiro.au/sps/ Masters Course at UQ- scheduled for Semester 2020, with a range of expert lecturers from the industry including BCC, PSM, Jacobs, Aurecon, CPB and UGL.
AUSTROADS	Tony Peglas and Nigel Casey attended the Austroads meeting April 2020- report submitted separately.
ATS ST BARBARA DAY FUNCTION	Diane Mather the Queensland ATS Chapter Chair kicked off the evening proceedings summarising the great year that the ATS QLD chapter has had including planned events for 2020. It should be noted that Diane is the first female ATS Chair and she has set the bar high by delivering a high number of quality events throughout 2019 and extending the engagement of the ATS within the tunnelling industry. Diane and the ATS have been working very hard on improving diversity and inclusion and this was clearly evident on the night with a significant number of female tunnelling guests at the dinner as well as people from all over the globe. Harry Asche National Chair Attended Event and spoke to ATS members. Special guests Paul Bryan and Erin Oldman from MATES in Construction attended the event providing a short presentation about the charity which was established in 2008 to reduce the high level of suicide among Australian construction workers. Paul shared insights into the level of suicide in the construction industry, even revealing the high number of people at the dinner who had been impacted by suicide. Paul also gave some invaluable advice towards the approach of actively speaking out and offering assistance to those who appear to be going through difficult times. The ATS were honoured to have them attend the event.

	There was a special appearance from Santa who assisted with the ATS Young Members door prize raffle. Prizes were kindly donated from Barchip, Bamser, Aurecon, Engineers Australia and Andrew Ridout.
ATS QUARRY DAY	12 March 2020 ATS QLD held a one day workshop at Mount Cootha Quarry. 70 delegates attended the one day workshop. The event was sponsored by: Gold Sponsor: Vermeer Silver Sponsors: Aurecon, Herrenknecht, Jennmar Active displays were faciltated by the exhibitors and guides were provided by Ausrocks Pty Ltd, Consulting Mining Engineers. Logistic support provided by the BCC quarry operators. • Remote control demolition (Brokk) • Shotcreting (Jemna) • Fire Bus (Stacey Agnew) • Telebelt Display (Mobile Conveying Services) • Drill and Blast (Orana) • Bluey Shotcrete supported by: Holcim (supply) • BASF (additives) • BarChip (fibres) Coffee vans were positioned on arrival and inside the Quarry Brokk Cross Passage Excavator Afternoon technical sessions were presented by: Alan Robertson, Director – Ausrocks Jiwoo Ahn ***GradIEAust***, Geotechnical Engineer – PSM Bari Thomas, Ground and Underground Engineering (GUGE) Leader – Aurecon Craig Wright, BarChip Australia Charles Howarth, Herrenknecht Australia Pty Ltd, Brisbane

Stacey Agnew Fire Bus



WA Report

August 2020
Jayson Bebek

COMMITTEE	**2019 WA ATS Committee** Chair – Jayson Bebek, Committee Members: Mike Bluc, Will Houghton (Young member Rep), Eric Hudson-Smith, Des Vliestra, Jiang Aizezi, Barry Moore
TECHNICAL SESSIONS & EVENTS	**Technical Sessions May 2020 to July 2020:** In line with Covid restrictions, no face to face technical sessions have been held during the period **Upcoming Events and Technical Sessions in 2020:** ***These session formats may change to online delivery due to coronavirus travel and gathering restrictions, however, will be delivered face to face if possible.*** Young Members: Student information session/site visit Tech Session: Sugden Award Winners Paper Presentations Tech Session: Tunnel Construction Guidelines Tech Session: Snowy Hydro Project Tech Session: Remediation of damaged segments
YOUNG PROFESSIONALS	No update.
INDUSTRY	Work on the Au $1.176B Forrestfield Airport Link project is ongoing. Tunnelling was completed in April and the TBMs have been demobilised. Two cross passages remain to be excavated with a number of others in the final stages of completion. Approximately 25 metres of damaged tunnel section under reconstruction using Spheroidal Graphite Iron lining. Track laying is in progress and the stations are well advanced. Completion of these tasks is still on track for completion late in 2020. Trains are expected to be operational in late 2021.
GENERAL	Recommenced face to face committee meetings for 2020 in June following easing of restrictions in WA. Barry Moore and Jiang (Aziz) Aizezi have joined the WA committee, to fill vacated positions COVID.
STUDENT AND GRADUATE ENGAGEMENT	Planning has recommenced for two student engagement events to be held at Curtin University and University of Western Australia Following delays due to COVID restrictions. The intent of the information sessions will be to demonstrate to engineering students the diverse range of engineering disciplines and specialisations that are engaged across tunnelling projects and may include a tunnel project site visit.

ATS2020 Conference moves to 10th - 13th May 2021

The ATS2020 Conference Organising Committee were committed to delivering the Australasian Tunnelling Conference on the scheduled dates of 29th November - 2nd December 2020. However, due to the dynamic situation with respect to COVID-19 in Victoria, and throughout Australia, we have made the necessary decision to postpone the conference until May 2021.

We have not taken this decision lightly, and have waited for as long as possible before making this hard decision; however, we are no longer confident that we can hold the type of conference we want to hold with ongoing restrictions, uncertainty around borders reopening, and domestic travel restrictions in place for many of our supporters and stakeholders.

We are very grateful for, and value the support of the industry and will transfer all sponsorship, delegate registration, exhibition commitments and entitlements over to the new dates of 10th - 13th May 2021 at the Melbourne Convention & Exhibition Centre.

For the conference itself, we will be developing appropriate attendance policies and any necessary restrictions with guidance from our venue partners, as well as government health departments, and will continue to update all stakeholders in the lead up to the conference to ensure that everyone is aware of any attendance measures that may need to be adhered to.

We thank you for your support and look forward to seeing you all in May 2021. If you have any questions or queries please do not hesitate to contact ATS2020 Event Manager Louise Telford louise@elleevents.com.au

Tunnel emergency exit designs emerging in practice

In 2018 Austroads published guidance on the design of emergency egress signages in road tunnels.

In the absence of an AS/NZ design standard jurisdictions had developed bespoke requirements for emergency signage. Requirements varied between jurisdictions and between tunnels within the same jurisdiction, reflecting requirements that have evolved from project to project.

The project requirements for Sydney's WestConnex New M5 project as well as other existing Australian and New Zealand tunnels were a key input into the report.

The report was finished before the completion of the detailed design for Melbourne's West Gate Tunnel Project and was subsequently used as a basis for the tunnel emergency egress signage detailed design package.

Tony Peglas, Technical Director, Infrastructure, Aurecon, worked on the detailed design of both the West Connex New M5 and West Gate Tunnel Projects.

"While the West Gate Tunnel Project is still to be constructed, the guidance has ensured a consistent, efficient and safe design of the emergency egress points within the tunnel, compatible with the tunnel control centre operational procedures," Tony said.

"The report is also useful for refurbishment of existing tunnels as demonstrated by recent signage upgrades undertaken in the Sydney Harbour Tunnel," he said.

The guidance is being worked into the next edition of *the Guide to Road Tunnels Part 2: Planning, Design and Commissioning,* easing its adoption into the design of new tunnels and refurbishment of existing tunnels.

Austroads Tunnels Task Force

As part of the Austroads Transport Infrastructure program, the Tunnels Task Force provides guidance on the planning, design, operation and maintenance of road tunnels in Australia and New Zealand with a focus on effective management and safety.

The Tunnel Task Force consists of jurisdictional representatives from around Australia and New Zealand, and representatives of the Australasian Tunnelling Society (ATS) and Australasian Tunnel Operators Group (ATOG).

The Task Force maintains Austroads' Guide to Road Tunnels which is actively used by specialists in tunnel technology, proponents of road tunnel solutions, engineers, senior decision makers and regulators. In the 2019-20 financial year, the four parts of the Guide were downloaded more than 2,500 times.

The Task Force also coordinates the development of technical research projects with seven projects currently in the pipeline scheduled for delivery in 2020 and 2021.

ART6165: Revision of Austroads Guide to Road Tunnels Part 2: Planning, Design and Commissioning
This review of Part 2 of the Guide to Road Tunnels will consolidate the findings of Austroads' most recent research and best-practice international guidance to improve tunnel design and operations. The new edition is expected to be published at the end of 2020.

ART6122: Dangerous goods in tunnels – Stage 2
This project will deliver a new decision-making methodology to help industry and authorities assess tunnel access for vehicles carrying dangerous goods. The project builds on work completed in 2019.

ART6011: Use of a driving simulator as a safety-assured method of assessing and approving alternative in-tunnel aesthetic solutions
The methodology report has been completed for this project which will evaluate the performance of a state-of-the-art simulator as a way for designers to evaluate how drivers behave in medium to long road tunnels. The project will provide confidence in the use of the virtual environment to test changes in tunnel environments including measures designed to improve concentration and reduce distraction. This project is currently on hold due to COVID-19 restrictions.

ART6137: Use of perceptual countermeasure treatments to reduce crash risks in tunnels
This study will evaluate the application of low-cost countermeasures in tunnels to reduce crash risk by improving driver speed behaviour and lane discipline. This project builds on work completed in 2018. This project is also currently on hold due to COVID-19 restrictions.

ART6153: Tunnel fire incident information system
This recently started project will provide online access to tunnel fire incident data gathered from across Australia and New Zealand. This work builds on a project completed in 2019.

ART6243: Guide to Road Tunnels update: sustainable road tunnels
This project is due to start later this year and will update the Guide to Road Tunnels with content that will help practitioners ensure that existing and new road tunnels are designed and operated in a sustainable manner. It will likely cover sustainable resource use and environmental impact throughout a tunnel's life cycle.

ART6233: Nationally consistent signage for the guidance of over-dimensioned and dangerous goods vehicles
This project, due to start later in the year, will produce tunnel signage designs to reduce the frequency of over-dimensioned or dangerous goods vehicles entering tunnels or overpasses. The project will be completed mid-2021.

