CityRail: A system on the brink

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Abstract

In many cities rail transport is the backbone for public transportation with major effects on land use patterns. In Sydney the railway network is at capacity due to inefficient operations and lack of expansion over the past 50 years. The cost of adding new rail infrastructure is significant. This thesis looks at ways to improve the capacity and utilisation of the existing system in the short term, by utilising best practices from Australia and overseas. Suggestions are made for lower cost infrastructure upgrades instead of new lines and the improvement of existing regimes through better planning, timetabling, junction and work practices. These capacity enhancements give enough time for options for future expansion that will serve the existing population more appropriately and improve accessibility at a reasonable cost to the New South Wales government. The model suggested provides for alternative solutions to change an essentially radial railway network to a network which services a polycentric city focused on the key centres of Parramatta, Liverpool, Hurstville, Chatswood, as well as the Sydney CBD, while also complementing the proposed metro system.

Acknowledgements

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All images are the authors unless otherwise stated.

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1. Introduction

CityRail comprises of 1600 suburban and interurban carriages, and carries approximately 945,000 people per weekday across the entire network (CityRail 2008). It comprises a network that is characterised by flat junctions – there are only six grade separated interchanges within the entire network (Central Flying Junctions, Illawarra Dive, South Line flyover at Merrylands, Richmond line Flyover at Seven Hills, Westmead Dive at Westmead, and Northern Line Flyover at Strathfield.) This coupled with the use of extensive variations in stopping patterns across a system that is predominately dual track, has extensively constrained and complicated a network that is not running at its maximum capacity.

There has been considerable controversy within the media and concerned politicians as to whether the system is really at capacity, or what can be done to alleviate problems. The Sydney Morning Herald has begun significant campaigning within this important issue by producing the Sydney Transport Inquiry—an independent inquiry into the public transport system of Sydney, which has brought this issue to the forefront of debate. There have been conflicting views as to whether the system is at capacity—generally media articles including SMH (2009 a,b,c) and the Daily Telegraph (2009) state that the system is at capacity, whilst with the October 11 timetable increased peak frequency, and the RailCorp documents state that the system has a small amount of capacity left.

An interesting point that is raised within both arguments about capacity is that the maximum frequency that can be operated by CityRail is twenty trains per hour per track, yet only the North Shore line approaches this capacity with 18 trains per hour on a track at the height of peak hour. This raises the question of whether the capacity problems that exist now have been brought on by the infrastructure or by other factors within the network.

Passenger Congestion at Town Hall

This leads to the conundrum of whether both opposing views are wrong, or whether the answer lies midway between the two opposing points of view—whether the system is at capacity or not and whether this capacity can be effectively used with the constraints that define the network.

This thesis intends to show that there is spare capacity within the network, and also develop and guide potential future expansions of the railway network over the next 30 years to 2040. at a cost similar to current Government expenditure on the CityRail Network.

The aim of this thesis is to enable the operation of CityRail at near maximum efficiency and provide for a sustainable framework for expansion of the network based upon the Sydney Metropolitan Strategy.

The research questions that this thesis undertakes are:

- Identify the key constraints and issues within CityRail network
- Identify world best practices for railways and potential ways this can be adopted within the network
- Identify options to relieve the existing congestion in the short term
- Provide a sustainable framework for expansion of the network in the future
- Provide for a framework integrating the Sydney Metropolitan Strategy and Subregional Strategies into a coherent rail expansion strategy.

1.1 Methodology

As part of the development of this methodology a detailed literature review was undertaken to provide a practical background for the thesis. The key concepts that the literature review identified for integration into this thesis were:

- Identification of world best practice
- How can rail systems be optimised
- Identification and minimisation of existing constraints
- Identification of appropriate routing for railway lines
- Review previous rail transport strategies for Sydney
- Determine the concepts that the proposal is based upon
- Provide for practical operational solutions, that work for the unique situation that the CityRail network operates under.

This provides the theoretical framework and background to this thesis and quantifies the core data used to create and underpin the proposal. It is found predominately within Chapter 2.

The sources of data for the thesis are divided into three categories, theoretical, secondary and empirical research. The theoretical research consists of data compiled within primary sources, such as Vuchic, which do not take into full account practical realities of the rail operation. This provides the theoretical underpinnings for the empirical and secondary sources. The empirical research is predominately primary data from CityRail and the Sydney Metropolitan Strategy, whilst secondary research consists of newspaper articles, observations from the author, and other people sources. This provides for an extensive review to base this thesis on.

Level Crossing

Source: Ben Chatwin (2009)

This research methodology is predominately a desktop exercise. There is no independent qualitative or quantitative research undertaken given the time, word and page limit constraints upon this thesis. This desktop exercise is also broken down into two components, the theoretical literature review, which provides the theoretical underpinnings for the proposal, by providing a clear framework that has real world applications. This thesis through the research methodology differs from other recent transport plans for Sydney by taking into account the operational difficulties and constraints unique to the CityRail network. These constraints are generally outlined in the empirical research, and observation by the author. By taking these into account this enables a transport plan to be developed that will best meet the needs, operational requirements and demands of a rail network for Sydney, as it is specifically tailored for the city.

The proposal is built upon the previous plans outlined within chapter two, the Sydney Metropolitan Strategy, as well as the literature review, taking into account the unique and specific operational circumstances of CityRail, which again are generally outlined in chapter two.

1.2 Background

CityRail (2006, 2008) states that the maximum capacity of a dual track pair is 20 trains per hour (20tph) per track pair, or a train every three minutes through the City Underground, with the exception of Sydney Terminal which is a train every two minutes. The primary determinant of this frequency is extensive dwell times at Wynyard, Town Hall and Central stations, as well as the removal of the original single deck signalling system on the City Underground starting in 1990, in conjunction with asbestos removal. This original signalling system as stated within ARHS (1987) was designed to take a maximum of 36tph or a train every 45 seconds. This book also states that when this signalling system reaches capacity, additional speed controls can be added for a maximum of 42 trains per hour. This signalling system was removed to enable the final transfer over to Double Deck trains, which had additional problems using the earlier signalling system and a higher dwell time.

In the 1960's the CityRail network reached capacity, without further amplifications, signalling works and costly line expansions, and government policy dictated that the maximum capacity of the existing system should be utilised. This brought about the engineering proposal for a hybrid single-double deck train, where the motor cars (1,4,5,8) were single deck cars, and the trailer cars (2,3,6,7) were double deck, to maximise capacity. The double deck Tulloch trailer cars introduced in 1964 provided a significant seated capacity boost to the system, and it was proposed that the system be completely converted to double deck operation as this type of operation maximised the number of people that were seated in each train. This conversion to a complete double deck system was completed in 1993 with the removal of the last of the single deck trains.

Single and Double Deck Rollingstock

Source: Ben Chatwin (2009)

The Sydney Millennium train is 164m long and has a seated capacity of 904 people. This compares to the single deck Xtrapolis trains that were introduced into Melbourne at the same time. The Xtrapolis trains are 143m long and seat 528 people. Making the lengths of the trains identical (143m) brings the seated capacity of the Millennium Train to 791 people seated, compared to 528 for the Xtrapolis. As the double deck train has more people physically travelling in the same space as a single deck train, it requires a longer stop, or dwell time to allow people to board and alight the train, which reduces capacity of the overall system.

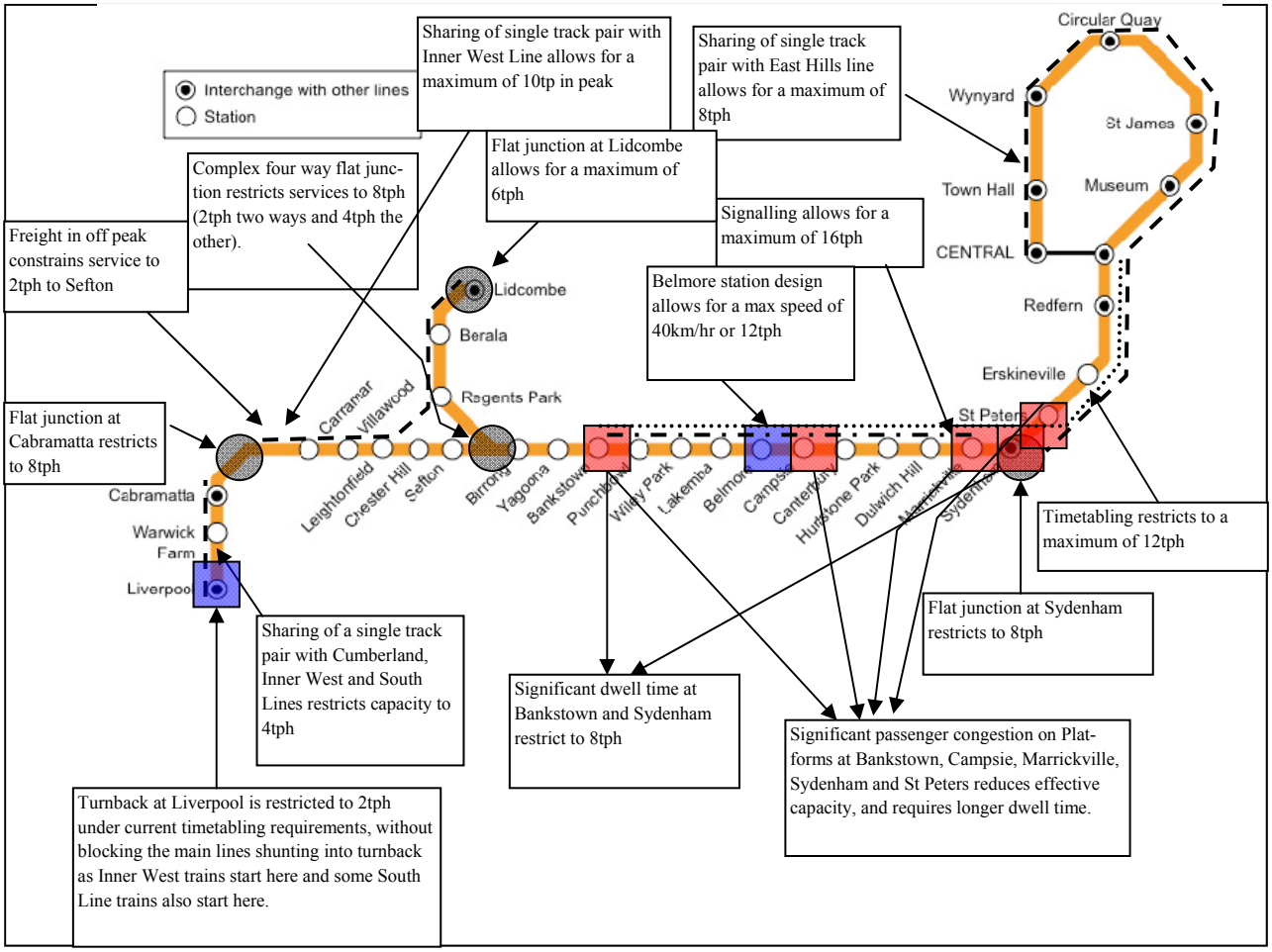
As passenger loads increase on a deck train pass the maximum number of seated passengers, the service reliability drops, as these trains are set for maximum seated capacity, which restricts the availability of standing locations. This also means that there is significant congestion once people start standing, as this restricts mobility and egress of the train. Double deck trains are ideally suited to long distance runs with relatively long distances between stations, where seated capacity is the most important determinant, but single deck trains are ideally suited to shorter runs, which are all stations, requiring a high capacity, high speed and high frequency service, generally in the inner and middle ring suburbs.

