Analysis of the proposed Auckland CBD rail tunnel project, and a potential modification to increase capacity and operational performance.

Nicolas Reid: Nicolas.reid@gmail.com. +61 432 902 066

1. Executive Summary

The Auckland rail system is currently approaching capacity due to the limit on the number of trains that can fit through the twin-track approach to Britomart station. A CBD tunnel project is being investigated to connect Britomart with the Western Line at Mt Eden via the central city. This will provide two more tracks accessing Britomart allowing an increase in system capacity as well as shortening the route of the western line while providing greater accessibility to the rail system via three new stations under the CBD. The project represents the most significant investment in the history of Auckland passenger rail and will form the centre piece of the network for generations to come.

However, it is identified that the proposal connection to Britomart has some unnecessary drawbacks despite the substantial capital investment, namely that the expansion in capacity will be less than double the current limited capacity, and that the central capacity would still be only two-thirds of the capacity of the existing suburban system. Furthermore conflict between through-running and terminating trains for slots in the existing Britomart approach tunnel would greatly limit the peak capacity of the Auckland rail network, as terminating trains must necessarily occupy two slots on existing approach tunnel as they enter and exit via the same route. Other drawbacks include the inter-mixing of operationally different 'rapid transit' and locomotive hauled trains at Britomart, the reduction in the potential for Britomart to function as a regional terminus, and the need to retrofit Britomart to support rapid transit style services on platforms 1 and 5 at great expense. There is also a strategic drawback of the proposal. While the system is approaching capacity now, no new capacity would be available until the entirety of the project was complete at a lead time of 7 to 10 years and a cost of approximately $1.5 billion dollars. This represents a significant period of unrealisable potential patronage growth on the network.

A modification to the CBD tunnel concept is proposed to address these drawbacks. It is proposed that the CBD tunnel be extended a further 900m eastward connect directly to Quay Park junction via a cut-and-cover tunnel under Quay Street. The existing Britomart station and approach tracks would be bypassed, while a new pair of tunnel platforms would be built adjacent to Britomart and connected to the existing station concourses via short underpasses.
The existing Britomart station and its approach tunnel would be untouched and continue to operate in their current capacity as terminal station for diesel and electric powered services, while all services using the CBD tunnel would use the new purpose-built 'rapid transit' platforms adjacent. Connecting the eastern end of the tunnel to Quay Park junction via a new pair of tracks (rather than the existing Britomart approach tracks) would provide triple the current system capacity (rather than double), and would therefore match the capacity at the core of the system to that at the periphery. This would allow the CBD tunnel to be utilised to its fullest capacity for electric suburban rapid transit services while allowing the existing station to accommodate various diesel or electric express, regional and intercity services.
The modified proposal also allows for capital expenditure and capacity increases to be introduced in stages. As a first stage the initial 900m cut-and-cover tunnel and new platforms adjacent to Britomart could be constructed and opened first, allowing a doubling of system capacity with a 3-4 year lead time and a cost of approximately $250 million dollars. This

would allow rail patronage to continue to grow while the second stage extension through the CBD to Mt Eden was being constructed.

The modification represents the addition of 900m of new tunnel and an fourth pair of underground platforms to the existing proposal at an estimated increase in total project cost of 15-20%. However, the modification would provide 100% more capacity over the existing proposal plus considerable benefits in terms of in operational flexibility and project staging. Therefore the relatively minor additional expenditure of the modified proposal may result in greatly improved outcomes in cost-benefit analysis, particularly if long term growth over the lifetime of the infrastructure is taken into account.

2. Introduction: Britomart capacity restrictions affect the whole network

The Auckland rail system is comprised of three double track lines entering the central area from the suburbs (the Western, Southern and Eastern lines respectively), meaning that the maximum capacity of the whole system, is equal to the number of trains these three tracks in and their corresponding three tracks back out can carry. There are two extensions to the rail network currently under construction (the Onehunga and Manukau branches) while other lines and extensions have been proposed. However all of these will simply connect to one of the existing three main lines, none will increase this maximum capacity further.

The existing Auckland rail network is almost at capacity. Currently the Western and Southern lines must share two tracks between Newmarket and Quay Park, and from Quay Park to Britomart all three lines must share just the two tracks through the eastern approach tunnel. All services must enter and exit Britomart station via the same dual track throat tunnel from Quay Park Junction in order to access the five terminal platforms inside Britomart. This section of track is the primary restriction on network capacity.

