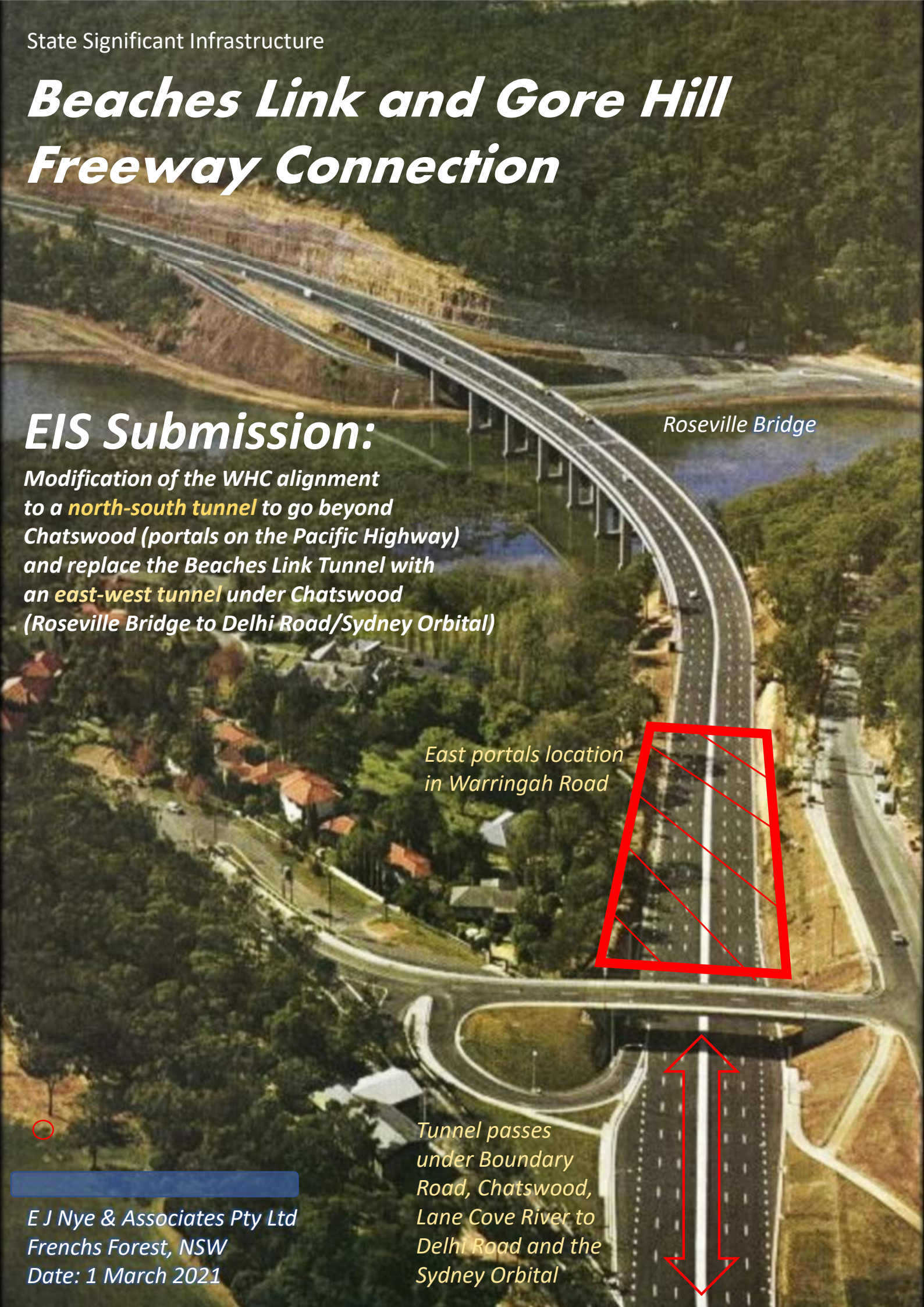
State Significant Infrastructure

Beaches Link and Gore Hill Freeway Connection

EIS Submission:

Modification of the WHC alignment to a north-south tunnel to go beyond Chatswood (portals on the Pacific Highway) and replace the Beaches Link Tunnel with an east-west tunnel under Chatswood (Roseville Bridge to Delhi Road/Sydney Orbital)



E J Nye & Associates Pty Ltd
Frenchs Forest, NSW
Date: 1 March 2021

Executive Summary

Sydney's population is expected to grow from the current 5 million to 10 million by 2066 (ABS – 2017). That is only 35 years away, and on a timescale for major infrastructure, not that far into the future. For example, the Sydney Harbour Tunnel is already 30 years old and the Sydney Harbour Bridge will be 100 years old in 2033.

It is important, therefore, that we get our major infrastructure right! Especially if the capital cost is in the billions of dollars. There are also significant flaws in the current proposal with regards to road safety and delay.

Unfortunately, both the Western Harbour Crossing (WHC) and the Beaches Link Road Tunnel (BLRT), fall well short of what I would consider the most cost-effective solution, without even considering other factors.

The BLRT concept in the current proposal has been taken straight from the old Department of Main Roads (DMR) 1969 archives, and the WHC has just been tacked on to it through an already compromised Warringah Expressway.

It is obvious that credible alternatives schemes have not been assessed and a lot has happened since 1969! Which requires new thinking.

Without giving an endless list of these changes, perhaps the most important is the growth of Chatswood and its potential to grow going forward as a regional CBD. This growth will accelerate soon with the completion and full operation of the Sydney Metro Rail Project in 2024.

Chatswood already has significant traffic congestion issues, both for east-west and north-south traffic. Chatswood is already Australia's largest commercial centre outside city CBDs

The BLRT does nothing for the wider road network on the North Shore because it deposits all its traffic at the southern end of the Northern Beaches (weekends will be even worse).

Just one issue on road safety/delay will be mentioned here, as an example, the risk of head-on collisions on the Sydney Harbour Bridge. The lane widths do not comply with current road standards and a movable road barrier should be installed along the full length of the bridge to prevent these collisions. Concentrating road traffic through the Warringah/Gore Hill Expressway there is no redundancy in the road network should a traffic accident occur and will occur, no matter how many "safety in design" principles are applied.

This submission is not about providing a commentary on possible tweaks to the WHC and the BLRT, it is about getting a complete rethink of the combined projects to improve traffic flow and road safety north of the harbour, improve the economic viability of Westconnex (by directing more traffic to it) and not leaving lose ends around, like the traffic congestion at Chatswood, both now and into the future.

The EIS fails to satisfy the EIS legislative requirements of reporting Alternative solutions.

(note the front cover photograph, of the Roseville Bridge at the time of completion, no vegetation on the embankments (and hence the potential to accommodate widening and tunnel portals appears quite visible)! The Roseville Bridge was completed in 1966.

Executive Summary

Commentary

Contents

1. List of reasons for a rethink! (with 4 figures attached, Figure 3, updated).
   (for meeting with the WHBL - Traffic Leader, 11 Feb 20102 – North Sydney)

2. Text and images - 4 posts made to 'Linkedin' over several months
   (during 2020 and 2021).

3. Memo to the Minister for Transport and Roads (dated 18 Nov 2020)
   (minus the updated figures given in Item 1 above).

Attached to this EIS submission is a paper published last year – "Sydney Heads Rail Tunnel – a treasure trove of planning opportunities" just to show there are also alternative or complimentary transport modes that should be considered when planning the growth of the North Shore and beyond (it not all about transport either, but city planning).

Commentary

I am sure others will address the traffic distribution predictions given in the EIS between the various road corridors. The shifts in traffic volumes are insignificant given the cost of the project. A tolled BLRT will never get the volumes of traffic predicted in the EIS because the tunnel is a side issue in the overall road network on the North Shore. This is for both east-west and north-south traffic.

The Roseville Bridge is a significant asset *whose full potential has not been realised* and the EIS traffic numbers predicted *degrade its importance*. Toll avoidance, however, will ensure that it keeps its status, along with Warringah Road, as the major east-west traffic route within the North Beaches.

For all the money being potentially spent, the Spit Bridge remains in its current form. I have a potential solution for this, but this is not included in this submission, and it is not a high-level bridge replacement.

(i) The EIS fails to satisfy the EIS legislative requirements of reporting Alternative solutions.

It is evident that the study area has been limited to immediate connections to the existing network in and around North Sydney and has not taken a strategic planning approach.

It fails therefore to investigate north-south traffic improvement alternatives to and from the Warringah Freeway and WHC to the north of Chatswood.

Glaringly, the EIS also fails to report alternative solutions to the proposed BLRT.

The proposed BLRT is unlikely to provide much benefit to East-West traffic movements into and out of the Northern Beaches.

Investment in the Warringah Road corridor, which is the main access corridor into and out of Northern Beaches would result in higher economic returns compared with the BLRT.

Rail access from the Sydney CBD to the Northern Beaches, which would be a far more sustainable solution and would support the future commercial and economic development of the Northern Beaches, has not been reported.

ii) Inconsistent Planning and Design Approaches

It is also evident from the EIS that the proposed WHC northern connections to the Warringah Freeway are at a lower standard compared with its southern connections with WestConnex.