David Sugden Award winning paper

Implications of the evolving vehicle fleet on **ventilation energy consumption in NSW road tunnels**

DANIEL F. O'KELLY, BMechEng (Hons), BCom

Abstract:

The purpose of this paper was to investigate the implications of the evolving vehicle fleet on ventilation energy consumption in New South Wales (NSW) road tunnels. Three forecasts of the NSW vehicle fleet were developed, incorporating the adoption of alternative fuel vehicles. The NSW emissions estimation model and PIARC (2019) utilised the three forecasts to estimate vehicle emissions in future years up to 2040. This model was validated for the year 2018 in a Sydney urban road tunnel. As the NSW vehicle fleet evolves and vehicle technology improves, ventilation fresh air requirements for the dilution of emissions were modelled to reduce over time. The project measured the impact of changes to air quality criteria by relaxing the zero net portal emissions to allow portal discharge at an acceptable NO_2 exit-portal concentration of 0.12ppm. Annual energy savings were quantified for a hypothetical road tunnel. Analysis for the expected case fleet forecast concluded potential savings in annual energy consumption, financial costs and greenhouse gas emissions of ~83% when compared to the status quo.

Keywords: road tunnel ventilation, energy consumption, vehicle fleet, emissions estimation

1. Introduction

Road tunnels seek to improve the efficiency, safety and reliability of all road user journeys by reducing congestion on arterial and local surface roads, providing a higher level of traffic flow service and connecting key strategic commuter and freight routes across a road network. Mechanical ventilation systems are designed to dilute vehicle emissions to meet in-tunnel air quality requirements, prevent tunnel air from escaping through tunnel portals and to maintain a critical velocity in fire scenarios to prevent back-layering of smoke. Ventilation systems in New South Wales (NSW) road tunnels currently consume high levels of energy to operate axial fans and jet fans. The financial and environmental costs associated with the operation of road tunnel ventilation systems are significant.

One of the key changes that will affect the operation of future road tunnel ventilation systems is the evolving NSW vehicle fleet. Over the next 40 years, it is anticipated that vehicle propulsion systems in the NSW fleet will transition from traditional Internal Combustion Engine (ICE) vehicles (petrol and diesel) to hybrid, electric and alternative fuel vehicles (AFVs). AFVs are defined as natural gas, hydrogen, electric and hybrid vehicles.

A transformation of the NSW fleet (with the adoption and growth of AFVs) would result in a proportional reduction in vehicle emissions. Lower levels of mechanical ventilation would be required to achieve the air demand to dilute vehicle emissions to meet current air quality criteria. In the future, the air quality within road tunnels may trend towards equivalence to the air quality outside the tunnel.

Even though vehicle emissions may trend downwards, reductions in required mechanical ventilation levels would not be realised under the current road tunnel design criteria. The dominating requirement for future ventilation systems is the adherence to "only release emissions from ventilation outlets and not from the portals" under the Minister's Conditions of Approval (COA) for each road tunnel project (Department of Planning and Environment, 2019). This requirement is also referred to as the "zero net portal emissions" requirement. An illustration of tunnel air flows to avoid portal emissions is presented in Figure 1.

Hypothetically, if the NSW vehicle fleet transitions to 100% AFVs in the future and the "zero net portal emissions" criterion is still in place, it is currently anticipated that the ventilation system would be operated to maintain an ingress of air from all tunnel portals to ensure air is exhausted from the ventilation outlet.

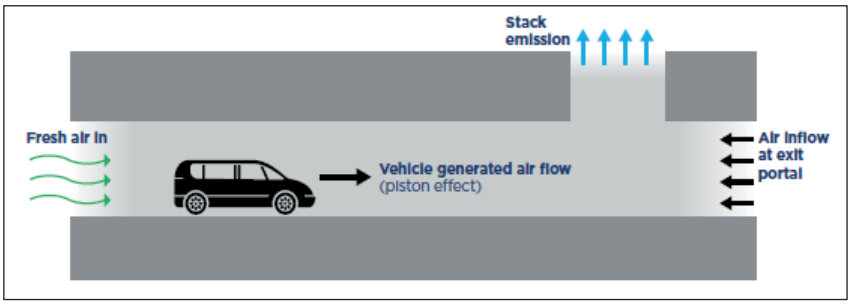


Figure 1: Illustration of tunnel air flow direction to avoid portal emissions (ACTAQ, 2014)

1.1 Purpose and Scope

This paper seeks to analyse the combined influence of changing factors and design inputs on future ventilation operation. Specifically, the study aims to synthesise the knowledge of the NSW fleet, growth of AFVs, air quality criteria, tunnel environment heat transfer and ventilation operation mechanisms into a tangible impact. These have been distilled into five questions that support the main purpose of the paper:

1. What are the future trends in the NSW vehicle fleet in terms of composition and magnitude?
2. Does the current RMS NSW emissions estimation model correlate with real-world tunnel data?

3. What are the impacts of changes in the NSW fleet on tunnel ventilation energy consumption?
4. What impacts will variations in air quality criteria have on tunnel ventilation energy consumption?
5. What are the cumulative impacts of the evolving fleet and air quality criteria changes on tunnel ventilation energy consumption?

A conscious decision has been made to take a "ground-up" approach for this study; conducting theoretical analysis rather than employing numerical methods and simulations. The intention is that the conclusions reached at the end of this study are derived from the analysis of commonly available data, the use of theoretical concepts and methods that clearly state the assumptions and allow for further scrutiny in future research.

2. Background

2.1 Vehicle Emissions and Air Demand for Ventilation

In 2019, PIARC published the latest version of the report *Road Tunnels: Vehicle Emissions and Air Demand for Ventilation*. This report is the industry's leading reference and guidance document in the design of road tunnel ventilation systems. The report sets out the methodology to calculate the minimum air demand required to dilute vehicle emissions (CO, NO_x and PM) to achieve the air quality criteria.

PIARC (2019) presents two methodologies for calculating air demand: the standard method and the fleet-specific method. The standard method involves utilising generic emissions tables based on the 2018 European vehicle fleet. This method is not applicable to NSW as the average year model of the Australian vehicle fleet lags the European vehicle fleet by approximately 4-7 years.

The fleet-specific method involves utilising the NSW fleet composition presented in O'Kelly, Casey & Garland (2016) in combination with base emissions factors provided in the appendix of PIARC (2019). Emissions factors are presented for each European Vehicle (EURO) standard. EURO standards are legislated European Union directives that specify the maximum levels of different emissions for vehicles manufactured in a certain year. In Australia these standards are termed Australian Design Rules (ADR). The periods of implementation for vehicle emissions standards in Australian with the equivalent EURO standard are depicted in Table 1.

The emissions factor tables specify the rate of emissions (grams per hour) for each pollutant, speed, gradient and EURO standard, exemplified in Table 2.

The use of the PIARC (2019) emissions rates in combination with the NSW fleet composition is referred to as the RMS NSW emissions estimation model.

2.2 NSW Vehicle Fleet Forecast

The NSW vehicle fleet forecast provides a transparent model of the NSW fleet evolution and the report by O'Kelly, Casey & Garland (2016) is publicly available online. The forecast was based on publicly available RMS vehicle registration statistics up to and including 2015. This enabled vehicle growth and attrition rates to be determined as well as the composition of the fleet in terms of age and fuel type. Results from the report were depicted as fleet profile graphs for the years 2000 to 2040 as shown in Figure 2, an example for passenger cars. The fleet forecast provides the percentage of each EURO emission standard for both petrol and diesel vehicles for each vehicle category: Passenger Cars (PC), Light Duty Vehicles (LDV) and Heavy Goods Vehicles (HGV). These vehicle categories align with PIARC's (2019) emissions factors and enable the calculation of generated emissions for different tunnel segments.

Figure 2: Percentage of kilometres travelled by Passenger Cars in NSW, by EURO standard (O'Kelly, Casey, & Garland, 2016)

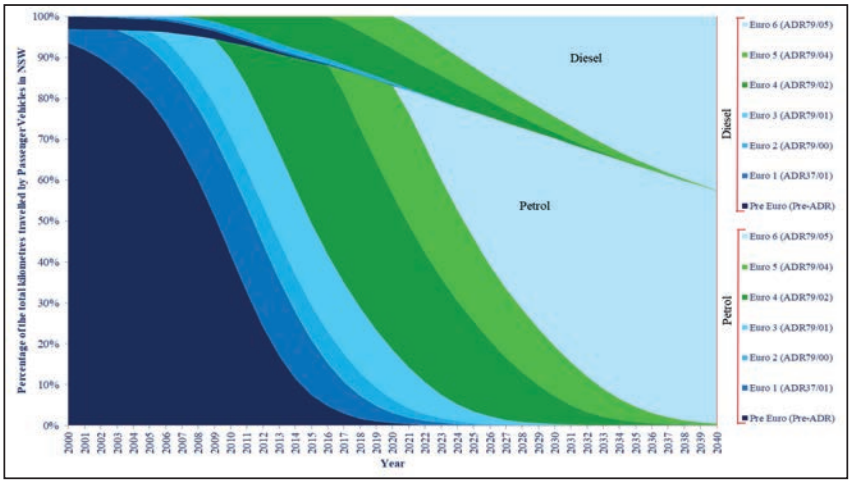


Table 1: Periods of implementation for vehicle emissions standards in Australia (O'Kelly, Casey, & Garland, 2016)