1.3 Constraints

Goldratt (1984) states that in any system is unable to reach its maximum potential due to a very small number of constraints, and that there is always one constraint that is stopping the system reaching its potential. Constraints for a railway network are simply factors, whether operational, infrastructure, or policies and people that restrict the maximum practical or theoretical capacity of the network. Chapman (2009) states that the theoretical capacity of a railway line is essentially infinite; however it is the signalling and station capacity that constrains the capacity. This is in agreement with Vuchic (2004), which states that the key determinant of carrying capacity is the busiest station on the line.

Chapman (2009) proposes that the capacity of a line is generally variable, based upon each of the individual constraints on the line. An example of this is shown in Figure 1.1, showing the Bankstown Line and the constraints therein, reducing capacity from the maximum standard of 20tph used with CityRail.

Figure 1.1 : Capacity constraints on the Bankstown Line



This shows that even though the nominal maximum capacity is 20tph, the reality is that the line is constrained to 4tph in the extremities, and 8-12tph from Bankstown to Central, then 8tph through the City Circle. This means currently the maximum capacity that the Bankstown line can have is 8tph, until the City Circle, Sydenham Junction and Cabramatta – Liverpool capacity constraints are sorted out – then the maximum capacity of the line can be 12tph. This confirms what Goldratt (1999) states that the restrictions on maximum potential are overall small, yet can be relatively easily fixed. It should be noted however that Goldratts theory is a hard constraint, as it is the single limiter to increased service, compared to other constraints such as the theoretical constraints such as platform capacity which is limited by peoples abilities, use and understanding of how to use the station. All lines suffer from Goldratts constraints like the Bankstown line, however by mitigating the main problem, increased frequencies and services can run up to the next hard constraint.

1.3 Constraints

Figure 1.2 below shows the key/major constraints within the CityRail Network, each discussed below

Figure 1.2 : Capacity Constraints of the CityRail Network

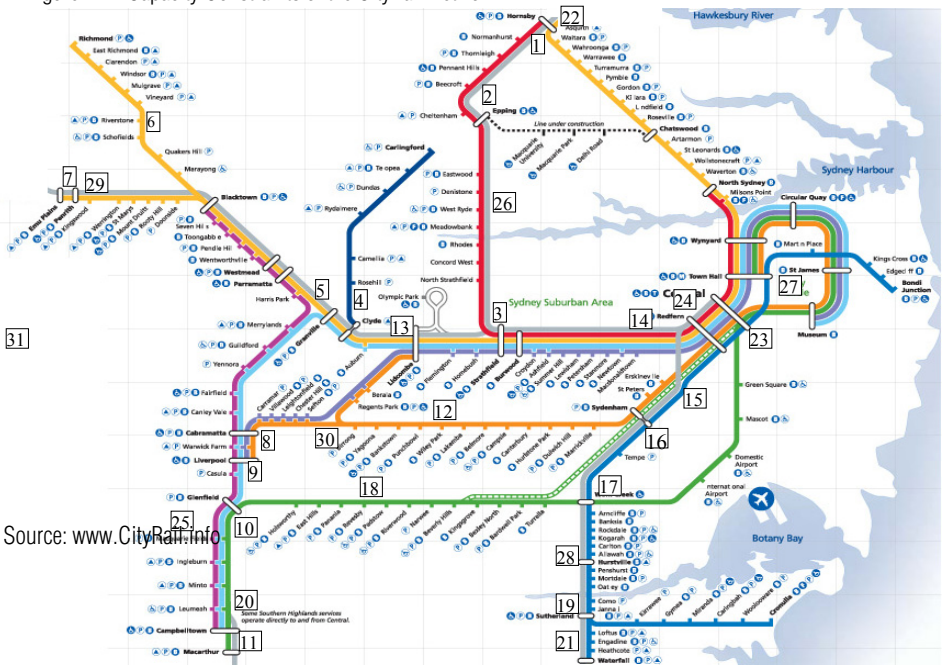


Table 1.1 : Capacity Constraints of the CityRail Network

1	Hornsby Station has a flat junction where North Shore and Northern Lines meet and also only has five platforms
2	There is only a single track pair that is shared between freight, suburban and intercity trains between Hornsby – Epping, and then two-four tracks to Strathfield junction
3	Strathfield Junction is only partly grade separated, with significant changing of tracks at this location.
4	The Carlingford line is single track with only a passing loop at Parramatta Road
5	Granville Junction is a major flat junction, and also has restrictive signalling.
6	The Richmond Line is single track from Quakers Hill with passing loops
7	Penrith has insufficient capacity for number of terminating trains
8	Flat Junction with significant volumes of trains
9	Liverpool has insufficient capacity for number of terminating trains
10	Flat Junction with significant volumes of trains
11	Insufficient capacity for number of terminating trains, and poor junction layout at Macarthur and Campbelltown
12	Lack of overtaking opportunities for express services
13	Flat Junction
14	Major Flat Junction where fast western line trains cross
15	Insufficient separation of local and express services due to lack of track
16	Flat Junction between Bankstown and East Hills line services
17	Flat Junction between East Hills, Freight and some Illawarra services
18	Lack of track capacity for future services
19	Flat Junction
20	Lack of capacity for future use of the SSFL
21	Three phase country signalling in operation
22	Three phase country signalling in operation
23	Insufficient separation of City Circle and Airport Lines
24	Four tracks merge into two for Cleveland Street
25	South West Rail Link
26	North West Rail Link
27	Approaching Capacity
28	The Junction of Hurstville is designed poorly.
29	The quad track of the Western Line finishes at St Marys, with a relatively low speed crossovers.
30	Sefton Park junction is a highly constrained junction, with tight radii curves, low track speeds, poor track geometry, and high levels of conflicting moves between trains
31	Extensive track sharing between lines leads to loss of reliability and reduces capacity.

1.3 Constraints

These constraints have caused capacity to be reached, even though at present there is spare capacity on the Eastern Suburbs, North Shore and City Circle lines, and significant capacity at Sydney Terminal. Sydney Terminal being a terminal station with fifteen platforms can enable a significantly higher throughput of trains than a through routed line with fewer platforms. This means that Sydney Terminal (with quad track through Redfern) could handle up to 60 trains per hour, which is triple the existing level of 20 trains per hour.

It has been noted within the Sydney Morning Herald (2009 a,b,c) that Sydney Terminal cannot cope with more than 20 trains per hour running in each direction. The reasons given is that there would be too many conflicts between trains on crossovers. This is a fallacy, as Brown (2009) states a two platform terminus can terminate a maximum of 24 trains per hour and maintain timetable stability. Sydney Terminal also has multiple pathing options between Redfern and the designated platform, enabling multiple trains to be entering and exiting the station at the same time. The key constraint of Sydney Terminal is the Cleveland St Bridge bottleneck, where the four through tracks merge into 2 to pass through Redfern Station, which can be alleviated by better use of existing tracks through Redfern. (See figure 2,2), and the associated signalling caused by this merge. At present there are 6 track pairs into Redfern (mains, suburbans, locals, Illawarra main, Illawarra locals, Illawarra relief). This does not change, rather the alignment of where the trains enter Redfern does.

A terminal station such as Sydney Terminal has significantly greater turnback ability, as it has multiple platform faces. This removes the key constraint for railway operations, as stated by Vuchic(2004), which states that the station is generally the greatest constraint not the tracks.

Concourse at Kings Cross

In 1932, St James in peak had 30 trains per hour terminating from the Kingsgrove, Bankstown and Oatley line, using only two platforms – which is a metro line level of service.

At present there is the potential for up to 200 trains per hour into the Central/Sydney Terminal interface. There are currently only 109 trains per hour into this area. This is predominately due to underutilisation of the local and main tracks from Strathfield, as well as underutilisation of the existing Illawarra local tracks from Sydenham. The North Shore line has a few spare slots at present as an interim on time running measure.

This thesis aims to show that there is additional capacity within the existing CityRail network, without the construction of any new lines – though there will need to be junction upgrades, and signalling enhancements to enable this to occur. However this is significantly less than the cost of building a new line – costs which range form 40million/ lineal kilometre, to 80 million/lineal kilometre. It also emphasise local connections – as Sydney Metropolitan Strategy (2005) and ABS statistics show (2001, 2006), the majority of employment is local, whilst the current rail network is heavily geared towards the Sydney CBD – with usually appalling frequencies at local stations, which reduces availability, and choice of travel.

This is intended to show that as a stop-gap measure there is spare capacity within the network to enable new lines to be built given that it can take a decade to build a new underground railway line, from proposal to implementation. This thesis will also show where new infrastructure should be constructed but will not go into depth given the word constraints.