This would result in lower levels of service on the northern side of the Harbour. This is a flaw in the planning design, largely because of the limited study area given to the design team and failure to investigate and report alternative solutions.

1. List of reasons for a rethink! (with 4 figures attached, Figure 3, updated).

(for meeting with the WHBL - Traffic Leader, 11 Feb 20102 – North Sydney)

A. North-south Connection

1. Given the potential increase in traffic with a rising population the Western Harbour Crossing connection with the Warringah/Gore Hill Expressway is unsustainable as the number of accidents (impacting on road safety and delay) will increase over time (refer to Figure 1 attached).
2. The standard of motorway design on the north side is not compatible with the high standards adopted for Westconnex on the south side of the Harbour. An example from the south side being the Rozelle Interchange (refer to Figure 2 attached).
3. The current proposal, while it in part addresses the north-south traffic, it does not extend sufficiently north to Chatswood and the Pacific Highway. Our proposal would strategically locate on-and-off ramps along its length.
4. Chatswood is expected to have significant employment growth of 38% by 2031, from a current base of 95,000(2015 study) to 130,000 workers. Chatswood is both a very significant traffic generator/attractor and has increasing traffic congestion problems (both north-south and east west).

B. East-west Connection

5. Boundary St (Chatswood)/Warringah Road are currently the main east-west arterial roads bringing traffic into the Northern Beaches (2014 report, at 80,000 vehicles per day) and the route should continue to be improved. The NSW Government has already spent $600m on road works on Warringah Road, grade separating Forest Way and Wakehurst Parkway in Frenchs Forest and increasing the railway bridge span over Boundary Street.
6. An east-west tunnel from the west side of the Roseville Bridge to Dehli Road, Ryde and connecting with the Sydney Orbital is a logical route given the current and future growth of Western Sydney to improve east-west traffic flow.
7. The Beaches Road Tunnel Link(BRTL) entry and exits are at the south end of the northern beaches and with the “double toll” (BRTL and Lane Cove Tunnels) and extra travel distance and time is unlikely to attract east-west traffic from most of the Northern Beaches. Note also the pinch point at the east portals of the LCT, only 2 lanes.
8. Without an east-west tunnel the rabbit runs and traffic on Dehli Road west of the Pacific Highway will continue to be used together with the long route to Macquarie and Lane Cove Road etc via Forest Way/Mona Vale Road to the north of Warringah Road.

C. Alternative Route – Plan

9. The attached concept plan is an alternative to the current Government proposal, and it has been developed to address the issues raised above (refer to Figure 3 attached).

10. The outcome of this short list is to persuade the WHC/BRTL team to assess this alternative given the billions of dollars involved in projects of this type and the problems, in my opinion, that have been highlighted with the current proposal.

11. The combined north-south and east-west tunnel is designed to direct as much traffic as possible into/from the Westconnex network on the south side of the harbour.

12. Please also refer to Figure 4 and the notes. This is the 1969 DMR concept for the BRTL.

Figure 1

Figure 1. Warringah/Gore Hill Expressway and 3 other road corridors that converge onto it

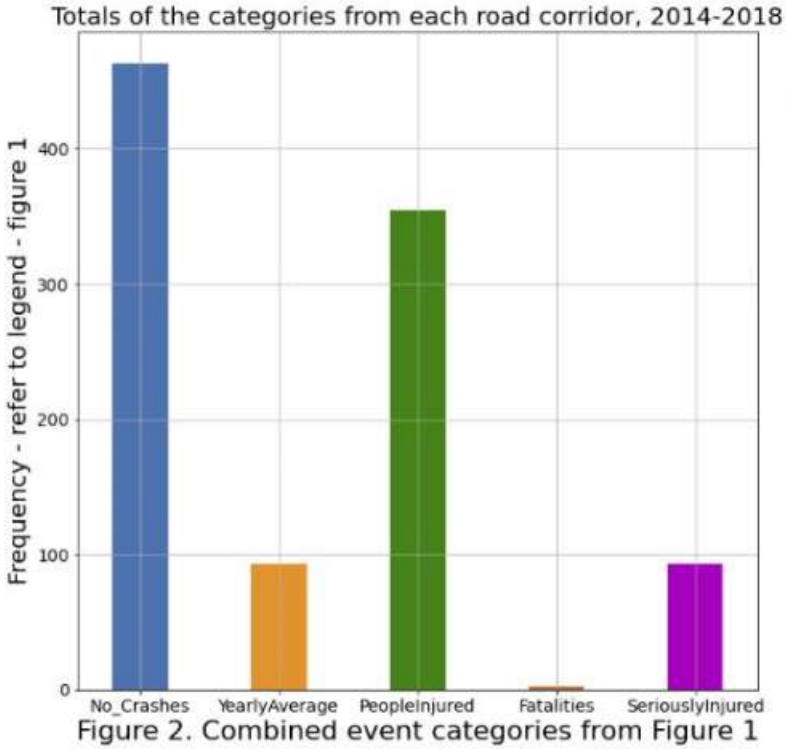


Figure 2. Combined event categories from Figure 1

a) Fatal head-on collision Sydney Harbour Bridge - 27 Aug 2020 – major traffic delays

c) Head-on collision Sydney Harbour Bridge 21 Dec 2020. Morning peak – low traffic due to northshore lockdown – bus delays

b) Vehicle fire in Sydney Harbour Tunnel - 25 Aug 2020 – major traffic delays

d) No image
Fatal motorcycle accident - Saturday 3.15pm 21 Nov 2020 – Warringah Expressway, near the north portal of the Sydney Harbour Tunnel.

Slide prepared by E J Nye & Associates Pty Ltd – 24 Jan 2021

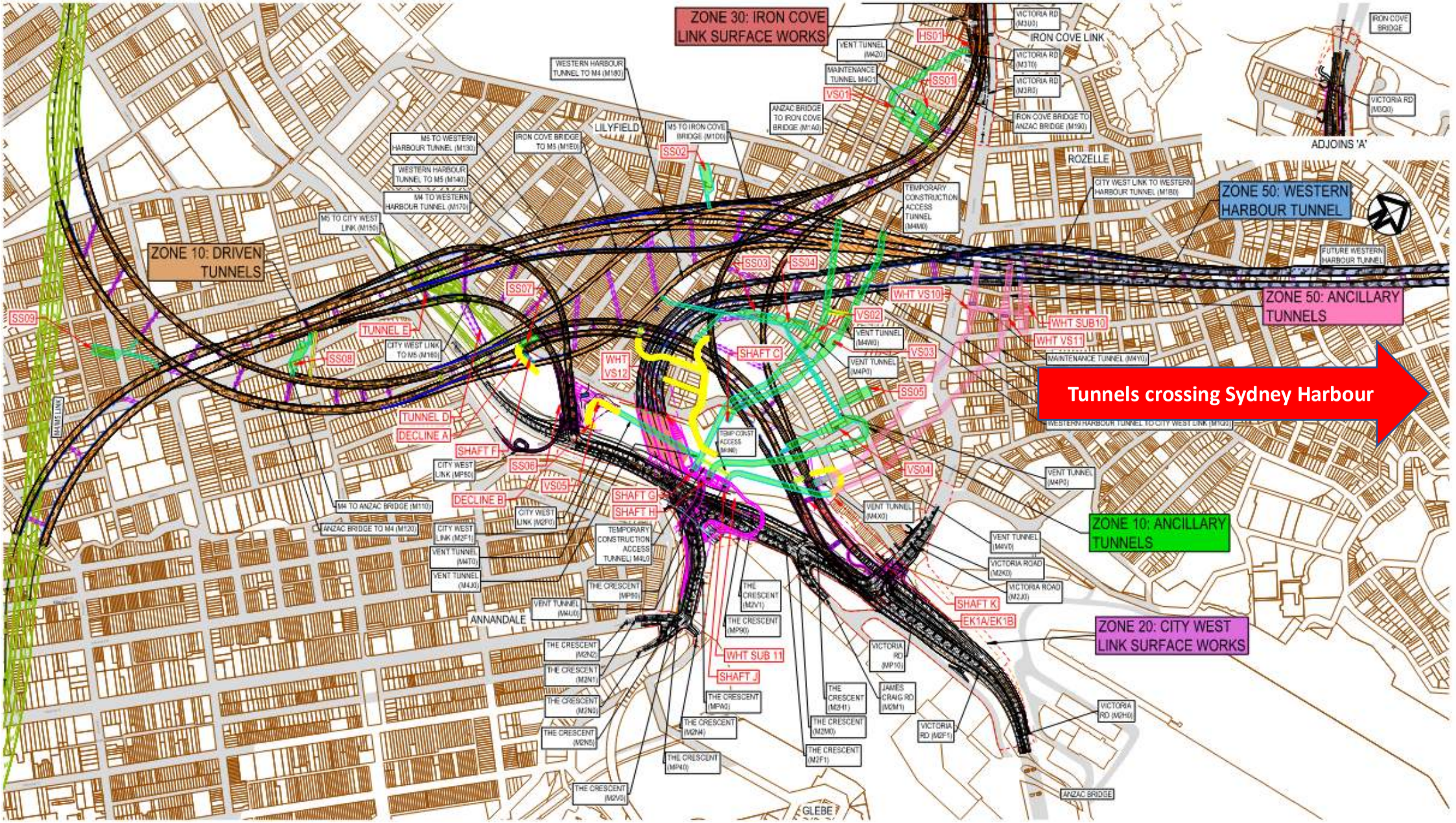


Figure 2 – Westconnex - Rozelle Interchange

(these are all tunnels -around 20km of them) except for lower centre and lower right)