Year	- 1995	1996-1998	1999-2002	2003	2004-2005	2006	2007	2008 - 2009	2010	2011-2016	2017-2020	2021-
Petrol PCs	Euro 0	Euro 1 (ADR 37/01)			Euro 2	Euro 3 (ADR79/01)			Euro 4 (ADR79/02)		Euro 5	Euro 6
Diesel PCs	Euro 0	Euro 1		Euro 2 (ADR 79/00)				Euro 4 (ADR 79/02)			Euro 5	Euro 6
Petrol LDVs	Euro 0	Euro 1 (ADR 37/01)			Euro 2	Euro 3 (ADR79/01)			Euro 4 (ADR79/02)		Euro 5	Euro 6
Diesel LDVs	Euro 0	Euro 1		Euro 2 (ADR 79/00)				Euro 4 (ADR 79/02)			Euro 5	Euro 6
Diesel HGVs	Euro 0	Euro I (ADR 70/00)		Euro III (ADR 80/00)				Euro IV (ADR 80/02)		Euro V (ADR 80/03)		

Table 2: Passenger Car CO Emissions Factors, Gradient 0% (PIARC, 2019)

gradient [%]: 0														
v [km/h]	0	10	20	30	40	50	60	70	80	90	100	110	120	130
standard	g/h	g/h	g/h	g/h	g/h	g/h	g/h	g/h	g/h	g/h	g/h	g/h	g/h	g/h
Pre Euro	261.67	250.48	250.48	304.69	321.33	323.58	321.71	388.59	455.47	531.44	593.94	709.70	825.46	956.20
Euro 1	2.20	21.85	21.85	39.24	50.78	46.25	56.71	86.31	87.20	126.96	158.36	216.03	252.35	344.10
Euro 2	1.28	11.93	33.81	17.79	24.72	22.60	33.23	41.53	53.77	75.71	102.95	176.29	267.07	526.64
Euro 3	1.20	9.38	25.44	13.06	16.88	14.94	20.98	25.13	32.32	43.52	60.76	103.64	156.86	300.38
Euro 4	1.58	8.54	10.59	9.20	11.19	13.23	9.49	13.87	24.24	18.70	31.36	56.41	125.69	311.50
Euro 5	0.78	4.21	8.57	5.23	7.26	9.44	9.44	15.15	17.39	20.41	33.20	55.97	102.12	182.92
Euro 6	0.64	4.21	8.57	5.23	7.26	9.44	9.44	15.15	17.39	20.41	33.20	55.97	102.12	182.92

2.2.1 Alternative Fuel Vehicles

The NSW fleet forecast only forecasts petrol and diesel vehicles, initially excluding AFVs due to their small proportion of the fleet (<1% in 2018). There are two prominent forecasts for the growth and change in fleet composition of AFVs. The *Electric Vehicle (EV) Outlook* (Bloomberg New Energy Finance, 2018) forecasts global EV adoption to 2040. Energeia (2018) was commissioned by the Australian Government to assess the Australian EV Market. The NSW government recently released a NSW Electric and Hybrid vehicle plan (Future Transport 2056, 2019) which presents the

Figure 3: Projected growth of Australian EV market (Future Transport 2056, 2019)

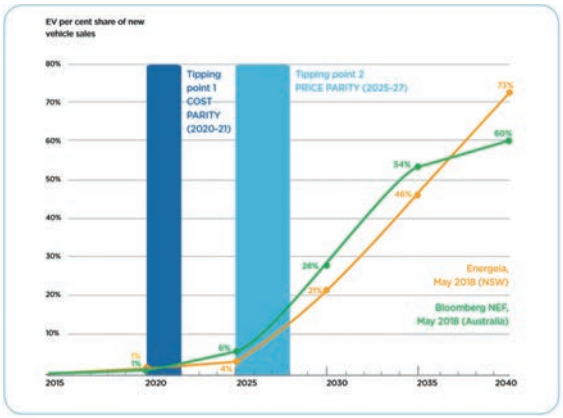


Table 3 Air Quality Criteria for NSW major road tunnels (RMS, 2018b; Department of Planning and Environment, 2018)

Tunnel	Year Opened	In-tunnel CO Criterion	In-tunnel NO_2 Criterion	Visibility Criterion	Zero-Portal Emissions Criterion	Ventilation System Configuration
Sydney Harbour Tunnel (SHT)	1992	150 ppm (congested) 125ppm (normal)	-	$0.009m^{-1}$ (congested traffic) $0.005m^{-1}$ (normal traffic)	-	Semi-transverse (operated as longitudinal system)
Eastern Distributor (ED)	2000	87 ppm (15-min avg.) 100 ppm (5-min avg.)	1ppm goal (not a project requirement)	$0.009m^{-1}$ (stopped traffic) $0.005m^{-1}$ (speeds > 50km/h)	-	Longitudinal
M5 East Tunnel (M5E)	2001	87 ppm (15-min avg.)	-	$0.007m^{-1}$ (congested traffic) $0.005m^{-1}$ (free-flowing traffic)	Zero Net Portal Emissions	Longitudinal, with one intermediate exhaust outlet and cross-over fans
Cross City Tunnel (CCT)	2006	87 ppm (15-min avg.) 50 ppm (30-min avg.)	-	$0.007m^{-1}$ (0-20km/h) $0.005m^{-1}$ (free-flowing traffic)	Zero Net Portal Emissions	Longitudinal
Lane Cove Tunnel (LCT)	2007	87 ppm (15-min avg.) 50 ppm (30-min avg.)	-	$0.007m^{-1}$ (0-20km/h) $0.005m^{-1}$ (free-flowing traffic)	Zero Net Portal Emissions	Longitudinal
WestConnex M4 East Tunnel (M4E)	2019	87 ppm (15-min avg.) 50 ppm (30-min avg.)	0.5ppm (15 min avg. in-tunnel)	$0.005m^{-1}$ (15 min. avg.)	Zero Net Portal Emissions	Longitudinal

two models previously mentioned for the NSW and Australian markets respectively. These forecasts are displayed in Figure 3, with cost and price parity points.

2.3 Air Quality Criteria for NSW Road Tunnels

In-tunnel and ambient air quality criteria are key design requirements for road tunnels in NSW. The purpose of road tunnel ventilation systems is to maintain a safe environment for tunnel occupants and minimise the degradation of air quality for local receptors. Each major NSW road tunnel project has been designed based on the requirements of preceding road tunnels, changing the criteria to reflect community concerns, lessons learnt and updates in research. A comparison of air quality criteria for Sydney's major road tunnels is presented in Table 3. In recent years, NO_2 emissions have become the 'dominant' criterion for which the greatest air demand for dilution is required. The in-tunnel policy states that all new road tunnels greater than 1 kilometre shall be designed to an NO_2 concentration of 0.5ppm on a 15-minute rolling average (ACTAQ, 2016).

3. Research Methodology

In seeking to answer the five research questions posed for this study, a model was defined to test the impacts of changes to the NSW fleet forecast and air quality criteria. The methodology followed in this study was:

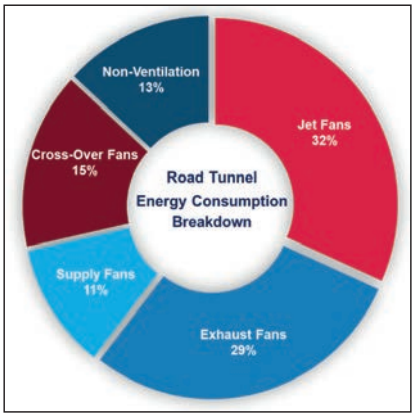
- Define the project model and associated parameters
- Assess future trends in the NSW Fleet incorporating AFVs
- Validate the current RMS NSW emissions estimation model
- Assess the impacts of NSW fleet trends on ventilation energy consumption
- Assess the impacts of changes to air quality criteria on ventilation energy consumption
- Assess the cumulative impact of changes on ventilation energy consumption

Table 4: Tunnel electricity consumption (RMS, 2014)

Project	Electricity consumption (MWh/annum)	Total (2 way) tunnel length (km)	Traffic (approx vehicles per day)	MWh/km per annum
Eastern Distributor[1,5]	4,400	3.2	110,000	1,375
M5 East[2,3]	54,000	8	100,000	6,750
CityLink[4] (Melbourne)	21,500	5	100,000	4,300
Lane Cove Tunnel[5]	15,400	7.2	70,000	2,139

1. The Eastern Distributor operates with managed portal emissions.
2. M5 East includes twin 4 km tunnels. The calculation above assumes energy consumption equivalent in both east and west bound tunnels.
3. M5 East has re-circulation type ventilation system and a 1 km exhaust tunnel to Turrella.
4. CityLink comprises two tunnels including Burnley Tunnel which is 3.4 km and Domain Tunnel which is 1.6 km.
5. Calculation assumes energy consumption equivalent in both tunnels

Figure 4: Breakdown of road tunnel energy consumption



3.1 Project Model Definition

3.1.1 Energy Tunnel Energy Consumption

An analysis of energy consumption data from a Sydney urban road tunnel was undertaken using control system logs from the month of June 2016. The following power ratings and fan efficiencies were provided for equipment in the tunnel:

- Jet Fans: 45 kW (100% efficiency)
- Supply Axial Fans: 376 kW (87% efficiency)
- Cross-Over Axial Fans: 363 kW (Variable efficiency – Data provided in OMCS logs)
- Exhaust Axial Fans: 500 kW (77% efficiency)

The key result was that the ventilation system accounted for **86.3%** of the total energy consumed by the tunnel in the month of June 2016. A breakdown of each subsystem's contribution is provided in Figure 4.

The energy consumption specifications for the tunnel's jet fans and axial fans will be used to assess the project model's energy consumption analysis. Table 4 presents a comparison of electricity consumption rates for certain road tunnels in NSW and Victoria.

3.1.2 Project Model Parameters

The model describes a typical road tunnel in an urban environment with a longitudinal ventilation configuration and one exhaust shaft at each end. The length of the tunnel is 4 km, consisting of two lanes in each direction with no on or off ramps. A schematic of the tunnel chainage with its gradients is presented in Figure 5.