1.4 Existing Patronage

CityRail has an overall patronage of 945,000 per weekday, with the split for suburban lines patronage shown below:

Table 1.2 : Suburban patronage

Suburban	2006	2008	% change	Raw Growth	Pax /km
North Shore	101,395	107,990	7%	6,595	4,276
Illawarra	110,785	114,295	3%	3,510	2,053
Inner West	36,200.5	39,026	8%	2,825.5	1,823
Bankstown	57,102.5	62,322.5	8%	5,220	1,784
Northern	53,108	57,543.5	8%	4,435.5	1,699
South	54,002.5	56,247	4%	2,244.5	1,680
Western	111,991	116,500.5	4%	4,509.5	1,440
East Hills	35,920	38,095	6%	2,175	762
Carlingford	1,320	2,530	92%	1,210	352

Source: CityRail 2008,2006

Table 1.3 : Intercity patronage

Intercity	2006	2008	% change	Raw Growth	Pax /km
Central Coast	54,181	54,480	0%	299	324
South Coast	24,810	25,620	3%	810	161
Blue Mountains	14,680	15,160	4%	240	97
Hunter	7,415	7,790	4%	375	37
Southern Highlands	2,680	2,410	-9%	-270	15

Source: CityRail 2008,2006

Note: The discrepancy between these figures and the 945,000 people per day is that these tables exclude the city stations of Redfern, Central, Town Hall, Wynyard, Circular Quay, St James and Museum, due to intermingling with lines. The .5 figures comes from stations which serve multiple lines – the station patronage was split evenly between the servicing lines, which gave half figures for certain stations.

Single and Double Deck Trains

Source: Ben Chatwin (2009)

This shows that the majority of patronage is provided by the Illawarra, North Shore and Western Lines (340,000) with the remainder of the suburban lines making a significant proportion, but under 100,000 passengers per day, per line.

The suburban network provides for approximately 600,000 trips per day, the Interurban network provides for approximately 100,000 trips per day and the remaining 245,000 trips are explained within the note above.

As Semple (2008) researched the timetable is heavily geared for outer suburban rapid commuter travel. This is clearly identified by the Western Line – which is 81 kilometres long (Penrith/Richmond – Central) having the highest patronage of any suburban line, yet the 7th highest per kilometre passenger levels. The Inner West and Bankstown lines show quite high per kilometre patronage, though lower overall patronage, as these lines are both relatively short by Sydney Standards, and also receive few express services, meaning the transport on these lines is dominated by local travel.

If we compare various interchange and major stations as shown in the table below, with the number of trains stopping, compared to the number of trains passing, especially in the inner city the differences are stark.

1.5 Trains Stopping

If we compare various interchange and major stations as shown in the table below, with the number of trains stopping, compared to the number of trains passing, especially in the inner city the differences are stark.

Between 7:30 and 8:30am in the morning peak to the city at selected stations

Table 1.4 : Station use and trains stopping

Rank	Station	Patronage	Trains Stopping	Trains Express	% stop	Boardings per Train	Trains Capacity
14	Burwood	11790	20	27	42	**192**	**13%**
18	Ashfield	10340	12	37	24	**177**	**12%**
36	West Ryde	6460	7	4	64	**229**	**16%**
47	Newtown	4525	5	42*	10	**162**	**11%**
21	Lidcombe	10050	14	14	50	**141**	**9%**
23	Auburn	9690	10	14	42	**229**	**16%**
22	Rockdale	9940	11	7	61	**220**	**15%**

Source: CityRail 2009, 2008,2006

Note: Newtown station is physically constrained due to 1900's rail amplification works, and only has two platforms. 7 trains run express past the platform face.

Note: Boarding's per train is an averaged figure from the patronage statistic which is the No. Of passengers from 6:00am-9:30am at that station. This is averaged out between all the trains that stop at this station during this time. However loadings at the station for trains which will arrive into Central between 7:30am-8:30am will be significantly higher – this is the core peak period.

Congestion at Town Hall Platforms 5/6

In general, given these stations high patronage loads, a significant number of trains should be stopping there. In general only Rockdale, or West Ryde receive a percentage of trains stopping that actually meets the level of patronage, as 60% of trains should be stopping to meet these services. Or more appropriate sweeper trains should be used. Interestingly the Illawarra line, even with a high number of services stopping at major stations, still has significant crush loads on all trains, due to lack of services.

The loadings per train are also of concern, given that these stations are located in the inner and middle ring suburbs of Sydney, where trains will already be quite full and the high level of loadings per trains will increase dwell time, which will reduce the frequency, reliability and safety of the network.

This given with the significant increase in urban densities located around inner and middle suburban railway stations necessitates increased services. For example Rhodes was an industrial wasteland with highly contaminated soils that has now become a very high density residential precinct, with significant levels of towers, and a large retail centre. A train every 30 minutes outside of peak times is unacceptable to deal with urban densities of this magnitude. The urban density of Sydney has been growing significantly since the policy of urban consolidation took hold in the 1960s. Urban consolidation essentially is maximising the density and increasing the use of land around nodes, primarily around railway stations. This level of service can also be seen to need to be upgraded in other areas which are experiencing significant urban infill.

Burwood especially being a Major Centre under the metropolitan strategy should have significantly more trains, except the interurban services stopping given its commercial/retail role, as well as the high volume of patronage. Burwood is also expected to perform a major interchange role with the West Metro. This would also maximise demand for this station, given its major interchange role between transport modes, and eventual employment and population growth.

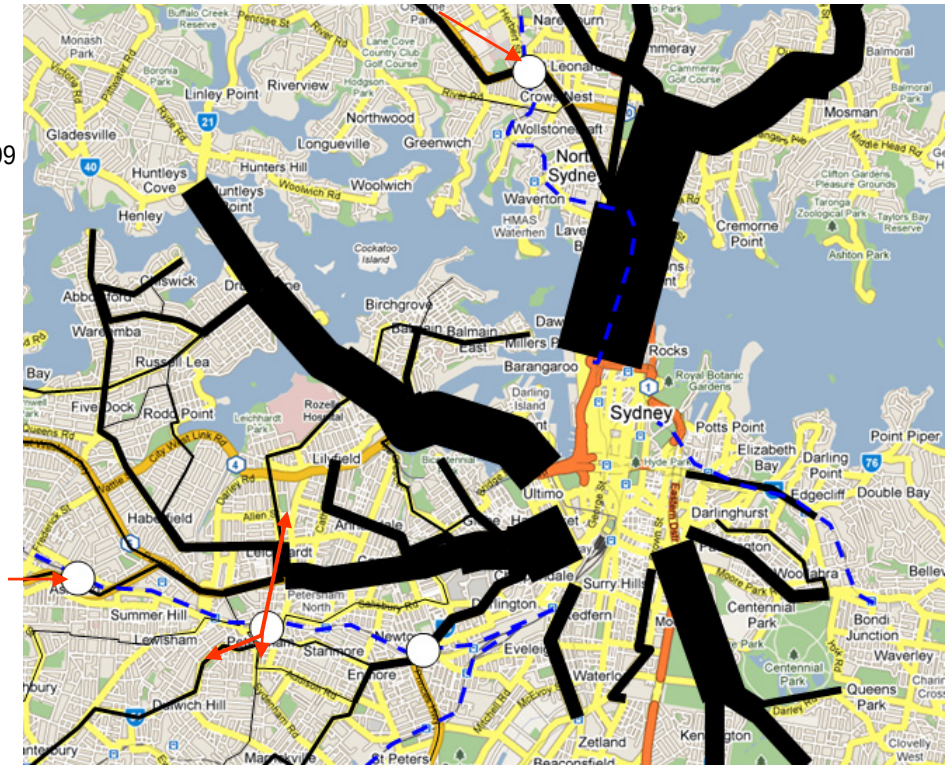
1.6 Connectivity with other modes

It should also be noted that there is probable untapped demand for rail services within the inner suburbs., given the very high volume of vehicular traffic, walking use, and bus use, as well as suppressed demand—where they do not make the trip, as there is no viable way to make it. At present due to the constrained capacity, and lack of service at many stations, most inner city residents will take the bus, rather than the train – especially in the Inner West Corridor. This is one of the key reasons for why the Parramatta Road is one of the most overcrowded bus corridors in Sydney, past Sydney University. This is a historical split as noted by Bourke (1997), where the tramways dealt with the local patronage (many bus routes in inner Sydney still follow the old tramways) and the railways dealt with the long distance commuter routes.

Figure 1.3 shows the level of buses along the four key corridors in Sydney between 7:30 and 8:30am into Central/Wynyard/Town Hall.

Figure 1.3 : Bus volume and rail interchange points

Source: Sydney Buses 2009



This figure clearly illustrates that there is interchange potential from buses to the railway system at Ashfield, Petersham, St Leonards and Newtown. Many of these bus routes, especially in the Parramatta, Victoria, Anzac and Oxford Road corridors follow the original alignment of the tramway routes, showing how there was significant competition between the two modes of transport, and that this continues today. Integration of transport modes may increase the use of both systems. This is especially important given the disparity in carrying capacity of the various modes – a train can carry up to 1,500 people per train, or 30,000 people per hour, whilst a bus can carry a maximum of 70 people or approximately 3,000 people per hour. It takes 22 buses to carry the same loads as a single 8 car train. Cervero (1996) states that buses should be primarily in a feeder role to a higher capacity system to take into account the greater flexibility for short runs that buses have as their strongest advantage.

An enhanced North-South Route running from Lilyfield down Norton Street, then Crystal Street into Petersham Station, then down Sydenham Road into Marrickville, then Marrickville Metro would enable a greater connectivity in the area. A better interchange with Ashfield station for all Hume Hwy routes would also enable greater interchange potential.