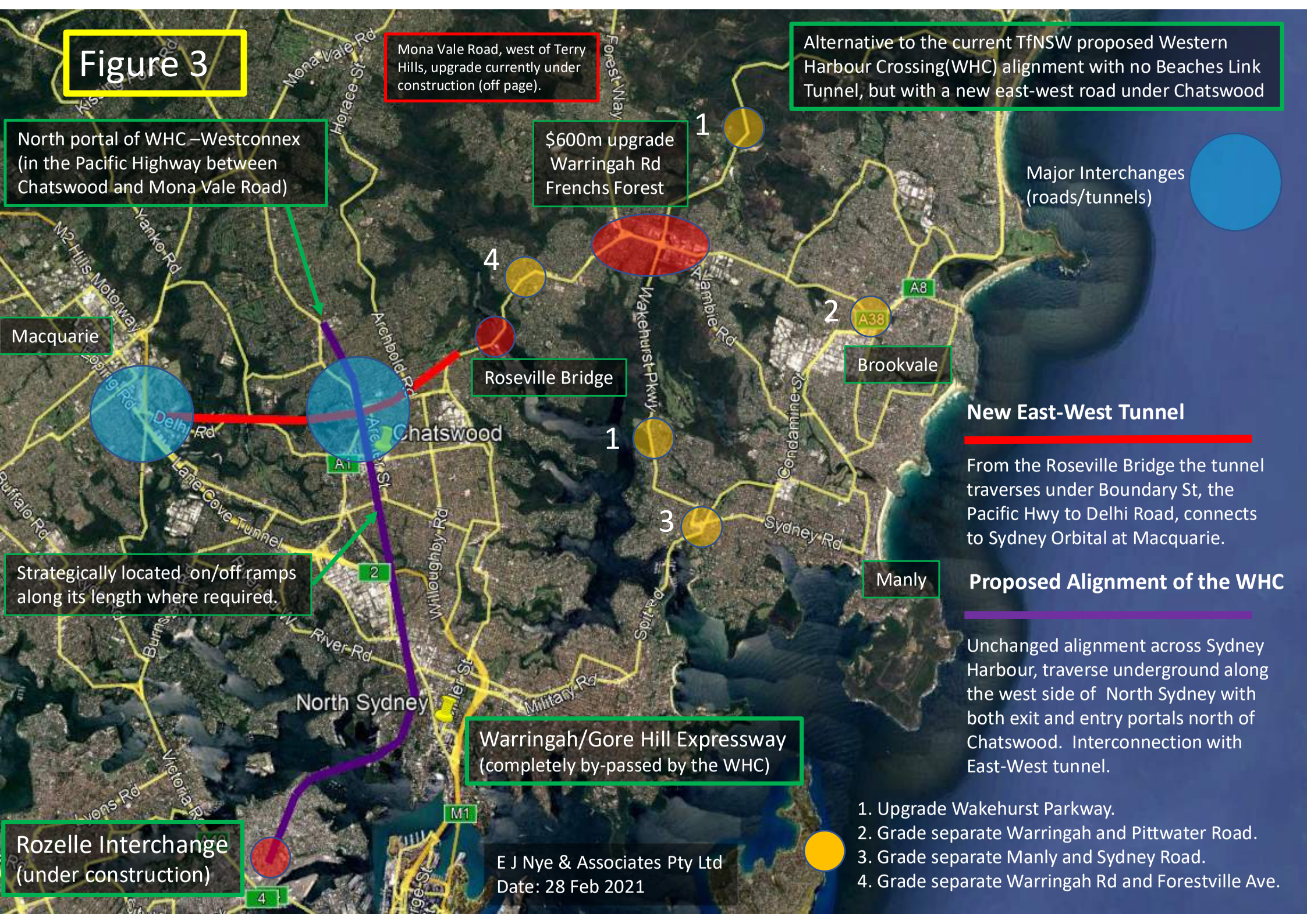


Figure 3
Mona Vale Road, west of Terry Hills, upgrade currently under construction (off page).
Alternative to the current TfNSW proposed Western Harbour Crossing(WHC) alignment with no Beaches Link Tunnel, but with a new east-west road under Chatswood
North portal of WHC –Westconnex (in the Pacific Highway between Chatswood and Mona Vale Road)
$600m upgrade Warringah Rd Frenchs Forest
Major Interchanges (roads/tunnels)
Macquarie
Roseville Bridge
Brookvale
Chatswood
New East-West Tunnel
From the Roseville Bridge the tunnel traverses under Boundary St, the Pacific Hwy to Delhi Road, connects to Sydney Orbital at Macquarie.
Strategically located on/off ramps along its length where required.
Manly
Proposed Alignment of the WHC
Unchanged alignment across Sydney Harbour, traverse underground along the west side of North Sydney with both exit and entry portals north of Chatswood. Interconnection with East-West tunnel.
North Sydney
Warringah/Gore Hill Expressway (completely by-passed by the WHC)
Rozelle Interchange (under construction)
E J Nye & Associates Pty Ltd
Date: 28 Feb 2021
1. Upgrade Wakehurst Parkway.
2. Grade separate Warringah and Pittwater Road.
3. Grade separate Manly and Sydney Road.
4. Grade separate Warringah Rd and Forestville Ave.