A number of key parameters are required, namely those that describe traffic flow, vehicle characteristics and the tunnel geometry. Normal operation traffic flow profiles were derived from tolling data from a Sydney urban road tunnel. Table 5 provides a summary of the vehicle characteristics used in the project model. The main vehicle characteristics are the vehicle cross-sectional

Figure 5: Vertical alignment of project model tunnel

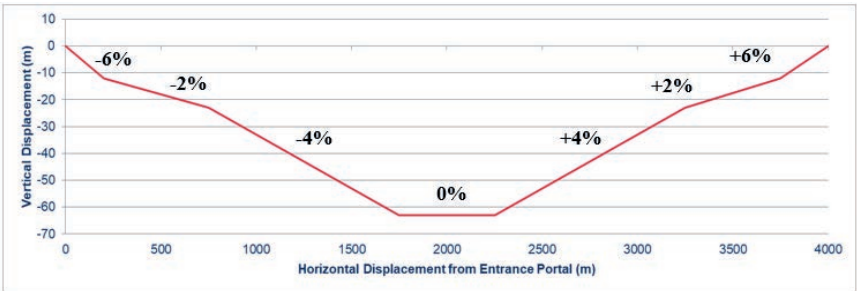


Table 5: Project model vehicle characteristics

Vehicle Type	Vehicle Cross-sectional Area (m^2)	Aerodynamic Drag Coefficient (-)	Vehicle Type Distribution
Passenger Car	2.5	0.4	72%
Light Duty Vehicle	5	0.6	12%
Heavy Goods Vehicle	7	0.8	16%
Weighted Average	**3.53**	**0.49**	

Table 6: Project model tunnel geometry and other parameters

Parameter	Value	Parameter	Value
Tunnel length	4,000 m	Cross-Sectional Area	80 m^2
Tunnel height	8 m	Perimeter	36 m
Road width	10 m	Wall surface friction factor	0.035
Hydraulic Diameter	8.9 m	Density of air	1.204 kg/m^3
Number of lanes	2		

(frontal) area, aerodynamic drag coefficient and vehicle type distribution. The weighted average characteristics represent a typical vehicle that passes through the tunnel. Table 6 provides a summary of the important tunnel geometry parameters in the project model.

3.2 Future trends of the NSW Fleet incorporating AFVs

A detailed analysis was undertaken to assess the future trends of the NSW vehicle fleet incorporating AFVs. Three scenarios were determined for this study:

- the 'base case', built on the NSW fleet forecast with the currently experienced trends in AFVs
- the 'expected case', with AFV forecasts derived from Future Transport 2056 (2019); and
- an 'accelerated case', based on Energeia's (2018) accelerated intervention case.

All three fleet forecast scenarios were created using the NSW fleet forecast (as presented in Section 2.2) with the inclusion of the respective AFV statistics derived from each source. An example for the 'base case' in the year 2020 is presented in Table 7 which includes the proportion of the fleet that are AFVs. The updated NSW fleet forecasts are presented as graphs in Section 4 of this paper.

3.3 Validation of the RMS NSW emissions estimation Model

The validation study processed 12 months of air quality, traffic and temperature data from January to December 2018, and incorporated over 300 million data points. The fleet composition was used in conjunction with PIARC (2019) base emissions rates to calculate the expected emissions from a certain number of vehicles travelling through the tunnel. A flowchart of the validation study inputs, and method is presented in Figure 6.

Figure 6: Validation Study Inputs and Methodology

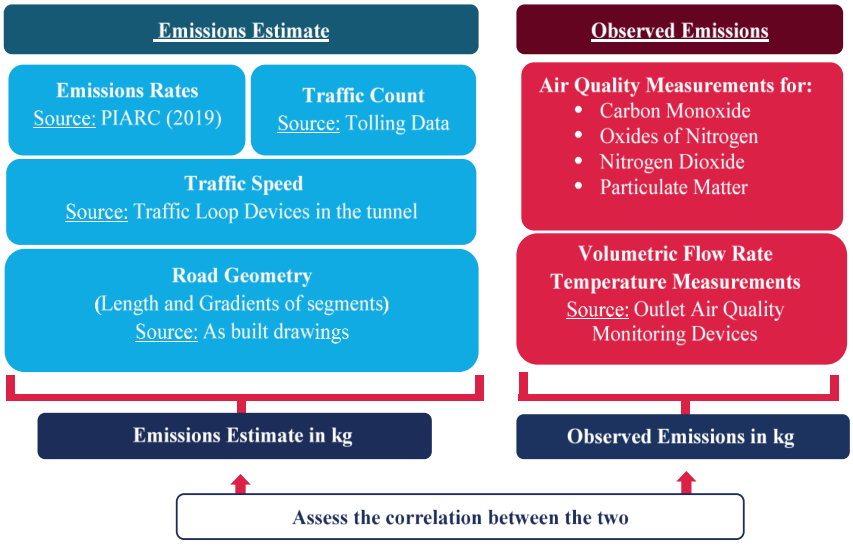


Table 7: NSW fleet composition for 2020, 'base case' scenario

Vehicle	Fuel	Year	Pre Euro	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Total
PC	Petrol	2020	0.6%	2.66%	3.52%	12.90%	40.41%	22.39%	0.00%	100%
	Diesel		0.02%	0.05%	0.61%	-	8.14%	7.92%	0.00%	
	AFV		0.78%							
LDV	Petrol		3.8%	2.27%	2.26%	6.43%	9.69%	4.33%	0.00%	100%
	Diesel		0.78%	0.37%	2.81%	-	35.62%	30.77%	0.00%	
	AFV		0.84%							
HDV	Diesel		11.8%	2.44%	0.00%	11.51%	15.76%	53.61%	0.00%	100%
	AFV		4.84%							

3.3.1 Estimation of Vehicle Emissions

The road tunnel is divided into a series of aerodynamic sections, each with its own road gradient and length as well as specific measured average speeds and traffic counts. Each direction of the tunnel, eastbound and westbound, was assessed separately.

The equation for the total mass of emissions generated in the tunnel per hour is:

$$G_{tun} = \sum_{k=1}^{z}\left\{\sum_{j=1}^{y}\left(\sum_{i=1}^{x} q\left(v_{(j,k)}, t_k\right) \times w_{i,j}\right)\right\}\left(\frac{n_{category} \times l_k}{v_{(j,k)}}\right)$$

G_{tun} = Total emissions generation of a pollutant along the length of the tunnel [g/h]
$q(v,t)_{j,k}$ = Base emission rate from PIARC (2019), depending on the average speed and road gradient in the section [g/h] or [m²/h]
$v_{j,k}$ = Hourly average speed of each vehicle category (PC, LDV, HGV) in each tunnel section
t_k = Road gradient within a tunnel section
$w_{i,j}$ = Weighting of a vehicle class' Euro Standard, determined from fleet composition.
$n_{category}$ = Number of vehicles in the tunnel from a vehicle category (i.e. PC, LDV or HGV)
l_k = Length of tunnel section

- For x number of Euro standards (Pre-Euro, Euro 1 … Euro 6)
- For y number of vehicle classes (e.g. PC Petrol, LDV Diesel, etc.)
- For z number of sections in each tunnel carriageway (eastbound or westbound)

The mass of estimated emissions (G_{tun}) allows for a comparison to the measured emissions in a comparable "grams per hour" metric.

3.3.2 Determining the Observed Emissions

The observational aspect of the validation study utilised the sensors within a Sydney urban road tunnel to record the real-world conditions. For confidentiality reasons the tunnel name cannot be disclosed. The observed emissions from the ventilation outlets were recorded in five-minute intervals across the twelve months of 2018. Measurements were then aggregated into hourly periods. The parameters measured at the tunnel's ventilation outlet's air quality monitoring stations and analysed in this validation assessment are:

- Carbon Monoxide (CO)
- Oxides of Nitrogen (NO_x)
- Nitrogen Dioxide (NO_2)
- Particulate Matter (PM_{10})
- Stack Temperature
- Volumetric Flowrate

A summary of the data quality for the validation study is presented in Table 8.

3.4 Impact Assessment of Changes in the NSW Fleet

For the impact assessment of changes in the NSW fleet, the following pollutant design constraints were applied:

- CO: 0.03 g/m3 at the tunnel exit portal
- NO_2: 0.00188 g/m3 (1 ppm) at the tunnel exit portal
- PM10: 0.00106 g/m3 at the tunnel exit portal

For the normal operation assessment, a probability distribution profile of average speeds was created, to reflect the proportion of speeds present in the validation study road tunnel for each hour of the day. The following probabilities (Table 9) are an example of two hours (5 AM and 5 PM).

The weighted average emissions generated per second value were then divided by the pollutant design concentration to calculate the required volumetric flowrate. By calculating the required volumetric flowrate for each pollutant at each hour of the day, a daily ventilation profile could be derived. The process was repeated for each year 2020 to 2040 and each NSW fleet scenario.

The peak-scenario ventilation assessment sought to determine the dominant air quality criterion (management of pollutant concentration or zero net portal emissions) during peak traffic capacity scenarios. The peak-scenario traffic flow profiles (Table 10) were used to determine the total emissions generated at each vehicle speed.