Is summary, there are a total of three tracks heading toward the city and three heading back out again, but only one track in and one track out of Britomart. Therefore the central capacity of the network is only 1/3rd of the potential capacity of the wider network.

The current maximum feasible capacity of the eastern approach tunnel is a throughput of approximately 18 trains per hour, and therefore the systemwide capacity of the rail network is also 18 trains per hour. Improvements to signalling plus greater use of quicker accelerating EMU trainsets may allow up to 22-24 tph under ideal conditions.

A basic ten minute service frequency on the three main lines during peak house would require 18 slots through the throat tunnel, leaving few if any slots for new lines, regional trains or intercity services. Without capacity expansion at Britomart the Auckland rail network cannot be extended to service new routes or support a much high frequency on existing routes.

3. Platform length and pedestrian congestion at the platforms

One way to increase capacity is to run longer trains, however this may be difficult given the platform lengths at Britomart. Currently Britomart can support trains up to seven car trains on the central platform, but only six car set on the other platforms. Thus six car sets are the current practical maximum for the fleet. Lengthening suburban stations to support eight car sets may be relatively straightforward however this may be prohibitively expensive at Britomart due to the constrained underground site.

The five platforms at Britomart are currently formed by two island platforms which service two lines each, plus a second island platform servicing only one line. These five platforms are accessed by two elevators, a staircase and three escalators at the main entrance. With significantly increased patronage flows the pedestrian access to and from the platforms may become a significant constraint.

4. The proposed CBD tunnel

A CBD underground rail tunnel from Britomart to Mt Eden Station has been proposed, where the tracks servicing platforms 1 and 5 at Britomart would be extended under the historic CPO building and the Westfield Downtown site to allow a tunnel to continue up the CBD to connect with the western line in the vicinity of Mt Eden Station. New underground stations would be constructed under Albert St to service the midtown CBD area, under Pitt St to service the uptown / Karangahape Rd area, and at upper Symonds St to service the growth area there. The tunnel would support electric powered trains only due to major issue running diesel trains in such a long, deep tunnel.

This would in effect add a second double track approach tunnel to Britomart from the west, turning it into a 'through station' by providing a second track into the station and a second track out. The three double-track suburban rail lines in Auckland would enter Britomart on two double-track tunnels (one from the east, one from the west). Capacity would therefore be approximately double that of the current network, possibly more than 36 trains per hour.
However under this configuration the central system capacity would still be only 2/3rds the potential capacity of the three main lines.
Britomart would operate as a hybrid station, platforms 1 and 5 would support through running of electric powered trains to and from the CBD tunnel, while platforms 2, 3 and 4 would continue to service terminating train entering and exiting via the existing eastern approach tunnel only.

Further benefits of the CBD tunnel include greater accessibility to the whole CBD via the new city stations and improved travel times from the west to the CBD.

5. Potential limitations of the proposed CBD tunnel

Ongoing investigation into the alignment of the CBD tunnel notes two key issues. Firstly, the grade of the proposed tunnel is approaching the maximum operating grade of an electric traction train. This is largely due to the need to climb from the underground track level of Britomart station to the much higher level of the Western Line at Mt Eden, over a relatively short length. The second key issue is the construction of the tunnel between Britomart and the Albert St road corridor, as the route must pass through the foundations of the historic CPO building and traverse the subspace of the Westfield Downtown site, where it is proposed a skyscraper with deep foundations will be built. This section would impossible to dig using a tunnel boring machine and would most likely be mined by hand, an difficult and expensive process. Furthermore this section would require a tight curve, which may limit the grade further as tight curves with steep grades are undesirable.

The design of the CBD tunnel connections to Britomart may cause the full capacity of the station to be unrealisable. The existing twin-track throat tunnel and the proposed twin-track CBD tunnel would each have a nominal maximum capacity of 18 trains per direction per hour. Used together this would give Britomart a maximum capacity of approximately 36 trains per hour in total. However, this would only be possible if all services were run through the station via platforms 1 and 5 without any services terminating, a patronage level which the

platforms themselves may not be able to support. To utilise the three remaining terminal platforms would mean a reduction in overall capacity as they would still require slots through the eastern throat tunnel despite not accessing the main CBD tunnel.
Any diesel or electric train entering from the existing eastern throat tunnel and terminating at platforms 3, 4 or 5 would require one slot through the eastern throat to enter the station and also a second slot to exit out the way it came in. Thus every one terminating train entering and exiting via Quay Park precludes the operation of two trains through the CBD tunnel. This means that the stations at midtown, K Rd and Symonds St would not be able to operate at full capacity as long as any diesel trains or terminating services were used on the network.
For example 6 terminating trains per hour during the peak would occupy 12 slots through the Britomart end of the tunnel, leaving only 24 slots (or 12 per direction) under the CBD, a total of just 28 trains per hour. In this example the construction of the billion dollar CBD tunnel project has only allowed a extra ten trains per hour to run.