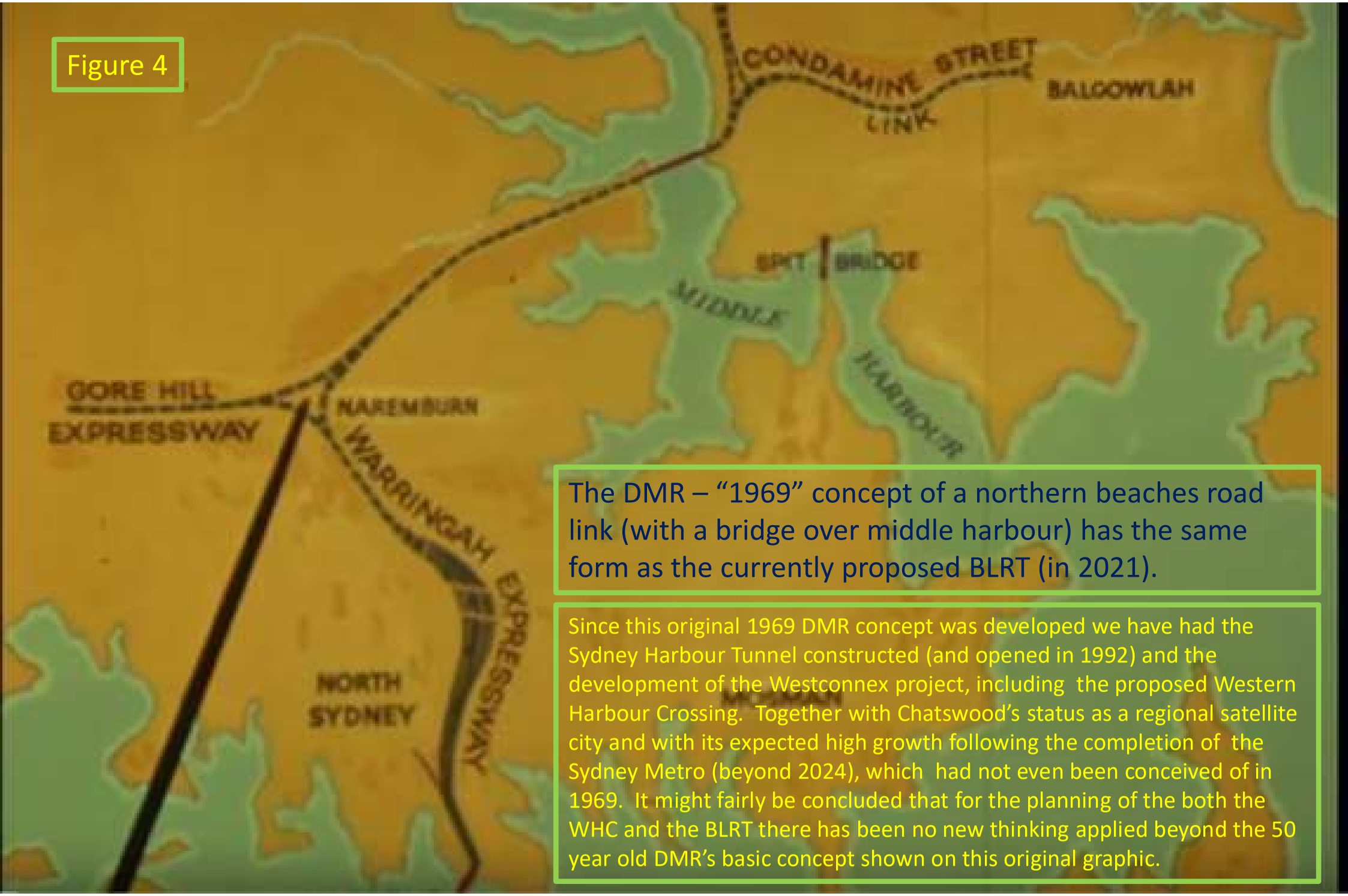


Figure 4
CONDAMINE STREET
LINK
BALGOWLAH
SPIT BRIDGE
MIDDLE
HARBOUR
GORE HILL
EXPRESSWAY
NAREMBURN
WARRINGAH EXPRESSWAY
NORTH
SYDNEY
The DMR – "1969" concept of a northern beaches road link (with a bridge over middle harbour) has the same form as the currently proposed BLRT (in 2021).
Since this original 1969 DMR concept was developed we have had the Sydney Harbour Tunnel constructed (and opened in 1992) and the development of the Westconnex project, including the proposed Western Harbour Crossing. Together with Chatswood's status as a regional satellite city and with its expected high growth following the completion of the Sydney Metro (beyond 2024), which had not even been conceived of in 1969. It might fairly be concluded that for the planning of the both the WHC and the BLRT there has been no new thinking applied beyond the 50 year old DMR's basic concept shown on this original graphic.

2. Text and images - 4 posts made to 'Linkedin' over several months

(during 2020 and 2021).

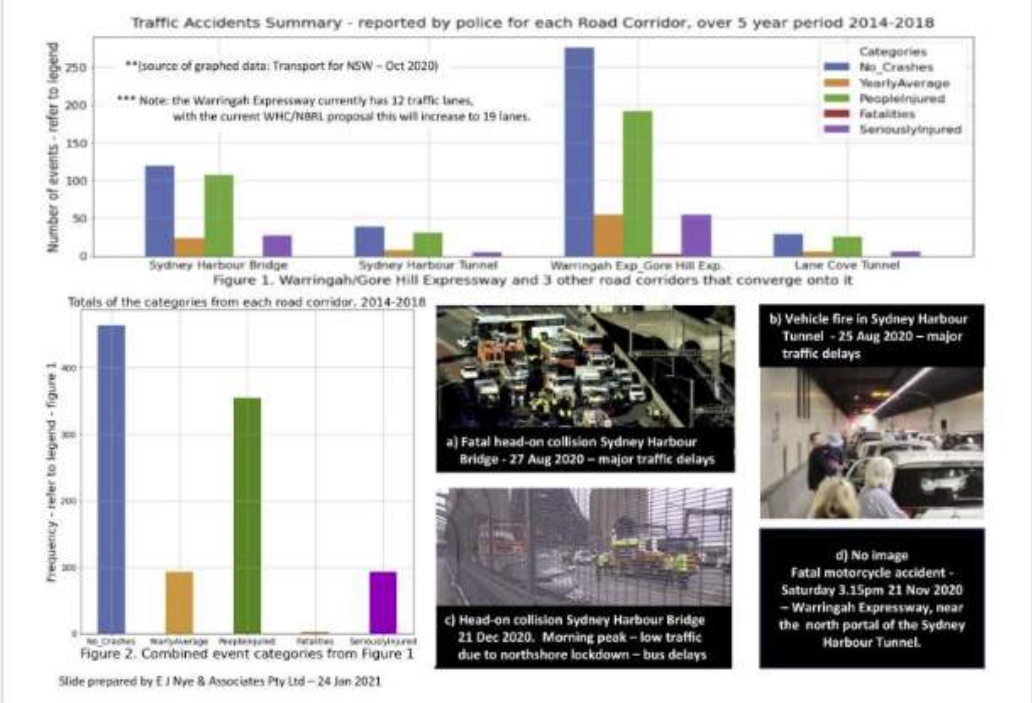
A. 7 Months ago

Pleased to publish another paper, "Sydney Heads Rail Tunnel – a Treasure Trove of Planning Opportunities" at the virtual WTC2020 Congress (September) from KL Malaysia. The paper also touches on the flaws in the Northern Beaches Road Tunnel (which should be scraped) and the north shore alignment of the proposed Western Harbour Crossing (keeping the currently proposed harbour crossing, but re-aligned to go north towards Chatswood, not North Sydney). The upgraded Warringah Road (at Frenchs Forest, see photograph below) could be a significant traffic attractor (away from Military Road) together with the duplication of Mona Vale Road, currently under construction. The biggest missing links on the north shore are a Boundary Street to Delhi Road tunnel connection (starting at the west end of the Roseville bridge) and upgrades to the Pacific Highway (via at least a north south tunnel by-passing Chatswood). The Federal Government initiated Northconnex tunnel study (2005) also considered a tunnel route under the Pacific Highway, traffic congestion at Chatswoods being significant issue. #Transport

B. 1 month ago

Western Harbour Crossing(WHC) and Road Safety (Warringah Expressway(WE))
"Thank you for your interest in road safety ...." the opening text to a letter from Transport for NSW in October 2020, following my request for accident data - Lane Cove Tunnel, Warringah/Gore Hill Expressway(W/GH), Sydney Harbour Tunnel and Bridge. Note the spike in traffic incidents for the W/GH Expressway. The frequency of traffic incidents will increase during construction and after, due to the number of traffic lanes in the WE increasing from 12 to 19. If completed in its current form, the number of traffic incidents along this whole, already compromised road corridor, will also increase with traffic volumes/population and the sheer complexity of the road network. I have posted previously a description of a better option, which extends the WHC tunnel up to Chatswood and replaces the Beaches Link with a road tunnel connecting Warringah Road (just west of the Roseville Bridge) to Delhi Road, under the Pacific Hwy. The WHC then is not reliant on the WE. There will be a significant increase in road accidents in this corridor and road safety and the network will be compromised compared with more effective alternatives.

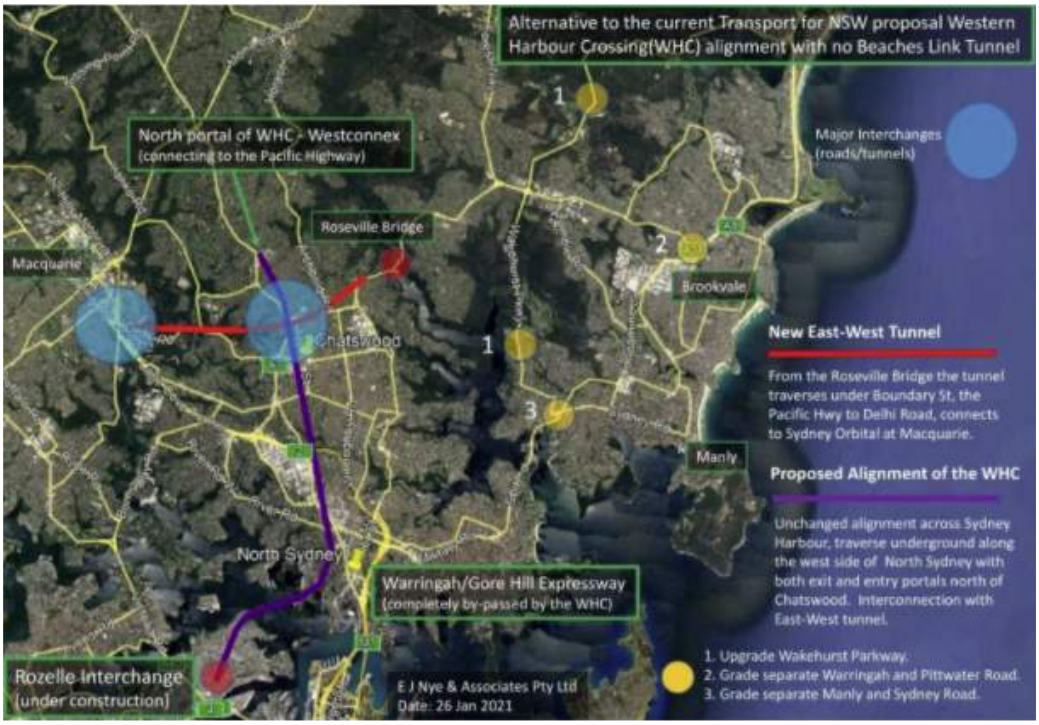
#roadsafety #sydneyconstruction #westernharbourtunnel #transportfornsw



C. 1 month ago

Proposed Western Harbour Crossing(WHC) - Warringah Expressway(WE) connection a design folly and professional embarrassment.