3.4.1 Calculation of the Piston Effect for Vehicle Induced Airflow in Road Tunnels

A detailed derivation was undertaken from first principles for the calculation of the vehicle-induced inflow of fresh air from tunnel entrance portal, a phenomenon known as the 'piston effect'. The piston pressure change equation is:

$$\Delta p_{piston} = \frac{1}{2}\rho \frac{c_d \alpha}{(1-\alpha)^2}\left(v_{vehicle} - v_{tunnel}\right)^2$$

where c_d is the coefficient of drag, ρ is the density of air, α is the blockage ratio (Vehicle area divided by tunnel area: A_v/A_T) and $v_{vehicle}$ is the average speed of vehicles travelling through the tunnel. For the air flow between the entrance portal and exit portal of a tunnel, the change in pressure from the movement of air is expressed as:

$$\Delta p_{12} = \left(\xi_1 + \lambda\frac{l_{12}}{d_h} + \xi_2\right)\frac{\rho {v_{tunnel}}^2}{2}$$

where location 1 is the tunnel entrance and location 2 is the tunnel exit, Δp_{12} is the change in pressure from the tunnel entrance to the tunnel exit, ξ_1 is the friction factor at the tunnel entrance, ξ_2 is the friction factor at the tunnel exit, λ is the Darcy-Weisbach wall surface friction factor, l_{12} is the tunnel length from entrance to exit and d_h is the tunnel hydraulic diameter.

The two equations Eq. (3) and Eq. (4) are solved simultaneously to determine the "operating condition" and the air velocity, which can be converted to the volumetric airflow given the tunnel cross-sectional area. A comparison between an arbitrary fan curve from an industrial fan supplier (Schotz, 2019) and the project model's peak-scenario "piston effect curve" for vehicles travelling at different speeds is presented in Figure 7. The piston airflow was determined in practice using Microsoft Excel's Solver function to set the difference between the tunnel resistance pressure change and piston effect pressure change to zero.

Table 8: Summary of data quality

Number of hours available in the study	8760	8760
Hours assessed	7125 (81%)	6755 (77%)
Hours excluded	1635 (19%)	2005 (23%)
Magnitude of Data:		
30-second traffic loop data points	176,436,000	176,436,000
15-minute tolling data points	35,040	35,040
5-minute air quality data points	105,120	105,120

Table 9: Probability distribution of traffic speeds for 5 AM and 5 PM (example)

Traffic Speed (km/h)	20	30	40	50	60	70	80
5:00 AM	0%	0%	0%	0%	0%	75%	24%
5:00 PM	0%	0%	1%	2%	4%	88%	6%

Table 10: Peak-Scenario Traffic Flow Profile

Traffic Speed (km/h)	20	30	40	50	60	70	80
Traffic Flow (veh/lane/h)	2700	3300	3720	3980	4100	4120	3800
Traffic Density (veh/lane/km)	135	110	93	80	68	59	48

Figure 7: (a) An arbitrary fan curve relating flowrate and static pressure and (b) A 'piston curve' from the project model, relating volumetric flowrate to change in pressure.

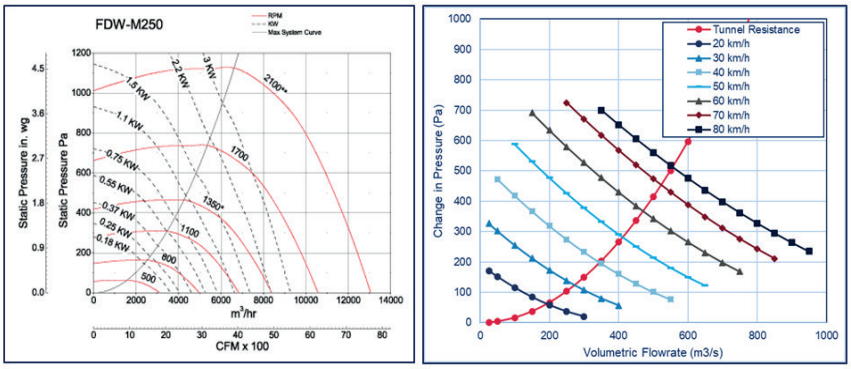
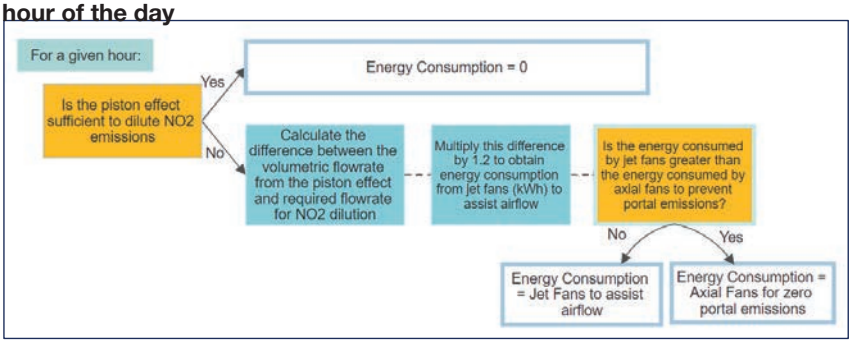


Figure 8: Methodology to determine the energy consumption for each hour of the day



3.5 Impact Assessment of Changes in Air Quality Criteria

The methodology for the impact assessment of changes in air quality criteria closely followed the methodology in Section 3.4. Instead of assessing the changes in the vehicle fleet, the 'expected case' scenario for the NSW fleet was kept constant as the model's fleet input and the pollutant concentration criteria at the tunnel exit were varied.

For the assessment only the variation in concentrations of NO_2 at the exit portal was addressed. For each NO_2 exit-portal concentration, the following were determined: the energy consumed by the ventilation system if portal emissions were allowed across the whole day, and the energy consumed by the ventilation system if portal emissions were allowed only during off-peak periods (8pm to 5am inclusive). Figure 8 shows the methodology to determine the energy consumption each hour of the day under the normal operations traffic scenario for the 'expected case' NSW fleet..

The number of hours per 24-hour period (across the whole day) and 10-hour period (during off-peak hours) whereby the vehicle piston effect sufficiently induced an acceptable volumetric airflow to meet a multiple of the background NO_2 concentration was plotted for each year from 2020 to 2040. An appropriate NO_2 exit portal concentration was determined.

5. Results and Discussion

The methodology in Section 4 was conducted over the course of eighteen months. The results and ensuing discussion are presented in this section in relation to each of the five research questions.

5.1 Research Qu. 1: What are the future trends in the NSW vehicle fleet?

The future trends in the NSW vehicle fleet were modelled as three scenarios, based on the uptake of alternative fuel vehicles each year from 2020 to 2040. The three figures show the NSW fleet composition for the 'base case', 'expected case' and 'accelerated case' scenarios.

Each forecast attempts to account for different factors that influence the growth of AFVs such as model availability, charging stations, government policies, subsidies and technology improvements. However, what each of the NSW fleet forecast scenarios highlight is that a considerable portion of the fleet are still internal combustion engine (ICE) vehicles in 2040. This is true even for the 'accelerated case' whereby approximately 3 million vehicles are anticipated to remain in the fleet in 2040.

The trends of growth and attrition rates were assumed to remain the same for future (ICE) vehicles under the current model. This assumption could change, whereby an increase in the attrition rate of older

Figure 9: NSW fleet forecast - Scenario 1: 'base case', 2000 to 2040

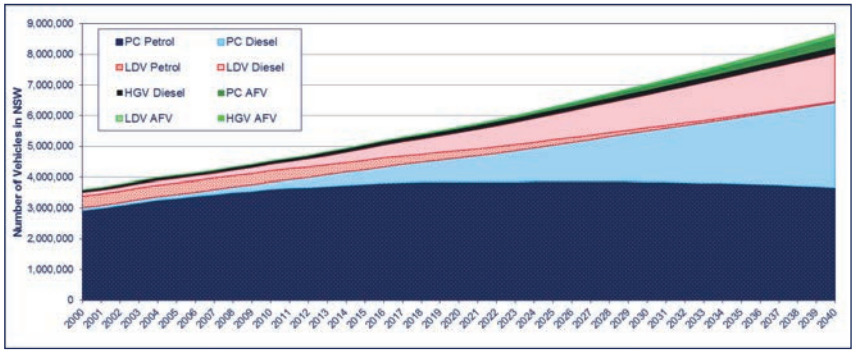


Figure 10: NSW fleet forecast - Scenario 2: 'expected case', 2000 to 2040

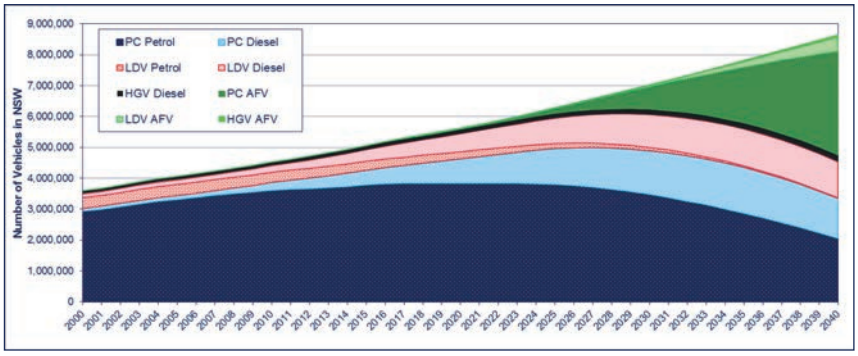


Figure 11: NSW fleet forecast - Scenario 3: 'accelerated case', 2000 to 2040

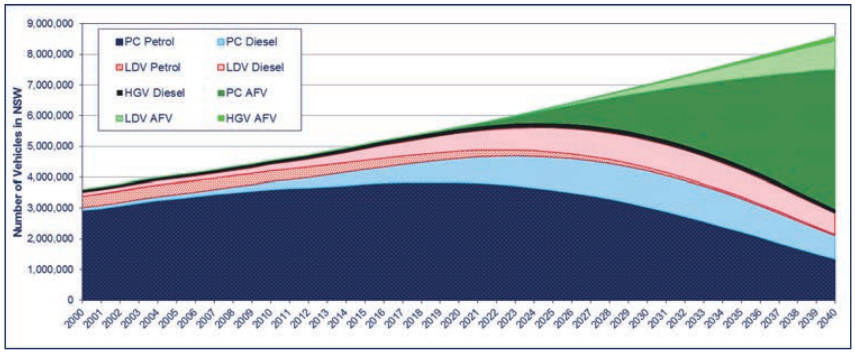


Figure 12: Growth rate and total volume of the NSW vehicle fleet and NSW population.