Figure 1.4 : Sydney Tram Network in 1932

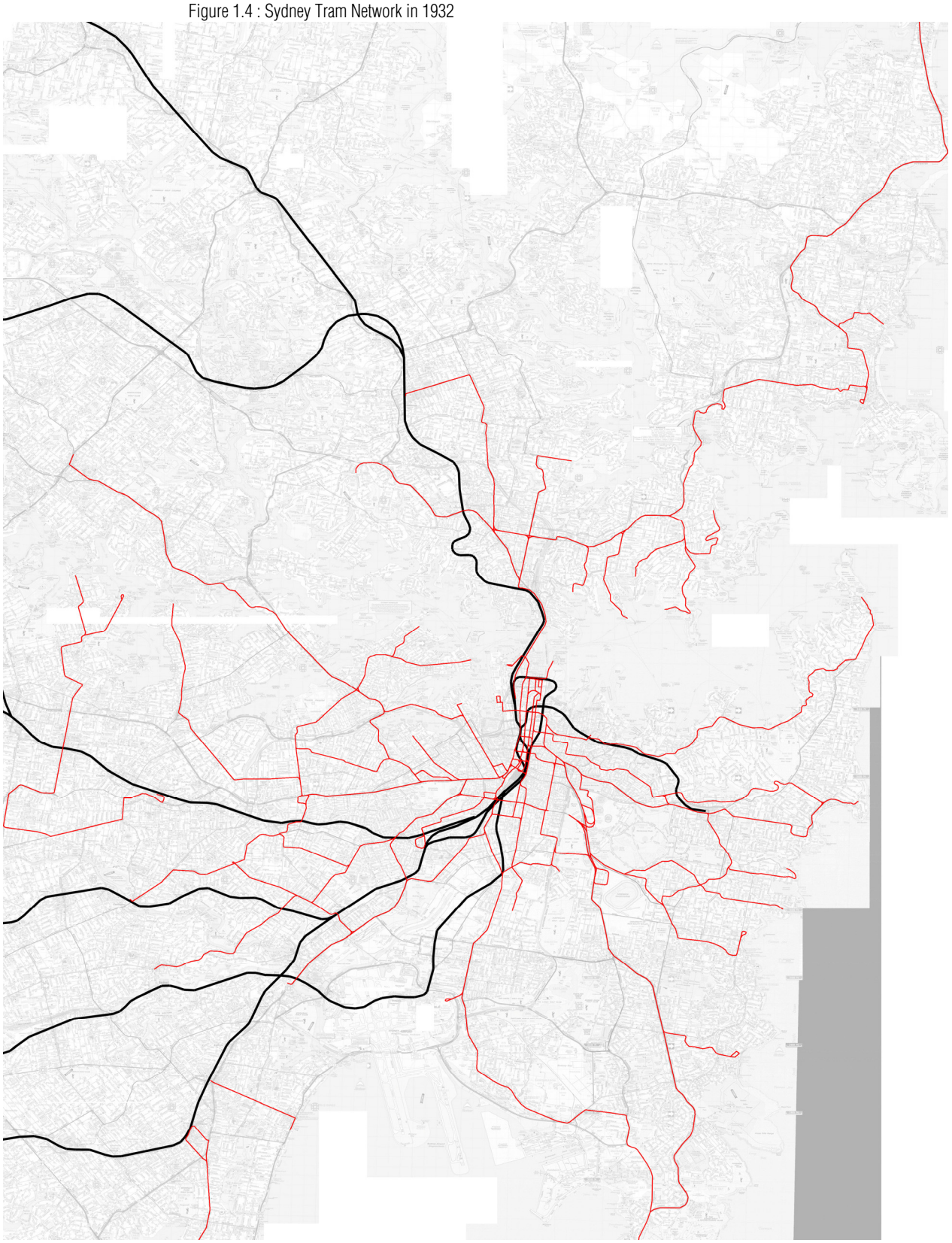


Figure 1.4 shows the tramway routes overlaid upon the existing railway network. The majority of the inner bus routes operated by STA still generally follow the tramway routes. This also shows the dominance that the tramway network had in the inner, and middle suburbs over the railway network. Juggernaut (1997) states that the tramway network essentially operated as the metro service, whilst the railway lines operated to the far suburban and country reaches of the state. This can still be seen today with the split between inner and outer suburban train frequencies.

1.7 Train Stopping Patterns

Table 1.4 below shows the number of stopping patterns per line, excluding intercity trains.

Table 1.5: Stopping patterns by line

Line	No. Of Stopping Patterns (exc intercity)
Western Line	25
North Shore Line	22
Illawarra and Eastern Suburbs Line	28
Bankstown Line	11
South and Inner West Line	22
East Hills Line	22
Olympic Park and Carlingford Line	4
Northern Line	16

Source: CityRail 2009

Total: 145 stopping patterns for 8 lines.

Note: This is using the timetable and approximate stopping patterns spread within. There is potential for a small margin of error.

This shows a very high level of possible train patterns across the majority of lines, which reduces the accessibility and convenience of the railway network for local and casual travel. This level of stopping patterns (especially coupled with the general low frequencies), necessitates the use of a timetable, to ensure that connections can be made, and to minimise waiting times, which act as a general deterrent to local travel. It is noted within the Subregional Strategy, ABS, and CityRail (2006, 2008) that local travel makes up the dominant travel patterns for residents, and is also the least tapped market, as shown by figure X. This is a clear market for improved services.

PIDs at Wolli Creek

Source: Ben Chatwin (2009)

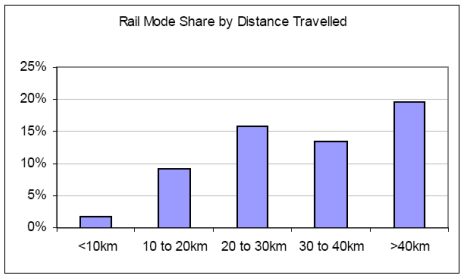
Figure 1.5 : Rail mode share by distance

Rail Mode Share by Distance Travelled

The table and graph below show the mode share of rail by trip distance for residents of Sydney Statistical Division on an average weekday, 2005.

Rail Mode Share by Distance Travelled, Average Weekday 2005

Trip Distance	Rail Share
< 10km	1.8%
10 to 20km	9.3%
20 to 30km	15.7%
30 to 40km	13.5%
>40km	19.7%



Rail's share of all trips increases with distance travelled. Of all trips less than 10km 1.8% are by train compared with 19.7% of all trips over 40km.

Source: Household Travel Survey, Transport Data Centre, Ministry of Transport.

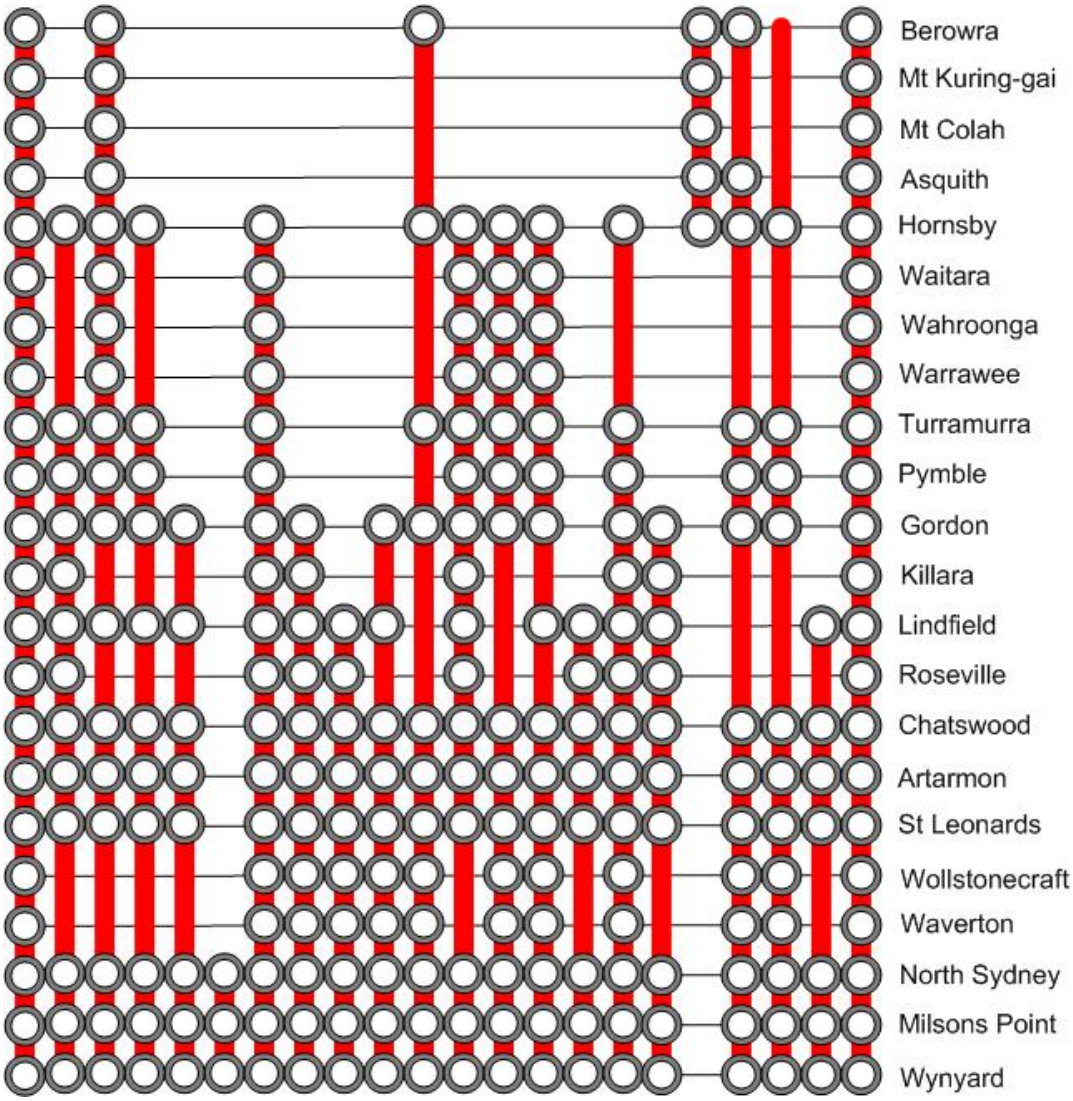
Source: CityRail 2008,2006

This figure from CityRail (2008) shows the precedence set to long distance commuting. However a question remains, that generally cannot be resolved, as to whether there is a dominance of long distance commuting, because it is how the network is geared, or because it is what people want. In comparison to many other rail systems in Australia, there appears to be significantly longer commuting distances for Sydney than compared to Melbourne or Perth. Local commuting is a valuable market to tap into and as TDC (2008) shows, makes up the absolute majority of trips made in Sydney. This figure also shows that the use of rail for short trips, such as one to five stations, is essentially non-existent. This is probably due to the poor frequency of all stations services, and the dominance of limited stops services, where trains skip certain stations. This also shows that this is a market that CityRail is not managing to tap into.