Major strategic infrastructure must have a 100-year design life, an example of this is the Sydney Harbour Bridge which will have been in operation since 1933. The Government's proposal to connect the WHC to the Northshore road network would fail this test. The graphic is my concept for a better alternative to the currently proposed WHC and Beaches Link Road Tunnel (BLRT). As a local resident of the Northshore and an engineer experienced in the design of strategic infrastructure projects, what is currently on offer is a professional embarrassment. As per my post of a few days ago the WE is an already compromised road corridor. The BLRT also has no social or economic justification. The obvious missing road upgrade is between Warringah Road (west of the Roseville Bridge) and Delhi Road, Ryde, and as anyone living in Sydney would know Delhi Road, across the Lane Cove River, is a goat track at peak times. There are also numerous rabbit runs across to Macquarie, west of the Pacific Highway, if you use Boundary Street at Chatswood. Locals travel north up Forest Way to Mona Vale Road, across and then south again to get to Macquarie and Lane Cove Road.



The above figure has been updated as in Section 1.

D. 5 days ago

Beaches Link Road Tunnel - a NSW Government rabbit hole/money pit

A project out of the old DMR's 1969 archive – that is the graphic below! (identical form to BLRT). No acknowledgement, future growth of Chatswood and the impact of the new Sydney Metro on this growth. Chatswood has both significant east-west and north-south (Pacific Hwy) traffic congestion issues. Warringah Road is the main east-west access road corridor with the Northern Beaches, ignored future potential even after a $600m upgrade at Frenchs Forest (potential for new road tunnel link to Delhi Road, Ryde and the Sydney Orbital starting at the 6 lane wide Roseville Bridge). WHC and the BLRT will be constrained by the pair of 2 traffic lanes only east portals of the Lane Cove Tunnel at peak times. No awareness of road safety and delay on the Warringah Expressway and Harbour Bridge road corridor and the negative impact on both that will follow from the increased complexity of the road network. Too many ways to avoid this tolled road tunnel. Military Road, Warringah Road and Mona Vale Road (major upgrade east of Terry Hills, under construction). Please view previous post for one alternative that aims to address all the above issues which should divert more traffic to the WHC and Westconnex.

3. Memo to the Minister for Transport and Roads (dated 18 Nov 2020)

(minus the updated figures given in Item 1 above).

Attention: Andrew Constance, Minister for Transport and Roads

(uploaded to the NSW Government website, Contact Ministers))

From: Ted Nye
E. J. Nye & Associates Pty Ltd
10 Malbara Crescent
Frenchs Forest, NSW, 2086

Date: 18 Nov 2020
Mobile: 0422003275
Email: ted.nye@nyeconsulting-eng.com.au

Dear Sir,

Re: Western Harbour Crossing and Northern Beaches Road Tunnel
Alternative Alignments

I am professional engineer with over 40 years' experience in major transport projects, both road and rail (from concept to commissioning). At the end of this letter I have provided a list of some of the projects and places around the world where I have developed this expertise.

I am writing to you because I do not believe the current tunnel alignments on the north shore for both the Western Harbour Crossing(WHC) and the Northern Beaches Road Tunnel(NBRT) are commercially and economically viable or enhance road safety nor minimise potential delays.

This is particularly so with regards to road safety and delay and within the road corridor that includes the Gore Hill - Warringah Expressways and the Sydney Harbour Bridge. The current alignments being proposed for both these tunnels will direct more traffic onto to this corridor (it already has 160,000 + vehicles/day). This will result in a greater number of traffic accidents and incidents within the corridor and the feeder roads to this corridor (i.e. the Lane Cove Tunnel, the Sydney Harbour Tunnel and the other remaining surface feeder roads e.g. Military Road).

When there are traffic accidents/incidents in the feeder tunnels or on the Harbour Bridge they have the potential to cause significant traffic grid lock over a wide area of the Sydney's road network and this will occur irrespective of the WHC and NBT tunnels being linked together under the Warringah Expressway.

This corridor is currently the northern gateway into/from the WHC and ultimately the whole of Westconnex.

Westconnex includes a road network investment of many billions of dollars. For example, just one element of Westconnex, the Rozelle Interchange alone will cost around $3billion (and it includes numerous multi-level tunnels for the purposes of providing grade separation).

On 10 August I messaged the Minister for Planning and Public Spaces, Rob Stokes, and outlined the above concerns with reference to the inadequacies of the EIS (please see the

attached correspondence). Unfortunately, with regards to both road safety and traffic disruption my concerns were graphically realised on the 25 and 27 August, just a few weeks later! (please see Attachment 1).

I then requested from TfNSW the traffic accident statistics for the Lane Cove Tunnel, Sydney Harbour Tunnel, Warringah Expressway and the Sydney Harbour Bridge(the response is Attachment No. 2) I have also prepared a graph of the data provided (Attachment No. 3). You can easily compare the accident statistics for each infrastructure transport element from the graph.

Sydney, with a population heading towards 10 million in 2066, deserves two completely independent major road crossings of the harbour in the areas relevant to this discussion to minimise the issues raised above. At least with one throughfare fully operational the Sydney traffic is not completely grid locked around the Harbour.

In order to achieve this, I have proposed the alternative alignments for both the WHC (land tunnels only) and the NBRT outlined in Figure 2 (Attachment No. 4). The concept provides redundancy to the road network i.e. Westconnex/WHC and the Warringah Expressway /Sydney Harbour Bridge operate completely independently from one another.

The replacement tunnel for the NBRT also provides an important missing link, connecting Warrringah Road with Dehli Road (and the Sydney Orbital) starting from a portal just west of the existing Roseville Bridge (Attachment No. 4).

My proposal, I believe, is also consistent with the large scale thinking behind Westconnex, while the ad hoc solution around the Warringah Expressway corridor is not (i.e. with numerous additional merging and diverging traffic lanes, plus disruption to traffic flow and actual delays associated with the Sydney Harbour Bridge in particular). I wonder how emergency services will cope with major accident scenarios within this expanded and compromised corridor (refer an actual scenario described in Attachment 1).

From a commercial and economic viewpoint, in my proposal the traffic catchment area is also significantly larger than the Government's current proposal. The NBRT, given its limited catchment area, will I predict, have a similar fate to the Cross City Tunnel. There are numerous opportunities to avoid this tolled tunnel (Military Road, Warringah Road and Mona Vale Road).). This, however, leads to another problem of increased traffic congestion on Boundary St, Eastern Valley Way and around Chatswood, the rabbit runs to Dehli Road from the Pacific Highway and on Lane Cove Road, north of the Sydney Orbital, heading down to Macquarie.

The Government's current project proposal does nothing for the Pacific Highway and traffic congestion around and through Chatswood. Chatswood could be expected to grow significantly once Stage II of the Sydney Metro is up and running.

As mentioned previously, Sydney's population is currently is 5 million and is projected to be 10 million by 2066(ABS figure). A high proportion of this population increase will eventually occur on the Northern Beaches and in the not too distance future heavy rail will have to be

considered. More roads will not solve the problem as the area densifies (for example, the proposed Frenchs Forest Town Centre on Warringah Road).

The Gore Hill/Warringah Expressway and the Sydney Harbour Bridge corridor should be avoided by any new project with traffic diverted elsewhere to ensure the viability of Westconnex and to not degrade the efficiency of this already constrained and compromised road corridor. The key words here to hold are "ensure redundancy" within the road network.

In conclusion, there is a well-known engineering expression - if it doesn't look right, it probably isn't. This, in my opinion, clearly this applies to the current proposals for both the WHC and the NBRT north of the Harbour. Today and in the future, there is a desperate need for alternative routes across the Harbour.

I would be happy to come to your office and give a presentation on the above to you and your transport planning team.

Yours sincerely,

Ted Nye
B.Eng(Civil), NER, FIEAust.
Director, E J Nye & Associates Pty Ltd

Mobile phone: 0422003275
Email: ted.nye@nyeconsulting-eng.com.au

Cc Rod Staples - Secretary Transport
Tim Reardon - Secretary – Department of the Premier and Cabinet
Rod Stokes MP – Minister for Planning and Public Spaces

Enc. Attachments 1 to 4 (not repeated here)

Addendum: Summary List of My Involvement in Projects Past & Present (not given here).

Sydney Heads Rail Tunnel – a Treasure Trove of Planning Opportunities

E. Nye[1], P. Prince[2] and Dr Sam Lackey[3]
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ABSTRACT: Sydney is a fast-growing city with a population of over 5 million. By 2066 this is expected to increase to 10 million people. Road congestion is a growing problem, particularly if measured by the ever-increasing travel times experienced by private and commercial vehicles. Given these concerns it is imperative that Sydney's rail network be expanded to both improve the rail network and enhance the quality of life. This project would involve over 60km of twin bored rail tunnel construction in both rock and soft ground. Two very wide water crossings, one being at the Heads to Sydney Harbour and the other at Pittwater will be required. The paper describes the project concept and options and touches on the likely construction duration and cost.