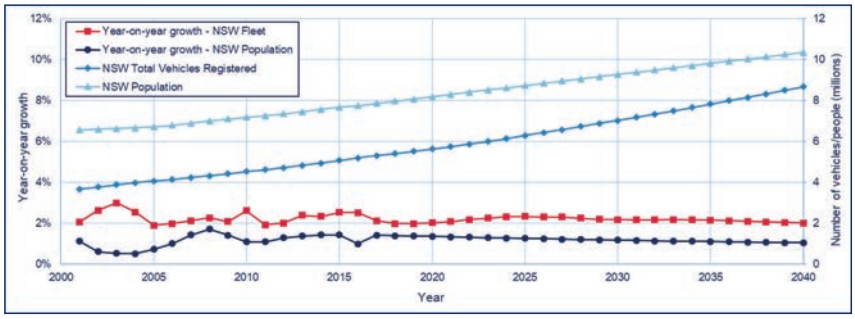


Table 11: Validation Study Key Statistics – Eastbound

Measure	CO	NO_x	NO_2	PM_{10}
Estimation Bias	87.5 %	82.6 %	97.4 %	148.9 %
Regression Line Coefficient	0.81 ± 0.004 (p-val < 0.001)	0.73 ± 0.0027 (p-val < 0.001)	0.93 ± 0.0043 (p-val < 0.001)	1.15 ± 0.007 (p-val < 0.001)
Regression Line Intercept	0.40 ± 0.0271 (p-val < 0.001)	0.41 ± 0.0155 (p-val < 0.001)	0.03 ± 0.0034 (p-val < 0.001)	47.67 ± 1.1582 (p-val < 0.001)
Coefficient of Determination (r^2)	0.87	0.91	0.86	0.76
Sum of Observed Emissions	44,280 kg	32,385 kg	4,697 kg	911 kg
Sum of Calculated Emissions	38,750 kg	26,762 kg	4,574 kg	1,357 kg

Table 12: Validation Study Key Statistics – Westbound

Measure	CO	NO_x	NO_2	PM_{10}
Estimation Bias	109.1 %	122.3 % %	137.9 %	192.9 %
Regression Line Coefficient	1.13 ± 0.0094 (p-val < 0.001)	1.31 ± 0.0067 (p-val < 0.001)	1.67 ± 0.01 (p-val < 0.001)	1.94 ± 0.0121 (p-val < 0.001)
Regression Line Intercept	- 0.13 ± 0.0306 (p-val < 0.001)	- 0.1 ± 0.011 (p-val < 0.001)	- 0.06 ± 0.0025 (p-val < 0.001)	4.81 ± 1.0972 (p-val < 0.001)
Coefficient of Determination (r^2)	0.66	0.84	0.77	0.71
Sum of Observed Emissions	19,229 kg	9,287 kg	1,452 kg	501 kg
Sum of Calculated Emissions	20,988 kg	11,354 kg	2,002 kg	1,070 kg

vehicles may be seen as new AFV models are introduced to the market. Conversely, a supply limitation of AFVs due to market could cause vehicle owners to retain their vehicles for longer.

Another key assumption in the model is the constant growth of the total number of vehicles from 2020 to 2040. To ensure that this assumption was appropriate, the year-on-year growth rate and total volume of the NSW fleet was compared with the NSW population (NSW Department of Planning, 2019). These are plotted in Figure 12. A relationship between the growth rates of the vehicle fleet and NSW population is present in the ratio of approximately 2:1.

5.2 Research Qu. 2: Does the NSW emissions estimation model correlate with tunnel data?

5.2.1 Validation Study Results

A summary of the key statistics for each pollutant (CO, NO_x, NO_2 and PM_{10}) is presented in Table 11 for the eastbound direction and Table 12 for the westbound direction. The estimation bias is the ratio of estimated emissions over observed emissions. An estimation bias greater than 100% indicates the model overestimated the observed emissions.

For brevity, only the scatter plot for the calculated vs. observed NO2 emissions is presented as the "pollutant of interest". Each point in Figure 13 represents one hour. The red line is the linear regression line with 95% confidence interval bounds. The black dashed 45° line represents equality between the observed and calculated emissions. Data points above the black line represent an over-estimation by the model, and below the line represents and underestimation by the model.

Figure 13: Scatter Plot: Nitrogen Dioxide (NO2) emissions – eastbound direction

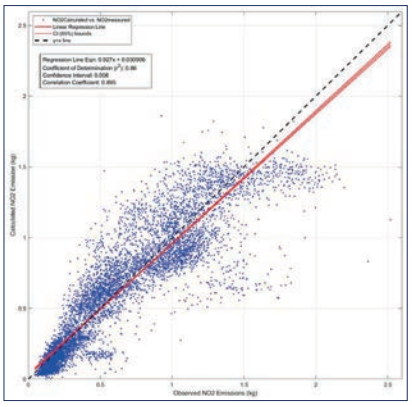


Figure 14: Scatter Plot: Nitrogen Dioxide (NO2) emissions – westbound direction

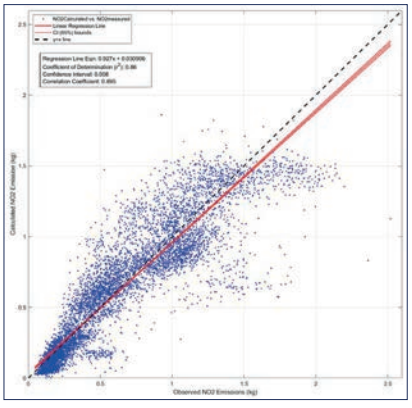
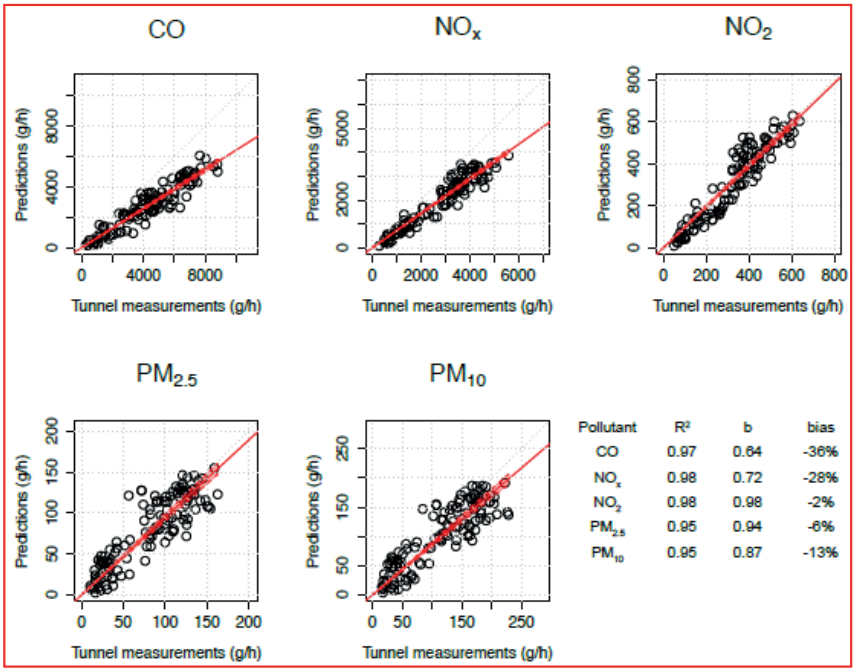


Figure 15: Results from a similar validation study using a Brisbane road tunnel (Smit, et al., 2015)



5.2.2 Discussion

There is a strong correlation between the observed and calculated emissions for all pollutants across the assessment period. A similar validation study, undertaken on a Brisbane road (Smit, Kingston, Wainwright, & Tooker, 2016) sought to validate the previous set of PIARC (2012) emission factors. Smit, et al. (2015) used a vehicle emissions software program and a slightly different methodology for a shorter timeframe. However, the estimation bias for all pollutants are similar to this paper's validation study. A summary of the results from the Smit, et al., (2015) study is presented in Figure 15.

Figure 15 Results from a similar validation study using a Brisbane road tunnel (Smit, et al., 2015)

The most prominent influence on the emissions model's over or underestimation is road gradient. The eastbound direction is typically uphill (+2% on average) and calculated emissions tend to slightly underestimate whereas estimations for the westbound direction systematically tend to overestimate. The road gradient of the westbound tube is typically downhill (-1% on average). A likely reason for this observation is the unpredictability of driver behaviour when driving downhill, switching between coasting and accelerating. Driving on uphill road gradients requires periodic acceleration.

The validation study contains a range of sensitivities and uncertainties: the collection and averaging of traffic speeds and counts, time delays between emissions generation and measurement, changes in the fleet composition, secondary reactions of pollutants, instrumentation error, inaccurate instrument sampling techniques, emissions from natural gas and diesel buses and background air quality assumptions.