1.7 Train Stopping Patterns

Figure 1.6 shows the stopping patterns on the North Shore line, with the extensive variations in where trains stop. The difference in the majority of cases is one or two stops, which reduces the potential for a turn-up-and-go service, and also forces reliance upon a timetable to ensure that you arrive in a timely manner. Rationalisation of stopping patterns would enable a higher capacity service as running such variable stopping patterns, as well as the express services, constrains capacity. A line which has a very high per kilometre use, and is relatively short (being only 20 kilometres to Hornsby) ideally does not require express services, due to its proximity to the city.

Figure 1.6 :Stopping patterns on the North Shore Line



Source: CityRail 2009

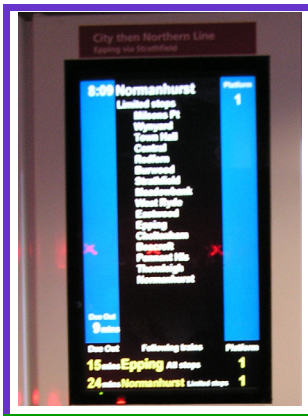
1.7 Train Stopping Patterns

The use of sweeper services on the CItyRail network is rare. A sweeper service is a train that comes in, and the majority of the passengers on the platform board this service. This empties out the majority of passengers from the platform, enabling it to fill up in time for the next service, analogous to a broom sweeping up dirt.

Platform 1 and 2 at Town Hall are an island platform, and are also the most congested platforms in the network, especially during afternoon peak. This occurs primarily due to the lack of sweeper trains. During the 3:30-7:00pm afternoon peak hour there are 23 stopping patterns, spread across the Inner West, Northern, South, and Western lines.

These stopping patterns vary from the all stations services, to skip-stop services, and then to super-express services. This variation in patterns means that people will be waiting on the platform, until their preferred service arrives. This reduces the effective capacity of the platform, meaning that the platform becomes more congested more rapidly, and then also then forms the main bottleneck for the network.

The Christie Report notes that the majority of express services only save around 5 minutes of travelling time compared to the standard service, yet have a higher load compared to the regular service. Christie theorised that the apparent saving of time of the express was considered more desirable than the slower service, even though generally they took around the same time, especially when waiting time was taken into account.



PIDs at North Sydney

Sweeper services must be introduced into the CityRail network along with rationalisation, standardisation and introduction of a clock face frequency. At present there are significant numbers of stopping pattern variations, which leads to additional congestion at platforms as passengers wait for the ideal service, but this reduces overall capacity of the network, by reducing physical capacity of the stations. The reduction of stopping patterns down to a maximum of two to three per line would increase the efficiency of the network by having all operating as sweeper services. Standardisation of stopping patterns between peak and off peak will also increase capacity by reducing the need for a timetable, and giving similar service patterns all day.

This would then enable for a greater utilisation and capacity of the network, as one of the key capacity constraints, of the network, platform capacity would be reduced. As Goldrat (1984) this constraint would then be reduced, enabling a higher frequency of service up to the next constraint. This would then also enable for passengers to become more used to needing to change trains, rather than a one seat service, that is the norm now.

1.7 Station Use

This list shows that the top 40 stations provide for 633,700 trips out of the 945.000 trips made with CityRail each weekday, which shows that an absolute majority of patronage occurs from a select group of stations.

Table 1.6: Top 40 station patronage

No.	Station	Trips per Day
1	Central	80050
2	Town Hall	77525
3	Wynyard	54425
4	Parramatta	26060
5	North Sydney	25000
6	Bondi Junction	19150
7	Martin Place	18305
8	Redfern	17990
9	Chatswood	17530
10	Strathfield	17015
12	Circular Quay	16215
12	Blacktown	15060
13	Hurstville	14095
14	Burwood	11790
15	Hornsby	11165
16	Kings Cross	10740
17	St Leonards	10365
18	Ashfield	10340
19	Kogarah	10325
20	Cabramatta	10080
21	Lidcombe	10050
22	Rockdale	9940
23	Auburn	9690
24	St James	9355
25	Fairfield	8655
26	Liverpool	8650
27	Epping	8575
28	Bankstown	8120
29	Museum	7975
30	Gordon	7205
31	Westmead	7145
32	Penrith	7135
33	Mount Druitt	6975
34	Granville	6825
35	Eastwood	6735
36	West Ryde	6460
37	Sutherland	6455
38	Edgecliff	6425
39	Milsons Point	6170
40	Campbelltown	6010

Source: CityRail 2008, 2006

Parramatta Station

Source: Ben Chatwin (2009)

Note: A trip equals an entry and exit out of a barrier, to make one journey. Total entries/exits out of barriers, are the numbers shown doubled, to account for the return journey.

1.7 Station Use

If we exclude the City Station (Central, Town Hall, Wynyard, Martin Place, Circular Quay, St James and Museum) we end up with a patronage of 370,000 from 33 stations. This means that 33 stations (out of 306) provide for 40% of the total patronage, and from 11% of the entire stations. It is also apparent that high volume stations drop off rapidly, with only 5 stations with patronage greater than 20,000, and only a further 16 stations above 10,000 passengers.

This either indicates that there is significant untapped demand – through the poor timetabling practices, or that there is significant potential for rationalisation of poor performing stations in Sydney. It is interesting to note that Newtown is ranked no.47, yet is adjacent to the longest commercial, retail and dining strip in Sydney, where buses come as frequently as every 2 minutes to service demand, along a highly congested road. One would assume that if there was increased frequencies stopping at Newtown Station, significant latent demand, which currently use the bus, or other modes, would transfer to rail – which is the fastest trip into Central from this area, taking only 6 minutes, compared to 12 minutes for the bus.

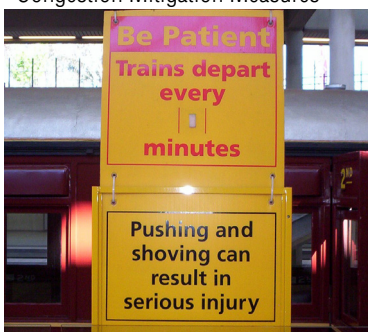
A major constraint that CityRail faces at present is actually moving people out of the core City Stations. Table 1.6 hows the number of barrier gates at each City Station, and the maximum throughput the station has as a consequence.

Table 1.7 : City station capacity

Source: CityRail 2008

Station	Barrier Gates A / M		Maximum pph	Current throughput	%utilised.
Central	38	5	74,280	44,550	60.1%
Town Hall	39	4	72,840	44,730	61.4%
Wynyard	38	2	65,280	41,880	64.1%
North Sydney	14	2	24,840	18,670	75.2%
Martin Place	14	2	27,840	14,530	52.2%
Circular Quay	10	2	21,600	8,680	40.2%
Museum	8	2	18,480	5,400	29.2%
St James	8	2	18,480	5,170	27.9%

Congestion Mitigation Measures



Source: Ben Chatwin (2009)

Note: To balance loadings, to show the maximum possible throughput, the assumption is that the 6:30-9:30 figure from CityRail (2008) is for a single hour. The majority of these people would be arriving into the CBD cordon between 7:30 and 8:30am, with less people for the remainder of the morning peak. This means that the actual percentage utilised will be slightly lower than shown above.

CityRail(2008) states that the maximum standard flow through an automated barrier gate is 26 people per minute. The maximum that CityRail (2008) observed exiting a barrier gate in a single minute was 31 people per minute. For the calculation of maximum capacity throughput of the station the numbers are as follows:

26 people per minute, per barrier gate
50 people per minute per manual gate (if tickets are not being checked)

This shows that Museum and St James has ample capacity to carry more people throughout the station, whilst Town Hall, Central, Wynyard and Martin Place have some capacity in reserve for greater patronage numbers.

This also clearly indicates that it is a timetabling problem, not a station capacity problem, in dealing with crowds, especially at Wynyard, Town Hall and Central. It clearly shows that there is the raw capacity to handle greater loads than current, but as the platforms do not appear to be emptying as rapidly as they could, it is most likely that the trains are not acting as 'sweepers'. A sweeper train means that when the train arrives at the platform, the majority of the people on the platform get on that particular train. If this does not occur the platform will become highly congested rapidly.

2. Literature Review

Transport planning theory is governed by multiple concepts and theories that have been developed over the years. This literature review is only concerned with those theories for maximising the use and efficiency of an existing transport system, and the practical, and theoretical levels of capacity and system design. This literature review is intended to show the theoretical underpinning of the proposed changes indicated in the next section for CityRail. It will also look at and briefly critique previous strategies proposed for CityRail.

As TBC (2003) clearly states, Capacity of a entirely or mostly grade separated railway is governed by a series of factors that both TBC (2003), and Vuchic (2007) show.

These factors are:
% of grade separated junctions
Use of appropriate turn-backs
Signalling Spacing
Maximum Dwell Time (for the worst station)
Train stock/variations in train stock
% of single track
Different stopping patterns

Capacity Constraint at Wolli Creek

Source: Ben Chatwin (2009)

Vuchic (2007), Timetabling for Tomorrow (1992) and TBC (2003) clearly state that the minimum headway is the maximum number of trains that can run in the system at maximum capacity. This is calculated by the minimum distance (in seconds) between trains, the amount of time (in seconds) required to dwell at the busiest stations, and then an arbitrary figure, for the operating headway. TBC (2003) states that a minimum of 10-35 seconds should be added onto the minimum headway generated above, whilst Mees (2009) states that running at ¾ maximum train numbers is appropriate. Vuchic (2007) comments that a system should not be run above 80% of capacity to enable an inbuilt margin for delay.

The operating headway is a period of time inserted into maximum frequency operations, to enable the system to avoid a cascade delay, if delays occur across the network.

A cascade delay, is when one train runs late, the train behind it runs later, the train behind that one even later, and there is no way to bring the system back to order, without major transpositions, which leave trains out of timetabled order, and rolling stock, drivers and other equipment in the wrong locations which can lead to significant problems during that day, and the next if not appropriately dealt with.

2. Literature Review

Vuchic (2007) simply states that the relationship between the required capacity on a line and its ability to provide capacity is the following:

- *The highest passenger demand that occurs on any intersection spacing (called the maximum load section) represents the critical volume that the line should carry*
- *The maximum capacity that a line can physically offer (in both vehicles per hour and people per hour) is determined by the station along the line that requires the longest headway*
- *Station headway is mostly a function of standing*(waiting) *time which in turn depends on the passenger exchange volume, (number of passengers alighting and boarding) and station operations*
- *Consequently assuming similar design and operating conditions at all stations, the busiest station (i.e. the one handling the highest passenger volumes) determines line capacity.*

The two elements critical for demand and supply of capacity of a line, Maximum Load Section and the critical station are independent: The critical station may be located away from the Maximum Load Section.