KEYWORDS: Rail, Transport, Tunnelling, Urban, Density, Housing, Population, Water-crossing

1. INTRODUCTION

1.1 Current Status of Tunnelling in Sydney

Two significant tunnel projects have recently been completed in 2019, the 4km long M4 road tunnel(part of Westconnex) and Stage 1 of the new Sydney Metro which includes 12km of twin bored tunnels (an additional 12km of rail tunnel for this project was the upgraded Epping to Chatswood Rail Link). The 10km long Northconnex and 9km long New M5(Westconnex) road tunnels will open this year, 2020. The 12km long tunnel excavation for the Sydney Metro Stage 2 in 2024. The Westconnex Rozelle Interchange construction commenced in 2020 while the 7.5km long M4-M5 Link tunnel started construction 2019. The Rozelle Interchange will connect all the Westconnex tunnels including the future Western Harbour Crossing. All road tunnels to date have been excavated using road headers and both stages of Sydney Metro are excavated by 7m diameter TBMs. The bored tunnel section crossing the harbour, just to the west of the Sydney Harbour Bridge, is a slurry TBM from Herrenknecht.

1.2 The Existing Rail Network

Apart from the Eastern Suburbs Railway, the existing rail network, including the Sydney Metro Stage 1 and 2, lie to the west of the Sydney CBD. The State Government at the time of writing have not provided publicly the details of the proposed Sydney Metro West alignment from the Sydney CBD to Parramatta and especially no details of the connection into the Sydney CBD. The existing northern rail line into Sydney that passes through Gosford and Hornsby carries both freight rail and passenger traffic. Freight rail is growing at about 3-4% per year and the freight trains can be up to 1.5km in length. On this line there also are around 360 passenger trains per day. Much of this rail passenger traffic would be transferred to the Sydney Harbour Crossing line with the proposal described in this paper, thus freeing this line for more freight rail traffic.

1.3 Expanding the Rail Network Across the Harbour

The Sydney Heads Rail Tunnel proposal expands the rail network to the east and north of the Sydney CBD by extending the Eastern Suburbs Railway further to the east to North Bondi, then under the Sydney Harbour Heads and then along the east coast up to Gosford with a total length of approximately 70km of twin bored tunnels.

The current urban sprawl in Sydney is to the west and south west. This is generally very low-density housing that will in the long term not be practical to be serviced efficiently by public transport, particularly rail, as Sydney's population climbs to 10 million by 2066 (reference 1). To get some time perspective on major transport infrastructure the city circle underground railway in Sydney was completed in the 1930s. The Sydney Harbour Bridge (SHB) will be 100 years old in 2032, just 12 years away.

The refences listed at the end of this paper provide more details than can be included here. The ideas initially put forward in the 2017 paper have been progressively developed over time.

2. ALIGMENT OPTIONS

2. 1 Option 1 – Newcastle to Canberra

Option 1 – Stage 1 is just an extension of the Illawarra Line which passes through Town Hall Station before heading east to the existing Bondi Junction Railway Station. There is at least 300m of existing twin tunnel east of this station. At both ends of the station there are rail cross-overs. The western cross-over was completed in 2006. New tunnels would extend the Illawarra Line from this station to a new station North Bondi (well back from Bondi Beach). An underground car park with at least 2000 car spaces would be built as part of the station complex. The tunnel would then continue under Sydney Heads and under Manly. There could be new stations at Dee Why and at the Warriewood Industrial Park. The tunnels then divert west and north as the railway would cross Pittwater on a bridge or through a tunnel before skirting around Woy Woy to the east then to continue the tunnel in sandstone rock to Gosford and possibly beyond. The length of twin tunnel between Bondi Junction Stations and Gosford Stations is around 60km (Figure 1).

2.2 Option 2 – Newcastle to Parramatta

Option 2 – is an extension of the proposed Sydney Metro West, construction of which might commence in the next few years. Sydney Metro West connects the Sydney CBD with the satellite CBD of Parramatta. We are proposing that the existing Martin Place Station connects directly with Sydney Metro West and hence to the Eastern Suburbs Railway line which as described above extends to the existing Bondi Junction Railway Station.

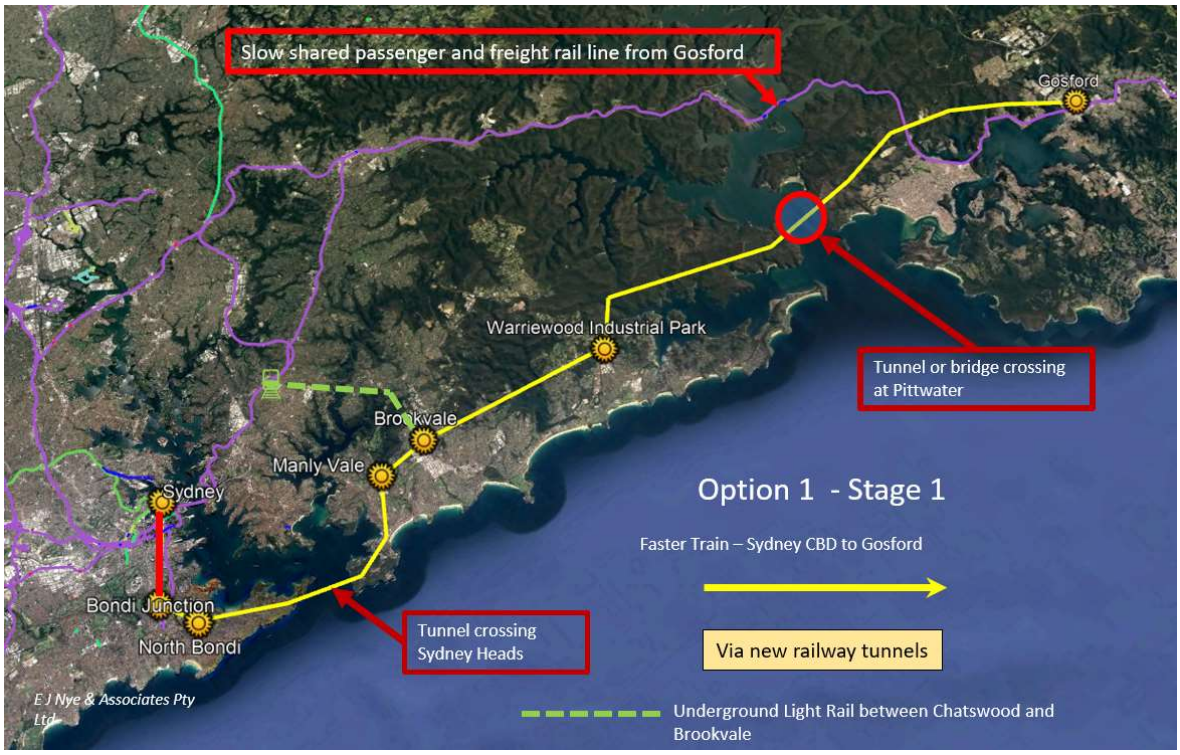

Figure 1 Alignment of proposed tunnels and light rail tunnels (dashed line)

The tunnels at Town Hall Station having been disconnected from Martin Place Station, would be extend north and swing around under the Stage 2 Sydney Metro Tunnels and then head south to a new station platform constructed under the existing St James Station. St James Station is only 12m in depth, below which is high strength sandstone rock. This new rail tunnel would continue south, possibly to Malabar.

2.3 St James Station

St James Station was constructed in the 1920s as part of the City Circle Loop. It was a cut and cover construction and is only 12m in depth. In Option 2 it is envisaged that a new station would be constructed in a rock chamber directly below. The central station platforms (which have never been used) would provide the spaced for lifts and escalator declines to the new station below. The ATS Journal reference (2018) includes plans and sections of the tunnel and station configuration.

An existing abandoned rail tunnel north of St James Station (this station was completed in 1925), the original plan for the underground developed by Bradfield in the early part of the 20th century linked St James Station directly to Town Hall Station and would be utilised as a 300m long pedestrian tunnel linking the St James Station to the existing Martin Place Station. The existing Martin Place Station will have a pedestrian link to the new Martin Place Station being constructed as part of Sydney Metro Stage 2.

3.0 GEOLOGY ALONG THE EAST COAST

The intention would be to tunnel in Sydney Sandstone where -ever possible. This can be partially achieved by having a tunnel alignment well back from the coast. Obviously, this is not possible at the Sydney Harbour Heads.

There are four areas of significance for potential soft ground tunnelling along the proposed Sydney Heads route. Firstly, the area between Rose Bay and Bondi, secondly the crossing between the North and South Head, then through the Manly Spit and finally, at the Narrabeen Lakes. Only the first two will be addressed in this paper. The Manly Spit and Narrabeen Lakes are being less of a concern at this stage.

Past seismic traverse from Rose Bay to Bondi shows that the depth of sand would be at least 60m. The tunnel along this section would be relatively shallow until it heads north towards Sydney Heads. This is due to the level of the proposed connection to the Bondi Junction Station and the steep topography and near sea level of the surface between Rose Bay and Bondi Beach. The topography then rises rapidly towards North Head, the sandstone rock cliff face at the Heads rises from the sea by at least 50m. To cross Sydney Heads the tunnel can either traverse the soft ground between North and South Head or be excavated at 100m below sea level in good sandstone rock.