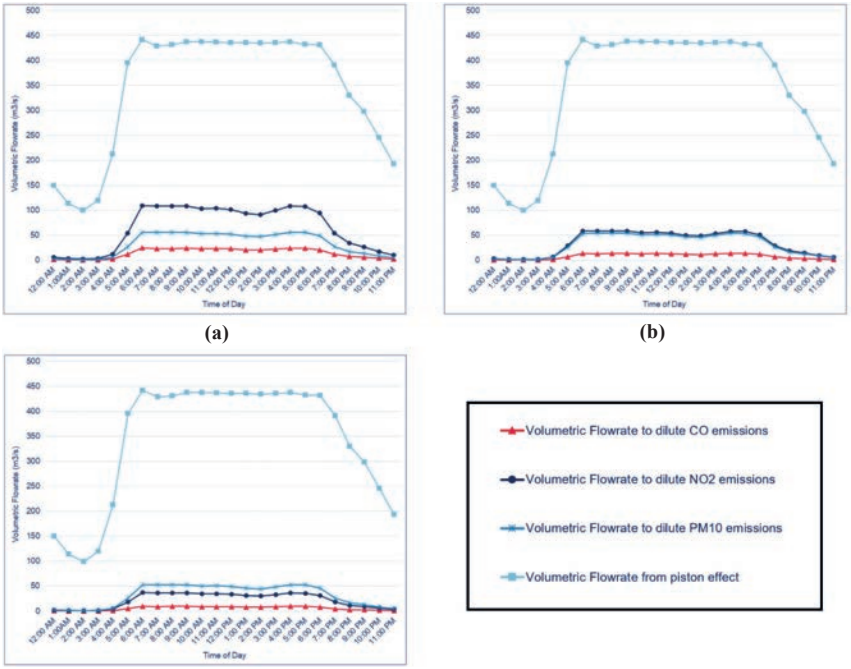
5.3 Research Qu. 3: What are the impacts of changes in the NSW fleet on tunnel ventilation energy consumption?

The impacts of changes in the NSW fleet on energy consumption were nil.

The only impacts from changes in the NSW fleet from different growth rates of AFVs are the emissions generated by vehicles. However, with the zero net portal emissions air quality criterion imposed, the induced volumetric airflow from vehicles is greater than the required airflow for emissions dilution. This requires the exhaust axial fans to operate 24 hours per day, even if no vehicles travel through the tunnel. Thus, even as vehicle emissions reduce under each fleet forecast scenario, the energy consumption remains constant

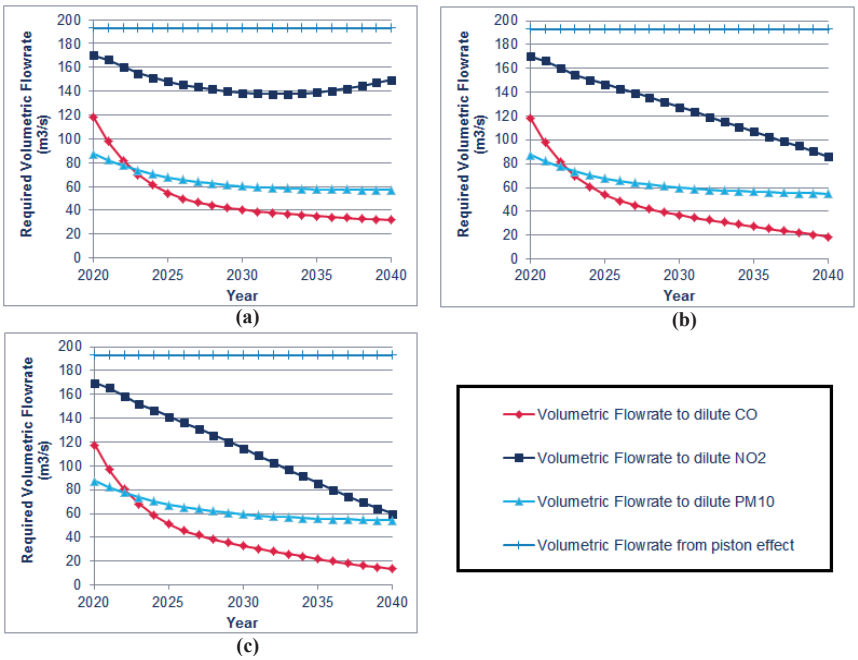
The normal operations daily profile of volumetric airflow for the 'base case' (a), 'expected case' (b) and 'accelerated case' (c) in the year 2040 are presented in Figure 16. It can clearly be seen that even as the required volumetric flowrate decreases for CO, PM_{10} and NO_2, the volumetric airflow from the piston effect dominates, requiring that axial fans are operated in order to exhaust all air through the ventilation outlet.

Figure 16: Daily profile volumetric flowrate for different requirements for (a) 'base case' scenario, (b) 'expected case' scenario, (c) 'accelerated case' scenario, 2040



Analysis of the required fresh air demand for peak-traffic at 20 km/h across the three fleet forecast scenarios from 2020 to 2040 provides an insight into changes in the dominant air quality

Figure 17: Required volumetric flowrate (m³/s) for different pollutants for (a) 'base case' scenario, (b) 'expected case' scenario, (c) 'accelerated case' scenario, 2020-2040



criteria over time. These curves are presented in Figure 17 for the 'base case' (a), 'expected case' (b) and 'accelerated case' (c). Under the base case, Figure 17 (a), an unusual trend occurs where NO_2 emissions decrease to a minimum in 2032 and increase to 2040. This is likely due to the increase in Euro 4, 5 and 6 diesel vehicles in the NSW fleet which generate more NO_2 than older vehicles.

5.4 Research Qu. 4: What impacts will variations in air quality criteria on tunnel ventilation energy consumption?

The main variation in air quality criteria on tunnel ventilation energy consumption is the relaxation of the zero net portal emissions criterion. The relaxation of this criterion enables tunnel air to be expelled through the portals. A systematic analysis of different portal exit concentrations was carried out, focussing on NO_2 as the driving pollutant for fresh air demand. The results of the number of hours each day the piston effect was sufficient to ventilate the tunnel are provided in Figure 18. The annual energy consumption from the ventilation system to meet each NO2 exit-portal concentration is plotted in Figure 19. Note that both analyses were undertaken for one direction in the tunnel. Energy savings metrics would be doubled when considering the whole tunnel.

The exit-portal NO_2 concentration of **0.12ppm** posed the most adequate benefit across all years from 2020 to 2040, balancing energy consumption and ambient concentration goals NEPM (2016). Taking the 0.12ppm NO_2 exit portal concentration as the target, the average annual energy savings from relaxation of the zero net portal emissions requirement would be approximately **12.1 GWh (~83%)** if implemented across the day, or **3.6 GWh (~25%)** if implemented during off-peak hours.

5.5 Research Qu. 5: What are the cumulative impacts of changes in the NSW fleet and air quality criteria on tunnel ventilation energy consumption?

The final question combines the results from sections 5.3 and 5.4. A target of 0.12ppm NO_2 at the tunnel exit was implemented and portal emissions were assumed to occur at all times. Table 13 summarises the average annual energy consumption levels, financial savings and environmental benefits from the

Figure 18: No. of hours per day that the piston effect provides sufficient ventilation when (a) portal emissions occur across the day and (b) portal emissions occur in off-peak hours at different exit-portal NO_2 concentrations (ppm), 2020 to 2040

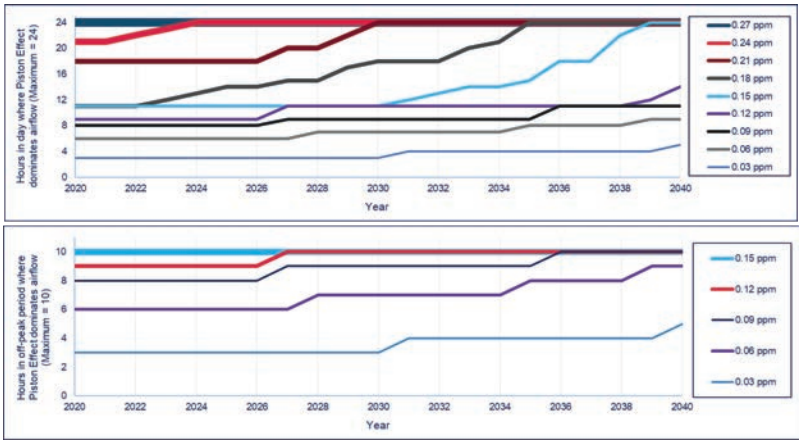


Figure 19: Annual energy consumption for (a) portal emissions across the day and (b) portal emissions in off-peak at different exit-portal NO_2 concentrations (ppm), 2020 to 2040

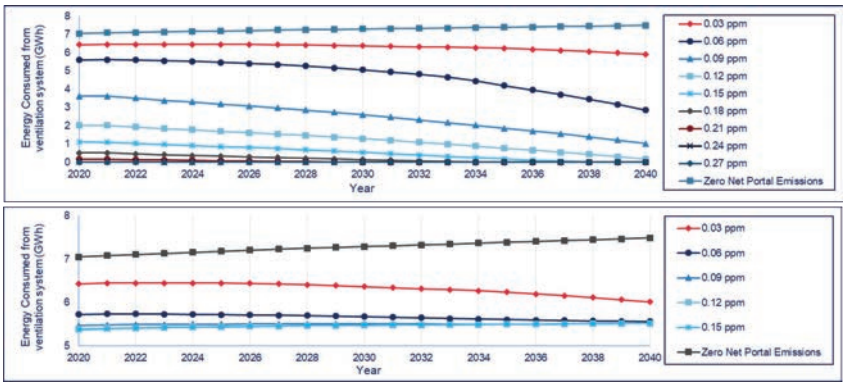


Table 13: Summary of implications of changes to air quality criteria and NSW fleet

	'Base Case'	'Expected Case'	'Accelerated Case'
Average annual energy consumption (GWh)	3.7	2.4	1.8
Average annual energy saving (GWh)	10.8 (74%)	12.1 (83%)	12.8 (88%)
Financial saving ($ millions)	1.302	1.456	1.536
Environmental saving (tonnes CO_2-e)	9002	10,074	10,627

relaxation of the zero net portal emissions criterion and changes in the NSW vehicle fleet under normal operating conditions. The cumulative impacts of changes in the NSW fleet are most prominent under the 'accelerated case' whereby no ventilation is required from 2037 onwards.

6 Conclusion

This study investigated the implications of the evolving vehicle fleet on ventilation energy consumption in NSW road tunnels. The annual energy, financial and environmental savings from the relaxation of the zero net portal emissions criterion and changes in the NSW fleet are summarised in Table 13.