This means that the following apply to CityRail.

- The section of maximum load section is between Redfern – Strathfield to the west, Redfern – Hurstville in the South, Central – Kingsgrove in the South West, and Wynyard – Chatswood in the North. An additional section between Blacktown and Granville also exists in the west. This is where overcrowding is at its worst.
- The station which requires the longest headway is Town Hall – with dwell times of up to 95 seconds not uncommon in peak.
- The need to share tracks with slow, and long freight trains.
- Central is the busiest station within the network, and is designed for very high volumes of passengers, with large circulating tunnels and spaces, and significant platform connections. However Town Hall provides for a greater capacity constraint due to a highly constrained station design, with limited circulation areas, and a very high level of interchanging.

Capacity Constraint;
lack of level access to trains.

Source: Ben Chatwin (2009)

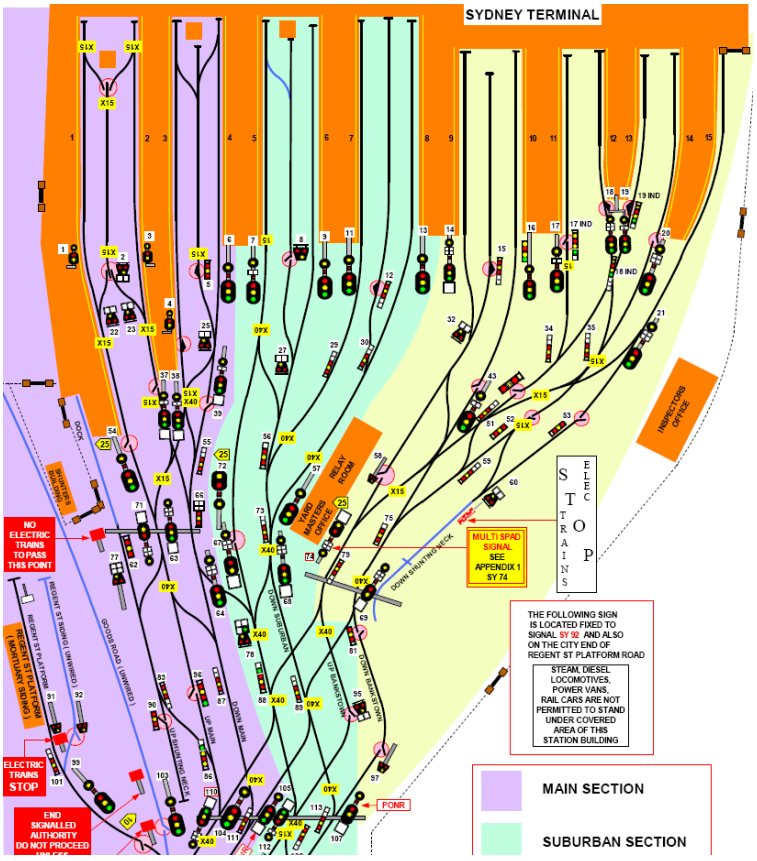
These are the key constraints to optimum operation of CityRail, and if these were fixed, would enable a higher intensity and frequency operation. Overall these are problems or issues that can be fixed, usually through changes to operational procedures, as well as amplification where required.

2.1 Headways

These concepts, when coupled with CityRail (2006, 2008) shows that the maximum headway of the system is 24tph. Incorporating the 80% of maximum capacity this means that the maximum standard capacity is 20tph, except into Sydney Terminal which is 30 trains per hour per track due to the large number of platforms. This does not mean in exceptional circumstances trains cannot be run at higher frequencies. During extreme delays (due to a fatality) in afternoon peak, a minimum headway of 90 seconds was observed on the Eastern Suburbs Line, for a period of 6 minutes. A similar situation was observed at Circular Quay, where other City Underground Line trains were being diverted to where a minimum headway of 100 seconds was observed for 8 minutes. The capacity constraints for CityRail are not so much the signalling, but rather the dwell time at key stations.

Interestingly the TRB (2003) states that the theoretical maximum trains per hour for an 8 car train network is between 30-34 trains per hour, and 35,000 to 45,000 people per hour per track, which indicates that double deck trains are probably constraining capacity and frequency. This contrasts with Vuchic (2004) which states that the Paris RER is the most efficient railway operation in the world which utilised double deck trains. However it is theorised that the high level of standing space – and a significant reduction in standard double deck seated capacity, three doors per train, and a highly efficient signalling system enables this system to operate at such high capacities.

Figure 2.1 : Sydney Terminal layout



Source: CityRail (2007)

Sydney Terminal can have a considerably higher throughput of trains than a through station, as it has multiple platforms, as well as multiple crossovers enabling multiple paths to be routed through the yard, reducing conflicts between trains. 30tph per track is considered the upper limit, as this is the limit of the existing signalling system for trains that can be up to 240m long. The theoretical reality indicates that up to 40tph could terminate here in a single hour, though the potential for delay is very high. Turnback of 30tph could also be done with a 5 platform terminus, assuming an 11 minute turnback time.

This is significantly lower volumes than what can exist on the London Overground Commuter lines, where there are significant volumes of trains into Victoria, Fenchurch, and Waterloo stations, with very short turnback times due to a lack of platforms, and very high volume of people and trains.

This figure 2.1 shows the entry into Sydney Terminal, showing the high level of crossovers and track capacity, showing that a very high frequency of service throughput into terminal roads.

2.1 Headways

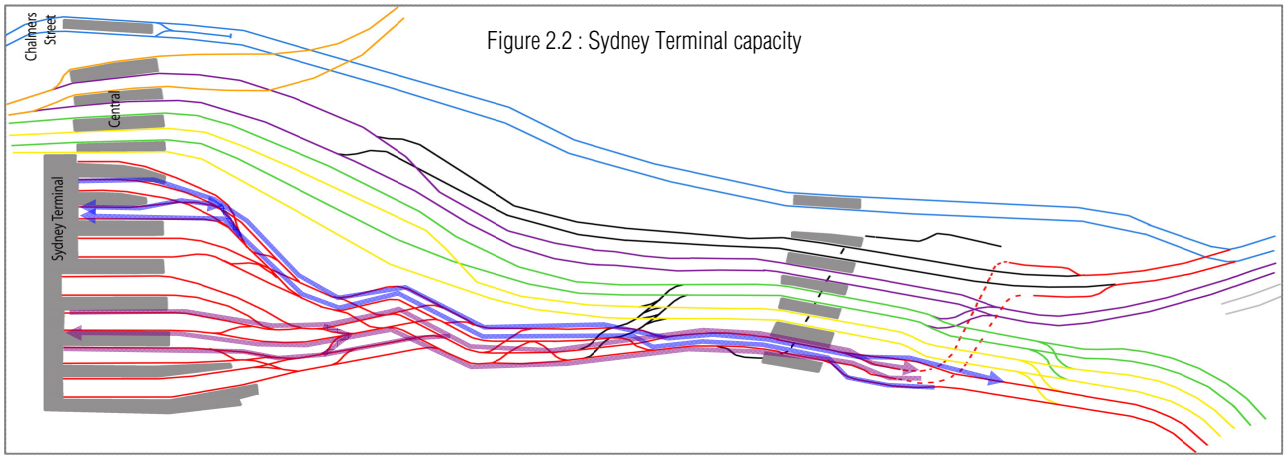
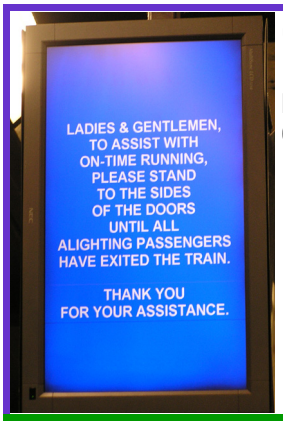


Figure 2.2 : Sydney Terminal capacity

The figure 2.2 above shows Sydney Terminal, with the use of 6 platforms, divided equally between western and southern services. Running at 30 trains per hour with an even split 15/15tph between the two areas. This enables a train to sit in any platform for a maximum of 10 minutes (with a safety margin of 2minutes) and then depart without interrupting the incoming service. This meets with CityRail's minimum turnback times of 8 minutes for an 8 car train, however is not enough time for interurban trains to receive a toilet decanting. This said however; all outer interurban destinations (Port Kembla, Mount Victoria, Newcastle/Broadmeadow, and Moss Vale) have decanting facilities, and this can be transferred here.



Capacity limits and passenger education

This shows that with the use of only 6 of the 15 platforms at Sydney Terminal (40% utilisation) 30tph can be turned back at Sydney Terminal. Trains requiring a longer stay at Sydney Terminal can use the other platforms, which are not as essential to the intensive operation of the service. It is assumed that there will be bunching, and simultaneous crosses of trains at the Cleveland Street junction until the separation of the south and western areas occurs.

This is similar to turnback times required at major termini in London commuter peak period times. London Waterloo trains between 7:30-8:30am have an average of 15minutes to a platform (132tph, 20 platforms and 8 approach tracks), London Victoria trains have an average of 13 minutes to a platform (172tph 19 platforms, 8 approach tracks) and Fenchurch Street has an average of 12 minutes to a platform (31tph into 4 platforms, 2 approach tracks). If all 12 non country platforms were used at Sydney Terminal, a train has a maximum of 24minutes at each platform, at 30tph (existing) or 12minutes at 60tph, which is comparable to the proposed times at Sydney Terminal.