4. LIVABILITY

4.1 Three Mega Cities and the Coastal Development

The Greater Sydney Commission has published a report in March 2018 recommending Sydney has three ‘mega’ cities in the greater Sydney area, two west of the Sydney CBD. However, the Sydney CBD is linked to numerous satellite CBDs and this is a trend we would expect to continue and encourage. To this end the retail and industrial area known as Brookvale, which is east of the CBD and SHB (it has a foot-print size three times that of the North Sydney CBD), should be redeveloped as another satellite CBD along with Gosford to the north on the east coast. This compliments the current three ‘mega’ city proposal as it enhances population growth management. A major University could also be sited at Warriewood on the new rail line alignment, since currently there are none on Sydney’s north shore. Liverpool has recently been rezoned to allow high-rise commercial and residential development and along with Parramatta will also be a satellite CBD. Along the alignment of Sydney Metro Stages 1 and 2, over time, we would expect other significant satellite CBDs to further develop or emerge (e.g. the Northwest Business Park, Macquarie Park and Bankstown). If the Option 1 alignment was adopted, Macarthur Park on the southern fringe of Sydney would likely develop into a significant satellite CBD.

4.2 Turn Down the Heat

Seven local Councils in Western Sydney launched a campaign in the latter part of 2018 called "Turn Down the Heat". This is in response to the rising population in Western Sydney and the double impact urbanisation and the natural difference in temperature between the cooler urban coastal environment of Sydney. On hot summer day this difference can be as much as 9 ^{0}C. There is a direct correlation between mortality rates where temperatures are in the region of 40 ^{0}C, especially for the young and old. There are also more days above 35 ^{0}C in the west of Sydney than along the coast. This project would provide development opportunities on the cooler east side of the Sydney CBD.

inflow through the head of the TBM, using an open face TBM, must be addressed with the potential low rock cover under this scenario. These are not the only alternatives to consider. The table below summaries some TBM options. There are numerous technical issues with any TBM tunnel but one in particular, from a risk and cost perspective is perhaps quite unique to this project. If a specialised TBM is required to traverse the paleochannel and to reduce cost, the same machine might be used twice, for say twin 7m diameter tunnels, or should the paleochannel be traversed by a single large diameter TBM, hence only one bore would traverse Sydney Heads.

By referring to Figure 1 the length of soft ground tunnel can be seen to vary depending on the depth of the tunnel below the seabed. With 20m of ground cover the expected length of the soft ground tunnel

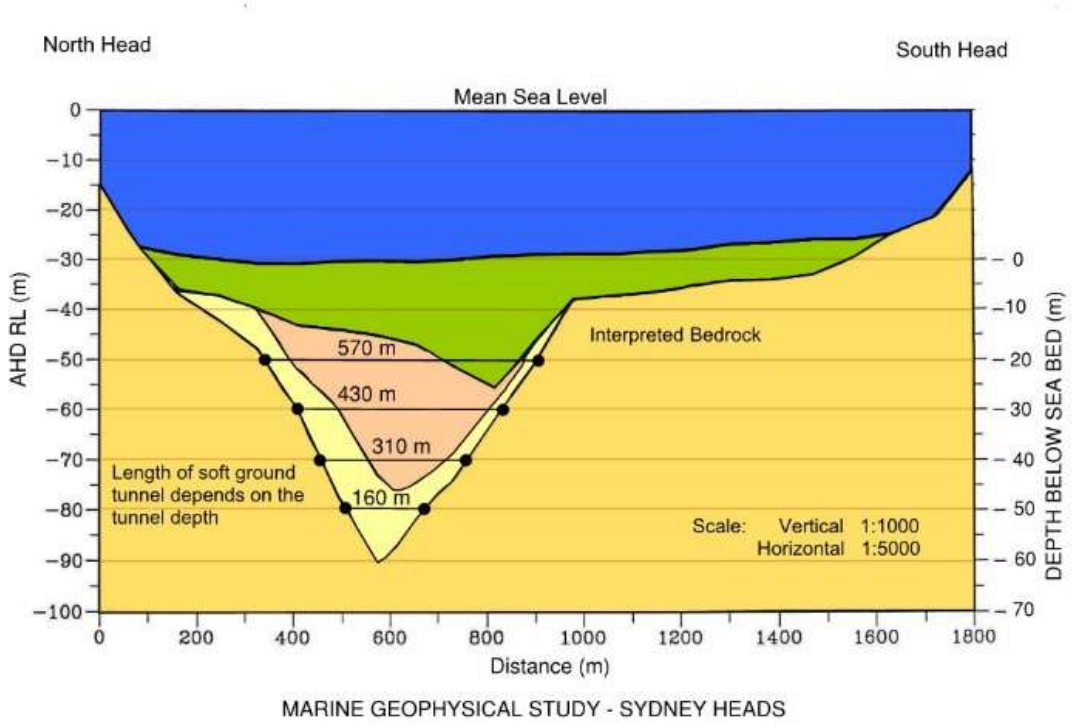

Figure 2 Seismic survey across Sydney Heads in 1996

4.3 Freight Line Capacity

The rail freight capacity between Gosford and Hornsby, on the current meandering and slow shared passenger and freight rail line, could be increased because much of the passenger rail traffic would be diverted to the new line from Gosford through to Brookvale and the Sydney CBD. It is also inevitable that the Central Coast will grow rapidly with the opening of the NorthConnex road tunnel this year. This will place significant pressure on this section of the northern rail line over time. To do nothing is not an option. Further discussion on these and other issues are given in the references listed for this paper.

5. TUNNELLING BETWEEN SYDNEY HEADS

As mentioned previously the most efficient TBM tunnel excavation would be one excavated purely in rock. Given their recent experience on the Sydney Metro Stage 1, an open face double shielded machine, with a segmental lining erected in the tail shield would suffice. Apart from providing a near dry low maintenance tunnel for train operation, the segmental lining, despite the experience on the Northshore Storage Tunnel, also provides a level of tunnel flooding security, during construction, through the use of this lining type. However, on this project the 23m rock cover under the Manly Spit paleochannel on the Northshore Storage Tunnel project, is unlikely to be achieved under the paleochannel at the Sydney Heads. The issue of water

would be 570m and at 50m depth below the seabed, 160m. The application of a specialised TBM, capable of traversing through the paleochannel, would not be expected to be as productive as dedicated TBMs for the excavation of long lengths of rock tunnel. Table 1 summarises three tunnelling options for traversing the Sydney Heads crossing.

The Sydney Heads tunnel crossing will have a large rock tunnel element, irrespective of the vertical alignment chosen. Site investigation will be required to confirm the actual percentage of rock and soft ground tunnel and the final alignment along the coastal zone will also impact on the actual percentages of the ground conditions encountered by tunnelling.

6. EXISTING BONDI JUNCTION STATION

It is worth providing some specific information about this railway station and the history of the Eastern Suburbs Railway Line. The interesting aspect of the Eastern Suburbs Line and this station is that there are already existing twin tunnels extending beyond the station. The first 200m of twin tunnel are in use with a crossover between tunnels so that trains could switch platforms for the return journey. However, an additional length of tunnel was also excavated and abandoned in 1974 when it was decided, for financial reasons, not to extend the line. The original proposal then included five additional stations (Charing Cross, Frenchman's Rd, Randwick, UNSW and

Kingsford), but the alignment would have been south away from the Harbour.

The original Bradfield Plan in 1946 for this line was for it to be extended to Bondi Beach. In 2000 a private group proposed extending the line 2.6km in a single tunnel to Bondi Beach, however, for several reasons the project did not materialise.

An additional cross-over between the tunnels on the city side of the station was completed in 2006. Spoil was removed by train in a 3-hour window at night. The new cross-over allows the frequency on the line to increase from 14 trains /hour to 20 trains/hour, however, beyond 2021 additional capacity improvements will be required.

7. CONSTRUCTION PROGRAM AND COSTS

Excluding initial planning, finance, approvals and tendering, the design and construction duration of this project, based on current Sydney underground rail projects, would be around 6 years. Without cost escalation, the total cost of the project would likely be in the range of $15 - $20 billion, without stations. The new stations could be paid for by developers given the development potential around and above station sites. The new stations would be built on brown field sites, but none are required to be constructed within the Sydney CBD (For Option 2 - a new St James Station would be incorporated in the new South- East Line). In the CBD this significantly reduces both the construction cost and land purchase costs. Published information indicates that a single CBD station costs around $400 million.

The combination of using existing CBD stations and long rock tunnel drives would be a cost benefit when a business case is developed for this project. Further work on cost benefit calculations will be carried out in the future. The business case could also address a light rail link between Brookvale and Chatswood. Brookvale could be developed into a large commercial precinct of a similar scale to Chatswood. The Sydney Heads Metro could also be extended north to Gosford, taking pressure of the current northern, shared freight and passenger rail corridor south of Gosford, by providing an alternative dedicated passenger service to the Sydney CBD.

The crossing of Pittwater could be either a major bridge or bored tunnel. An immersed tunnel would also have to be considered in any study. As is the Sydney Heads crossing any structure would have to traverse 2000m wide waterway.