The paper defined a number of secondary research questions that led to the final conclusions. The three forecasts of the NSW vehicle fleet encompass the range of likely AFV growth trends. The 'accelerated case' revealed that even under an aggressive growth scenario, a third of the vehicle fleet will comprise of ICE vehicles.

The NSW emissions estimation model validation study was a landmark investigation. It is the first validation study of the recently published PIARC (2019) to have been conducted, and the study's timeline spans one of the longest investigations for vehicle emissions validation. The key conclusions were:

- A strong correlation existed between the RMS NSW emissions estimation model and observations from a Sydney urban road tunnel.
- NO_2 emissions estimate tended to underestimate observed emissions by approximately 4% on uphill road gradients and overestimate by approximately 38% for downhill gradients

Without changes to the environmental air quality criterion of zero net portal emissions there are no realised energy consumption benefits from the increased adoption of AFVs under the expected and accelerated NSW fleet forecast scenarios.

A key conclusion was the acceptable NO_2 exit-portal concentration of 0.12ppm during periods of portal discharge. Analysis for the 'expected case' fleet forecast concluded potential savings of 83% compared to the status quo of zero net portal emissions. Future work would seek to scrutinise, validate and model the numerous assumptions and inputs identified throughout the project. Software such as IDA Tunnel and dispersion modelling may provide greater justification for the relaxation of the zero net portal emissions criterion. An investigation into the relaxation of zero portal emissions for specific NSW road tunnels should be conducted for the significant environmental and financial benefits that exist, especially as the NSW vehicle fleet evolves to include more alternative fuel vehicles.

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Australian and New Zealand Tunnel

Region	Location	Project	Client	Technical Advisor	Designer	Contractor
NSW	Sydney	NorthConnex	RMS	AECOM	Aurecon-SMEC JV	LendLease-Bouygues
NSW	Sydney	WestConnex Stage 2 (New M5)	Sydney Motorway Corporation	AECOM	Aurecon-Jacobs	CPB-Samsung -Dragados JV
NSW	Sydney	WestConnex Stage 3A (M4-M5 Link)	Sydney Motorway Corporation	AECOM	Aurecon-Jacobs	LendLease-Bouygues - Samsung JV
NSW	Sydney	WestConnex Stage 3B (Rozelle Interchange)	RMS	AECOM	Arcadis/WSPJV-MJA-PSM	John Holland-CPB
NSW	Sydney	Sydney Metro City and South East TSE Contract	TfNSW		Arcadis-MJA-PSM	John Holland/ CPB/ Ghella JV
NSW	Snowy Mtns	Snowy 2.0	Snowy Hydro	SMEC	Lombardi	Salini-Clough-Lane JV
NSW	Sydney	M6 Stage 1 (formerly known as F6 Stage 1)	RMS	Aurecon		
NSW	Sydney	Sydney Metro West - Tunnels and Station Excavation Works	TfNSW	MottMacDonald		
NSW	Sydney	HarbourLink - Western Harbour Tunnel	Tf NSW	WSP/ARUP		
NSW	Sydney	Syndey Metro Western Sydney Airport - Station boxes and Tunnels Contract	TfNSW	MottMacDonald		
NSW	Sydney	HarbourLink - Northern Beaches Link	RMS			
NSW	Illawarra	Maldon to Dombarton Rail Link	TfNSW	WSP		
Qld	Gold Coast	Gold Coast Seeway	Gold Coast Water		WSP	John Holland
Qld	Brisbane	Cross River Rail	Cross River Rail Delivery Authority	ARUP	PSM-RBG-Hatch-Geodata	CPB-Ghella-BAM
Qld	Brisbane	Brisbane Metro	Brisbane City Council	Jacobs		
Qld	Toowoomba	Inland Rail Kagaru to Gowrie PPP	ARTC	ARUP/SMEC	Aurecon/AECOM (Reference design)	
Vic	Melbourne	Melbourne Metro Tunnel and Stations PPP	MMRA	Aurecon Jacobs Mott MacDonald	ARUP/Arcadis/WSP	Cross Yarra Partnership comprising Lendlease, John Holland, Bouygues and Capella Capital.
Vic	Melbourne	West Gate Tunnel	Transurban	AECOM	Aurecon/Jacobs	John Holland/CPB Contractors JV
Vic	Melbourne	North East Link	VicRoads	GHD		
Vic	Melbourne	Hobson Bay May Sewer	Melbourne Water	GHD		
Vic	Melbourne	Melbourne Airport Rail Link	Rail Projects Victoria	Aurecon Jacobs Mott MacDonald		
Vic	Melbourne	Suburban Rail Loop	Surburban Rail Loop Authority	Aurecon Jacobs Mott		
WA	Perth	Forrestfield-Airport Link Project	Public Transport Authority	Various	GHD, Geodata	Salini-Impregilo-NRW JV
NZ	Auckland	City Rail Link Package 3	Auckland Transport	Aurecon-Mott MacDonald		Vinci-Downer
NZ	Auckland	Central Interceptor Project	WaterCare	Jacobs/MJA/AECOM	Arup/Beca	Ghella-Abergeldie JV
NZ	Wellington	Wellington Northern Corridor	NZ Transport Agency		AECOM, Parsons Brinckerhoff and Beca	
NZ	Tauranga	Tauranga Tunnel	Local Govt			

Prospects

Scope of work	Current status
Spanning 9 km, NorthConnex will be the longest road tunnel project in Australia. Cost $3B	Awarded to Lend Lease Bouygues JV. Under construction for completion in 2020
Provision of additional four new lanes in a driven tunnel next to the existing the M5 East tunnel	Completed July 2020
Twin 8.5km road tunnels linking M4 East and M5 East Duplication and major undergound interchange at Rozelle	Contract awarded June 2018. Under construction for completion in 2023
Underground interchange linking the M4-M5 Link to Anzac Bridge, Iron Cove Link and future Western Harbour Tunnel	Contract awarded Dec 2018. Under construction for completion in 2023
Underground rail Link from Chatswood to Sydnenham via Central Station	Contract awarded June 2017. Under construction for completion in 2021.
2,000 MW pumped storage hydro scheme	Contract awarded to Salini-Clough-Lane JV
4 km of motorway tunnel from New M5 to Presidents Ave Kogarah	EoI closed Dec 2019. Tender expected Q2 2020
22 km underground metro rail link from CBD to Westmead	Tender for Central Contract expected September 2020
Road tunnel linking WestConnex with North Sydney (Military Road)	EoI expected November 2020
Metro rail link from St Marys to the new Western Sydney Airport currently under construction	Tender expected Q1 2021
Road tunnel beneath Mosman connecting City with Northern Beaches	In planning
4 km single line rail tunnel forms part of 20 km rail link to Port Kembla	Registrations of Interest closed in April 2015 - On hold
Recycled water outfall pipeline including DN2100 pipejack, 1400 m long	Under construction for completion 2020.
New north-south tunnel(s) with connections running from Dutton Park in the south to Victoria Park in the north and new underground stations at Boggo Raod, Woolloongabba, Albert Street and Roma Street.	Construction commenced 2019
Brisbane Metro is a 21 kilometre service connecting 18 stations along dedicated busways between Eight Mile Plains and Roma Street, and Royal Brisbane and Women's Hospital and University of Queensland with easy links between Metro, bus and train services. Includes a new underground bus station at the Cultural Centre and a tunnel along Adelaide Street	Awarded to Acciona
126 km rail link which includes three tunnels totalling 8.5 km in length	EoI submitted May 2019. Tenders expected Q3 2020
New rail tunnel between Footscray and South Yarra with new stations in North Melbourne, Parkville, CBD (2) and St Kilda Road.	Contract awarded in Dec 2017. Under construction
Proposed twin road tunnels (6km) and elevated road structures linking the Westgate Freeway at Williamstown Road with City Link	Contract awarded in Dec 2017. Under construction
Potential road tunnel from Greensborough to Bullen linking the Western Ring Road to the Eastern freeway	Tenders submitted June 2020
Upgrade of existing Hobson Bay Main Sewer crossing of the Yarra River	Tender expected Q4 2020
Rail link to Melbourne Airport. Tunnel scope yet to be confirmed	In planning
90 km long rail loop to connect outer suburbs of Melbourne. To be delivered in four stages.	In planning for commencement in 2022
7.1 km twin-bored, concrete-lined and 6.2 m internal diameter tunnels extending from Guildford Road in Bayswater to Dundas Road in Forrestfield. Three stations; Airport West station will be located underground in the Brearley Avenue road reserve, between Second Street and Dunseith Drive, close to the current Domestic Airport precinct	Under construction
A 3.5 km loop linking Britomart with the current western line. Three new underground stations at Aotea Square, Newton and K' Road. Britomart to Downtown involves tunneling under the historic Central Post Office building which is now home to Britomart station. On the other side of Downtown up to Wyndham St will be cut and cover tunnels	Contract awarded July 2019
New sewer tunnel approximately 14 km in length from central Auckland to Mangere Wastewater Treatment Plant	Under construction
Four lane expressway from Levin to Wellington Airport including duplication of Mt Victoria and Terrace tunnels	Site investigation underway
Three routes for a road tunnel through the Kaimai Ranges, linking Tauranga with the Waikato	Currently being investigated by the NZ Transport Agency

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ISSN 2633-0466 Issue No 2 October 2019

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- Melbourne Metro Tunnel Project, VIC
- NorthConnex Project, NSW
- Pacific Highway - Tintenbar to Ewingsdale Tunnel Project, NSW
- Clem7 Jones Tunnel Project, QLD
- Tugan Bypass Tunnel, QLD
- Cross City Tunnel, NSW
- Bondi Junction Turnback, NSW
- M5 East Tunnel Project, NSW
- NorthBridge Tunnel, WA

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