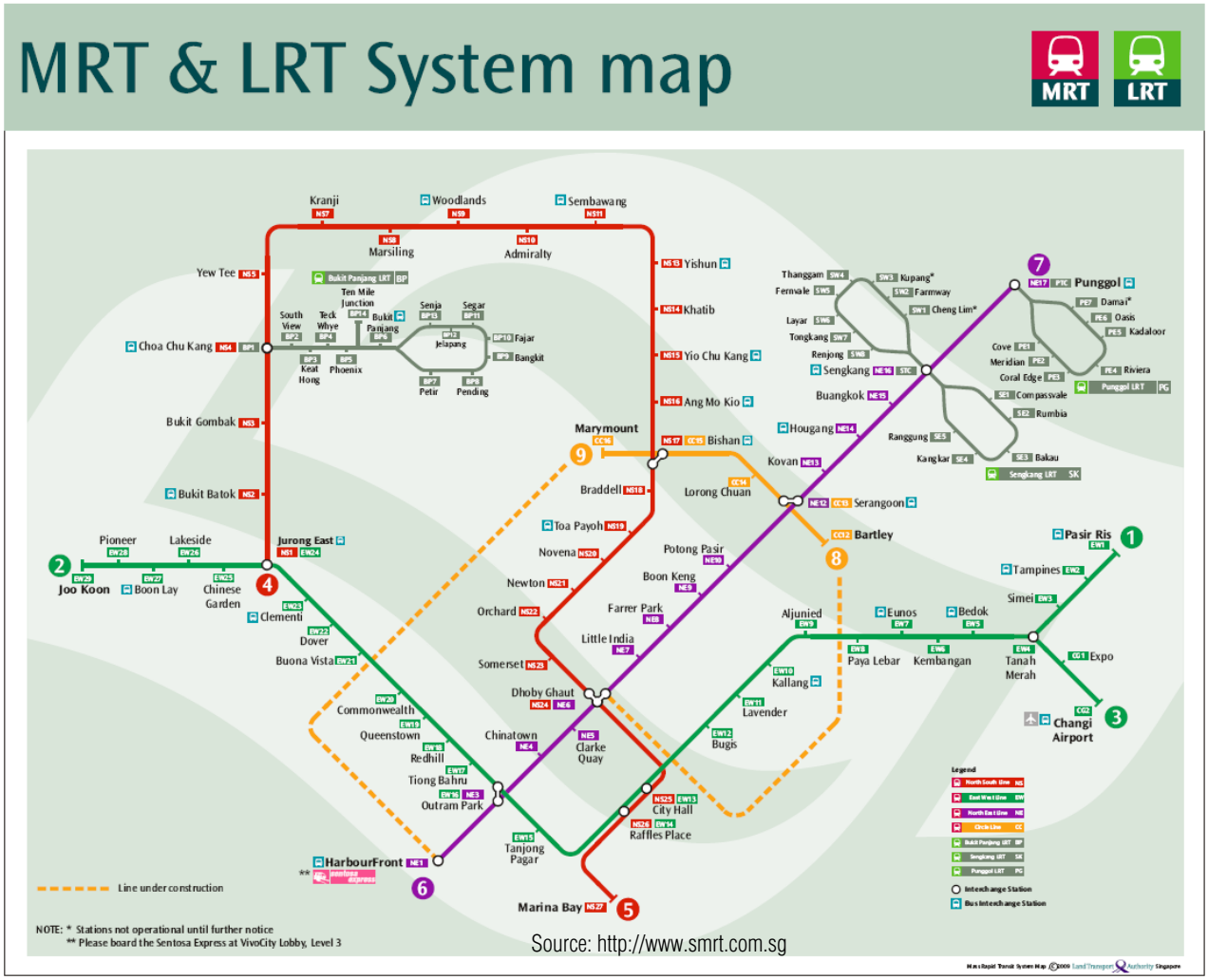
The maximum frequency that has been identified as being possible over a single crossover is 48 trains per hour, at the Brixton terminus of the Victoria Line on the London Underground. This shows that the maximum level of trains passing one crossover under this plan is 30tph, which is below the practical maximum, of a crossover.

The primary determinant of the lack of services into Sydney Terminal is the required stop at Redfern during peak – this stop has a very high dwell time of up to 80 seconds due to high levels of egress from the train, and the general use of Vset trains – which has narrow doorways, in which only one person at a time can exit. If this stop was abolished for services into Sydney Terminal (interchange at Sydenham, Wolli Creek, Sydney Terminal or Strathfield instead) the maximum throughput can be achieved.

2.2 Overseas Systems

Figure 2.3 shows the Singapore Metro System, which consists of 4 independent lines, and only one line has a branch at one end. This enables for very high frequency running of up to 20tph off peak. This Level of Service does not require a timetable; rather it is turn up and go.

Figure 2.3 : Singapore rail transit map



This compares favourably to the Moscow Metro which has the highest intensity operation of any metro service in the world, with an operating headway of 40tph in peak. The Moscow system is also looking at bringing the minimum headway between trains down to 70seconds, or 50tph to cope with demand.

2.2 Overseas Systems

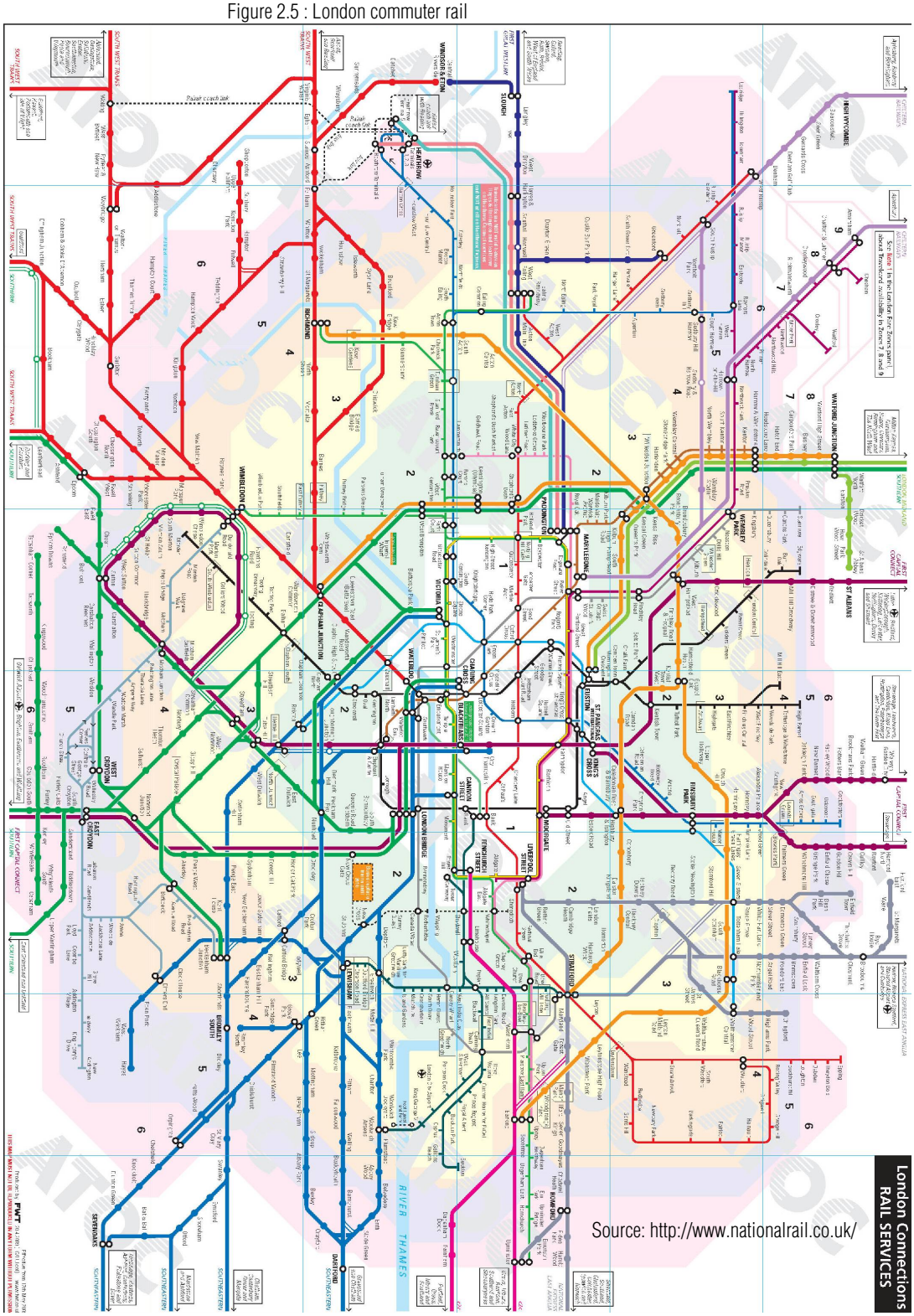
Figure 2.4 : Moscow Metro

Source: http://mosmetro.ru/

Singapore compares favourably to the Moscow Metro which has the highest intensity operation of any metro service in the world, with an operating headway of 40tph in peak. The Moscow system is also looking at bringing the minimum headway between trains down to 70seconds, or 50tph to cope with demand.

2.2 Overseas Systems

Figure 2.5 : London commuter rail



Finally this compares to the London commuter and sub surface lines, which are the oldest intensive commuter lines in the world. Figure 2.5 shows the intermixing of the various commuter lines (colour coded by operating company) into the main termini of London. This intermixing of services constrains maximum number of services. The purple line– the Wimbledon Loop line has services constrained to 2-3tph in peak due to the intermixing of services approaching Thameslink (the purple line through Central London). Similar operational constraints apply on all the lines shown on figure 2.5, where demand cannot be met due to the intermixing of services, and no new services can be incorporated.

2.3 Train Turnback

Vuchic (2004) comments that a integrated network like the NY subway, can be highly efficient in splitting passenger loads between main destinations, however unless timetabled very effectively can lead to major delays and problems. CityRail currently operates an integrated system; however it is highly prone to delays from a minor incident, which is undesirable. This integration also constrains capacity where it is most needed, which is why splitting the system into independent lines is more desirable than continuing with the existing integrated setup.

In general comparing, Singapore, Moscow and London to Sydney, operationally London's Overground Network is the closest to Sydney now. However to enable a high frequency service the Sydney network needs to be separated out to be more like a true metro system.

TRB (2003) and Chapman (2009) also notes that the minimum headway is also determined by the railway turnback, and whether there are any flat junctions on the route. TRB (2003) state that the optimal turnback is similar to what has been built at Bondi Junction, where there is a rear turnback (or two depending on train volume), and a dual scissor crossover before the platforms.