Furthermore, the fact that the proposed CBD tunnel design connects to Britomart does nothing to alter the two track pinch point between Britomart and the four tracks that join together a mere 500m away at Quay Park Junction. Therefore the combined maximum capacity of all services using the Eastern Line and the Parnell section toward Newmarket will remain as approximately 18 tpdph. Any capacity increase afforded by the proposed CBD tunnel could only be utilised by trains entering or exiting to the Western line at the southern portal. This is potentially problematic as diesel powered trains and possibly any locomotive hauled service would not be able to access the tunnel.

It is therefore anticipated that the proposed CBD tunnel would provide less than double the existing network capacity if a mix of electric and diesel services is to be maintained. This may represent a strategic limitation over the lifetime of the tunnel infrastructure and give only a limited scope to expand services beyond those that are immediately apparent. For example running ten minute headways on the existing three main suburban lines plus the Onehunga and Manukau branches would exceed the projected capacity of the network with the proposed CBD tunnel. This would limit the potential of any further proposals such as the Avondale-Southdown line, extensions to the airport, a Botany line or North Shore line, or a significant increase in services to regional locations such as Helensville and Pukekohe or intercity routes to Hamilton, Tauranga and Rotorua, or to operate any of the main suburban lines and headways greater than ten minutes.

Britomart station was designed as a terminal station, the capacity and layout of the station reflect this role. While any new CBD tunnel stations would be built as ‘rapid transit’ stations, Britomart would not function ideally for rapid transit operations. Another concern is the reduction of Britomart’s role as the central terminal station for Auckland. In the case of similar rail tunnels being constructed in Brisbane and Perth, new stations were constructed in addition to existing central stations that were maintained for terminating city and country trains. In the case of Auckland the existing Auckland railway station was demolished once Britomart was built, meaning that it can no longer fulfil this role.

One solution to the above issues would be to duplicate the eastern approach tunnel between Quay Park junction and Britomart in conjunction with construction of the CBD tunnel, to provide two tracks for through running electric services plus a third and fourth track for terminating services. This would match the track capacity from Quay Park to Britomart with the track capacity from Quay Park to points further out, and would provide slots for terminating trains to access Britomart without occupying any slots in the CBD tunnel.

While the platforms of the new CBD underground stations could be designed to support 8-car trains and provide for high passenger flows, this would be effectively useless unless platforms 1 and 5 at Britomart could also support 8-car trains and high passenger flows.

To achieve the capacity increase the entire length of the CBD tunnel must be constructed to connect Britomart to the Western line, i.e. there is little opportunity to stage construction to incrementally increase capacity to meet rising demand.

6. A modification to the CBD tunnel proposal to increase capacity and potentially improve alignment

In order to address some of the aforementioned potential constraints of the proposed CBD tunnel design, a revised alignment is suggested:

The tunnel alignment and design from Mt Eden station to the northern end of Albert St is unchanged, however it is proposed that the alignment in the vicinity of Britomart station be altered. Rather than connecting the CBD tunnel to platforms 1 and 5 in the existing Britomart station, it is proposed that the CBD tunnel be extended approximately 900m in length and relocated approximately 60m to the north through the downtown section such that the route continues underneath Quay St alongside and bypassing the existing Britomart station and connects directly to Quay Park Junction. A pair of platforms would be built under Quay St alongside the existing Britomart station and connected to it via an extension to the existing pedestrian concourse. Further pedestrian connections to the Ferry Building, Westfield mall and Queen St would be possible.
In effect, a two-track CBD tunnel would be built from Quay Park junction to Mt Eden station, with new underground stations at Britomart, midtown, K-Rd and Symonds St which would be serviced by electric traction rail vehicles. The existing Britomart terminal station would remain unchanged to be serviced by diesel and electric rail cars and locomotive services. The benefits of this proposed extension are manifold:

- Terminating trains accessing Britomart from the east would not have to compete with CBD tunnel trains for slots into Britomart. The CBD tunnel between Quay Park Junction and Mt Eden could therefore run at full capacity, in addition to the existing Britomart station operating to its own full capacity.
- This would match the track capacity through the central core to the track capacity of the suburban network (i.e. 3 double track lines).
- Overall this would result in a system wide capacity of more than 54 trains per hour, or approximately three times the current network. This would be comprised of 36 electric trains per hour through the CBD tunnel plus a further 18 terminating trains running to Britomart via Quay Park.
- This equates to a 100% increase in new capacity over the proposed alignment and a fuller utilisation of existing platform capacity at Britomart, for possibly less than 20% additional expenditure.
- High speed, high frequency ‘rapid transit’ style electric trains would be kept separate from locomotive hauled regional commuter and intercity trains, providing operational flexibility. Furthermore there would be less conflict between faster electric railcars and slower locomotive hauled services at key junction points (i.e. the existing Britomart throat tunnel)

- A greater expansion of regional and intercity services would be possible. Services would be logically divided between electric ‘metropolitan’ services using the tunnel platforms and terminating express, regional and intercity services using the terminal platforms. Issues such as the potential access to Britomart by the proposed Waikato commuter service would be avoided.
- The network could be upgraded to support 8-car suburban trainsets without the need for expensive retrofitting of longer platforms to the existing underground Britomart station. All CBD tunnel stations used by electric multiple units would be designed specifically for that application as ‘rapid transit’ stations.
- May allow a less steep grade over the upper portion of the CBD tunnel due to increased tunnel length overall. There is also the potential for the new Quay St tunnel platforms to be less deep than the existing Britomart ones, further easing the grade.
- A less tight curve could also be feasible between Albert St and Quay St. than the proposed curve between Albert St and Britomart.
- Would negate the need for complicated and expensive excavations under the CPO building, and allow for a much less constrained construction site via the Quay St road corridor. This may lead to significant cost savings to offset the cost of a longer tunnel and additional station site.

In terms of future expansion, this proposal would not negate an additional line such as the proposed North Shore line being connected to the existing Britomart station in the future. This would be more desirable than connecting to the CBD tunnel as this would restrict the capacity of both routes. However it is proposed that a similar extension alongside Britomart would be undertaken with this concept also, i.e. the North Shore line could follow an alignment from the Western Reclamation to an additional pair of new platforms under Customs St 50m to the south of Britomart station (to be similarly connected to the existing Britomart concourse), before continuing on to connect to the city side rail network at Quay Park on the Parnell Branch.

Furthermore, this alignment would be constructible in stages with incremental capacity gains at each stage. The first section from Quay Park to the new Britomart platforms could be built relatively cheaply and quickly, perhaps utilising cut and cover tunnelling under the Quay St corridor. This would allow an expansion of network capacity with much shorter design and build time than the whole CBD tunnel route. One possible staging of construction is as follows:

- **Existing:** Five terminal platforms at Britomart serviced by two tracks, mix of diesel and electric vehicles. Maximum nominal capacity 18 terminating trains per hour.
- **Stage 1:** First section of CBD tunnel constructed from Quay Park Junction to new Quay St platforms (approx 900m cut and cover): Five terminal platforms serviced by two tracks for a mix of diesel and electric vehicles, plus two new (temporarily) terminal platforms serviced by an additional two tracks for electric vehicles. Maximum nominal capacity 36 terminating trains per hour.
- **Stage 2:** Extension of CBD tunnel from Quay St platforms to Mt Eden via midtown, K Rd and upper Symonds St stations: five terminal platforms serviced by two tracks for diesel and electric vehicles, plus two through platforms for electric only only serviced by four tracks. Maximum nominal capacity 54 trains per hour (36 through running, 18 terminating)

- **Potential stage 3:** Construction of North Shore line to Parnell/Quay Park via two new Customs St platforms: five terminal platforms diesels and electrics plus four through platforms for electrics only. Maximum nominal capacity at Britomart 90 trains per hour (72 through running, 18 terminating). Not that this stage would require track amplification on the Eastern line or Parnell branch to achieve maximum capacity (or a new route to the east, such as under Symonds St to Newmarket via the universities and hospital).

7. Notes

- It is assumed that electrification of the Auckland suburban network will take place largely as proposed by ARTA
- It is assumed that a mix of electric and diesel traction will be used for the foreseeable future (e.g. at a minimum the Overlander service to Wellington and diesel powered services to Pukekohe and Waitakere/Huapai will continue to access Britomart even if all suburban trains are electric).
- 18 trains per direction per hour has been used as the maximum capacity of a two track railway, however with advanced signalling and track systems 20 to 24 tpdph may be possible.