8. COMPARING SYDNEY ROAD AND RAIL TUNNELS

As mentioned in the introduction road headers are used in Sydney for the excavation of road tunnels while TBMs are used to bore the twin tunnels in the more recent rail tunnels in Sydney(Epping Chatswood) and Sydney Metro Stages 1 and 2. A whole paper could be devoted to discussing this topic, however, here we are just highlighting the efficiency of rail in terms of construction cost and carrying capacity compared to a typical road tunnel in Sydney geology. Table 2 below is one way of presenting these differences for a typical 3-lane road tunnel and 7m dimeter TBM bored rail tunnel.

Table 1 Road and Rail Tunnels – Sydney Sandstone

Item	Description
Road	3-lane - tunnel face area = 100m^2
Tunnel	Excavation rate = 40m/week
	Capacity 6000 – 8000 people/hour
	Capacity/cum rock excavated = 80p/m^2
Rail	Single track – tunnel face area = 39m^2
Tunnel	Excavation rate = 200m/week
	Capacity 32,000 people per hour
	People capacity/cum rock excavated = 820p/m^2

9. OTHER POTENTIAL TUNNEL PROJECTS

In the process of developing the concept for this project other new tunnel options and modification to planned tunnels on the North Shore of Sydney were also conceived. Although only a passing description is given here it is worth noting that all major transport proposals should not be developed in isolation. If the Sydney Heads Rail Tunnel were to be included in the 2056 NSW Government Transport 2056 plan, I am sure the following tunnel options would even be even more relevant.

9.1 WHC and NBRT

The Western Harbour Crossing (WHC) currently proposed would join the Warringah Expressway on the east side of North Sydney. While a concept design has already been developed a timetable for its construction is not firm. This will link with the proposed Northern Beaches Road Tunnel, also surfacing at the Warringah Expressway on the east side of North Sydney. However, an alternative solution would be for the NBRT as proposed to not go ahead but be replaced by a tunnel from Warringah Road (just west of the Roseville Bridge, Roseville), then pass under Chatswood and join Dehli Road in North Ryde.

The WHC would surface on the west side of North Sydney on the Pacific Highway north of St Leonards. The Warringah Expressway is also the major link into the Sydney Harbour Bridge from the north. By removing the WHC and NBRT from the Warringah Expressway corridor the potential for road grid lock has been eliminated if there is a major incident on the Warringah Expressway. These two-alternative alignments to the current plan would ensure that the road network has some redundancy.

This compliments Sydney Heads Rail Tunnel Crossing which would reduce road traffic entering the road network including along Military Road, traffic that would normally cross the Spit Bridge.

Note also that the recent $600 million upgrade to Warringah Road at Frenchs Forest will be a significant traffic attractor, again diverting traffic away from Military Road, but unfortunately ending at a t-intersection at the Pacific Highway, Chatswood.

9.2 Underground Light Rail – Brookvale to Chatswood

To provide a transport link between Brookvale and Chatswood it is proposed an underground light rail be constructed. This would be independent of the existing rail network. Sydney Metro Stage 1 currently terminates at Chatswood but will extend to the Sydney CBD and beyond after 2024. A new city centre is being developed at Frenchs Forest where a new $600 million hospital has recently been completed and a $500 million Warringah Road will be completed this year. Frenchs Forest will become a satellite CBD with at least 6000 new residents. It is located midway between Brookvale and Chatswood.

10. BRIEF HISTORICAL CONTEXT

In Sydney in the early 1920's, John Bradfield planned and built the hugely visionary underground CBD City rail loop (1926 and 1932), which together with the connected Harbour Bridge crossing (1932), has been the single most important economic infrastructure in which the city has invested. The Harbour Bridge allowed the North Shore rail line (1890) to connect to the City Loop, giving CBD rail access from the northern suburbs. The underground CBD City loop became the centre-piece of the rail network allowing direct rail access to city destinations from the western suburbs (Western line,1855), the southern suburbs (Illawarra line,1932), the eastern suburbs (East Hills line, 1939,1948,1956) and more recently the Eastern Suburbs line (1979), the last suburban rail line funded and built by government.

Sydney has grown five-fold since Bradfield's City loop was built, to over 5 million people today. It had been nearly 40 years since the State Government invested in urban rail which has coincided with a period of high population growth, increasing economic development and increasing traffic congestion. Over this period State and Federal governments' have consistently relied on a policy of prioritising roads over rail to manage increasing movement demand.

Over this same period the State's land use policies, which have been a largely unbalanced and short-sighted response to the population increase and resultant housing demand, have been the largest contributor to the city's growing road traffic volumes and high levels of congestion. Lazy land use planning has allowed low-density urban development to take place across an increasing city footprint, especially in the west. Therefore, the city has very high car ownership levels and high road investments that are just too easy to justify, politically and economically. This can be compared with rail investment which has not been seen to be justified because of the land use policies of Government. The historically low-density land use policies and resultant reliance on cars and buses is also a major reason for increasing average trip lengths, as well as traffic congestion and its resultant high economic production costs.

There can be no doubt as to the social and environmental advantages of underground transport.

Today's tunnel boring machine technology and Sydney's geologically stable sandstone provide competitive construction costs, making a stronger economic and financial case for more rail tunnels in Sydney.

The stage one development of the Proposal of a new rail tunnel under Sydney Heads to the north of Sydney could reduce rail passenger travel times to and from Newcastle/Gosford and the Sydney CBD by up to 40 minutes compared with the existing service and existing route alignment.

The Proposal could enable a new city on the Northern Beaches larger in size than North Sydney and improve accessibility from Brookvale to the Sydney CBD with rail transit times of only 20 minutes, compared with the average existing transit time by bus of 40 minutes. A new large university could be located at Warriewood as currently there is none on Sydney's north shore.

11. PLANNING OPPORTUNITIES

This paper provides an overview of the merits of a proposed rail tunnel under Sydney Heads to provide a context technical discussion given the route alignment proposed. A search of the literature appears to confirm that this alignment has never been publicly proposed before i.e. a transport crossing of the Sydney Heads by tunnel, 7 km to the east of the existing crossings and all serving the Sydney CBD. Sydney also has limited to non-existent rail services to the east and north of the CBD. The project will form a vital missing link, positively impacting on all modes of surface transport in the Sydney metropolitan area and providing further expansion potential of the rail network east of the CBD and to the North Shore and beyond. Extending the Eastern Suburbs rail line from Bondi Junction across the Harbour connects the North Shore directly with three existing CBD stations and over 50 existing stations south of the CBD including a more direct rail route to both Sydney Airport and Sydney's proposed new western airport at Badgerys Creek. The CBD stations may require some upgrading (including fire and life) but in the context of a new station are essentially free. Any new CBD station would add about $400 million to the project cost. Bondi is a very high-density residential suburb with very limited off-street parking. North Bondi and North Shore residents will be able to travel to the CBD on one mode of transport and will not be impacted upon by surface road traffic (very large bus stations are currently located at both Bondi Junction and Brookvale).

Martin Place Station in the CBD will become an interchange station on the new Sydney Metro Stage 2 currently under construction: this project will enhance the functionality of this interchange station.

The cost benefits of tunnelling in Sydney geology is well known and measurable, very high rates of TBM advance can be achieved in Sydney's sandstone. Tunnelling under the Sydney Harbour poses some engineering challenges. However, with the knowledge gained from completed projects like the Northside Storage Tunnel and the completed Sydney Metro Stage 2 project (completion 2024) which also includes a bored tunnel harbour crossing with similar geological issues. With all this additional construction and geotechnical knowledge, these risks can be further managed. It is envisaged that a slurry TBM would be the ideal TBM for the Harbour crossing at Sydney Heads, if the alignment intersects the paleochannel.

There is also the potential to have a light rail connection between the new Brookvale and the existing Chatswood Station, via the new Frenchs Forest Town Centre. This independent transport mode would not impact on the operation of the Sydney Trains rail network. Brookvale could be developed into a large commercial prescient of a similar size to Chatswood with this direct rail link to the Sydney CBD.

12. SUMMARY AND CONCLUSION

The project is more than just another tunnel rail project. The advantages of a rail tunnel under the Sydney Heads include a treasure trove of planning opportunities that will have multiple benefits, including population growth management. Some of these are, reduced dependency on the SHB with a new and only land crossing 7.5km east of the bridge, reduced road traffic congestion by getting more people on to a faster rail service and a reduction in the urban sprawl by having higher density development around new railway stations. The Central Coast is a major asset for the growth of Sydney and its inhabitants with coastal access, higher rainfall and lower average mean temperatures than Western Sydney and importantly access to lower cost housing. Travel times from the central coast by train to the Sydney CBD could be reduced from the current 90 minutes (on a good day) to less than 60 minutes. Large visionary projects of this kind are required for Sydney because its population will double in size within 50 years. This "distant" time is only half the age of the existing SHB!

This paper presents one case which, if investigated further would most likely generate the real prospect of starting to seriously plan for and then develop new cities along a future Newcastle/Sydney-Canberra axis, also in the near future new satellite CBDs/cities in Brookvale and Gosford as Sydney's population grows to 10 million heading towards 2066.

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