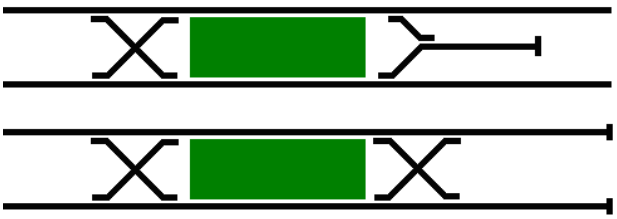
Mees (2009) states that the minimum turnback time for a 160m long train (time for driver to go from one cab to another) is 4 minutes, whilst if the process of Stepping Back is implemented – train pulls in, driver exits train, as another driver enters the cab at the other end – can take as little as 90 seconds.

Hset at Sydney Terminal

Source: Ben Chatwin (2009)

Current RailCorp guidelines states that a 4 car train can be turned around in a minimum of 5 minutes and a 8 car train in 8 minutes, using the same driver. This compares favourably with Connex Melbourne, where a three car train can be turned around in a minimum of 4 minutes, and a 6 car train in 5 minutes. TRB (2003) general controls state that a 200m train can be turned around using stepping back in 120 seconds.

Figure 2.6 : Optimum two platform terminus



Signalling spacing within the City Rail network is not of an issue, except in places where Country Signalling (3 aspect) is still in use, rather than the City Signalling (5 aspect). It is also a constraint between Lidcombe – Harris Park/ Merrylands due to a hasty resignallisation after the first Glenbrook train crash, as there was potential for a similar incident at this location. The Bankstown line is also similarily constrained by signalling between Sydenham – Bankstown, where it was resignalled to allow for a maximum headway of 4minutes, over the standard

Three aspect signalling limits a lines maximum capacity to 12-14 tph within CityRail, due to increased distances between signals, and increased safety overlaps. It is not necessarily a constraint of capacity insofar – the London Underground only uses 3 aspect signalling running at frequencies of up to 30tph.

2.4 Signalling

Country signalling exists on the electrified network at the following locations and constrains capacity:

- Leumeah – Macarthur
- Loftus – Port Kembla/Kiama
- Penrith – Lithgow
- Asquith – Newcastle

3 aspect signalling has the following phases.

- Red – Danger, train must not pass
- Pulsing Orange – Train will diverge at this signal.
- Orange – Next signal will be at Danger, or train will be diverging.
- Green – The track is clear and train can proceed at maximum speed.

5 aspect signalling has the following phases:

- Red-Red – Danger, train must not pass signal

•Red-Red-Green – low speed indicator. A train may proceed at a maximum of 25km/h to the next signal, where it must stop. The train in front may be within this signalling interval.

- Orange-Red – the train is diverging and the next signal will be at danger.
- Green-Red – The next signal will be at Danger
- Orange-Orange – The train will be diverging at this signal.
- Green-Orange – The next signal will be for a diverge, or Green-Red
- Green-Pulsing Orange – The next signal is at Green-Orange (only used at high signalised areas) This is a preliminary warning.
- Green-Green – The track is clear to the next signal and you can travel at maximum speed.

Country Signaling

Source: Ben Chatwin (2009)

This 5 aspect signalling enables trains to be closer together, and enable the driver to gradually slow down, much closer to the previous train than the 3 aspect signalling.

TRB (2003) states that the higher the frequency of signals and the higher aspect signalling enables for a higher frequency of trains. This is contrasted with Vuchic (2007) which states that the busiest station is the key determinant of frequency, rather than signalling, though this is acknowledged as a determinatnt.

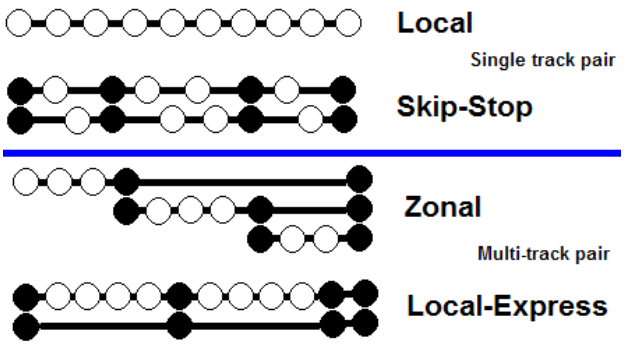
In CityRail the signal spacing varies from approximately every 100m (a train will occupy multiple blocks) in the City Underground to greater than 1000m in the Interurban network areas. In general this means that there is no need to take signalling into account, except in certain areas (Granville junction, and Bankstown line – both are capacity constrained by signalling design) and where country signalling is still in place.

2.5 Stopping Patterns

Handbook of Transport Modelling (2008), TRB (2003) and Chapman (2006) also state that the frequency of service that can be provided on a single track pair is fixed. Variation of stopping patterns reduces train frequency due to the express train taking up more paths than a local train, therefore reducing capacity.

Vuchic (2004) shows that there are four different types of stopping patterns that can be operated, being local, skip-stop, zonal, and local/express. Figure 2.7 shows these four patterns, and the operating characteristics. It should be noted that Skip-Stop patterns are the only way to increase speeds on a line that is at capacity, whilst Local-Express provides for the maximum possible carrying capacity, where speed is a major function. Skip-Stop and Local-Express form the highest capacity and speed options.

Figure 2.7 : Optimum stopping patterns



Railway Junction near Redfern

A skip-stop pattern system can maintain maximum capacity, but has problems for people ensuring that they are on the right train. A skip stop pattern means that a Train A skips one (or more) stations, then stops at others. Train B behind this one, then stops at the stations that train A skipped. There are also stations where all trains stop.

This shows that each train as its individual stations, as well as compulsory stops, where all trains stop. This is the only way known to increase overall speed of a line, whilst maintaining maximum frequency, for a single track pair. It is generally considered unacceptable for Sydney as it works best where there all the stations have fairly consistent patronage. In Sydney, Semple (2008) found that the majority of patronage only comes from 50 stations (out of 300), it makes a skip-stop pattern impractical. Rationalisation of stations is also strongly discouraged, as this reduces urban renewal potential.

At Present CityRail attempts to provide five different service types, generally on the same track pair, which constrains capacity, and leads to further complications when timetabling and operational design. The system used is generally a hybrid Local-Express and Zonal system with the addition of freight services and this is done on single track pairs in places, which reduces the capacity of the line.

This intermingling of express and local services is of major concern when the line approaches saturation capacity with the existing stopping patterns and has no real expansion possibility. In Melbourne this has been dealt with by making the majority of trains on a single track pair, local services, which means all trains stop all stations, which increases journey time, but increases the raw carrying capacity of the line.

2.5 Stopping Patterns

The five types of stoping patterns operated within the CityRail networke are listed below.

•Local metro-style services

These services are trains that stop all stations at a high frequency. The predominate examples within Sydney is the Homebush – City, Hurstville – Bondi Junction and Chatswood – City corridors, albeit at a greatly reduced frequency compared to a true turn-up-and-go metro service.

•Intermediate suburban services

These services are trains that run from intermediate termini such as Blacktown, stopping at all stations until an inner suburban station, then generally run limited stops or express to the city centre.

•Outer suburban services

These services are trains that run from outer termini such as Penrith, Campbelltown/Macarthur or Cronulla. These services generally run as all stops until an intermediate suburban station (such as Blacktown) then run as an express or limited stops service to the City Centre only stopping at major stations.

Tunnel Portal at Kings Cross

•Interurban Services

These are trains that have originated outside the Sydney Basin area. These trains generally only stop at the outer terminal suburban station, then run express to the City Centre stopping at only the most major interchange stations..

•Freight Services

Freight services are trains that are carrying bulk commodities from place to place. These trains are generally in excess of 600m in length and are generally slow moving. The majority of freight trains are from outside the Sydney Basin, originating in Key centres such as Melbourne, Brisbane, Parkes Intermodal, or the key coal producing areas of NSW.

2.6 Self-Defence of Incompetence

A very important concept that both Mees (2009) and Vuchic(2004) state is the self-defence of incompetence. Vuchic (2004) states that

> *With time organisations have a tendency to develop a pattern of operation that is convenient for personnel, rather than for passengers and long-term operating efficiency … This pattern of operations is not easy to change, because in an organization a resistance to change develops that may be designated as "self-defense of incompetence" … The less competent employees are, the more they resist any changes … Management must undertake energetic steps to break the pattern of service deterioration, decreasing economic efficiency, and resistance to innovations. In some cases, to introduce changes, management may need support of political leaders, external advisors, citizen advisory groups, and other bodies to get a better perspective on the conditions of service, needed improvements, and obstacles that should be overcome.*

Mees (2009) states that this applies in Melbourne as in general they avoid new concepts, changing of route structure (by implementing greater shuttle services), and not 'thinking outside the square'. These issues can be also seen in Sydney, where there has been no new radical service changes since the 1970's when the Eastern Suburbs Railway Line opened. The latest version with the Cumberland Line was rapidly repealed, with the exception of 5 services in peak times.

Tangara entering City Underground

The self-defence of incompetence in the CityRail Network can be seen as:

- All trains must go to the City
- Carlingford Line is the exception due to its location at a major freight yard and low patronage
- Express-Local trains must be run on the same tracks.
- That Express trains provide speed and value for customers (even when they are usually only 5-7minutes faster than an all stations service)
- Express services take priority over servicing local stations/services
- That commuter services are the most important
- Relative lack of service at inner suburban locations.

These self-defence mechanisms generally constrain capacity and decrease operational flexibility, which overall reduces the effectiveness of the CityRail Network.

Self defence of incompetence does not mean that the staff in the organisation are incompetent. Rather it means that the established policies and procedures have been in place for so long that they are entrenched, and an alternative method is not looked at, as this is the 'way things are done here'. Generally this can be seen as the inertia of the system; that over time things will be done in a certain way, and changing the way this procedure or policy is implemented is very difficult. A very recent example would be the RailCorp policy of locking people in trains in an emergency, and passengers waiting for assistance from rail staff. This policy was shown to be flawed in the Waterfall Train Crash Enquiry of 2003, yet 6 years later, there has been no substantive progress in changing this procedure, due to the inertia of changing a procedure that has been in place since power operated doors became dominant 30 years ago.

2.7 Previous Proposals

Previous strategies for rail in Sydney have generally focused on how to connect areas of Sydney that have low or no rail access to the rail network. However as Mees (1994) states, (though this is still relevant for Sydney as we have a similar level of coverage) Melbourne per capita has one of the highest per capita level of rail service in the world.

The first major proposal for railways in the 'modern era' – the electric train's era, is **The Bradfield Plan.**

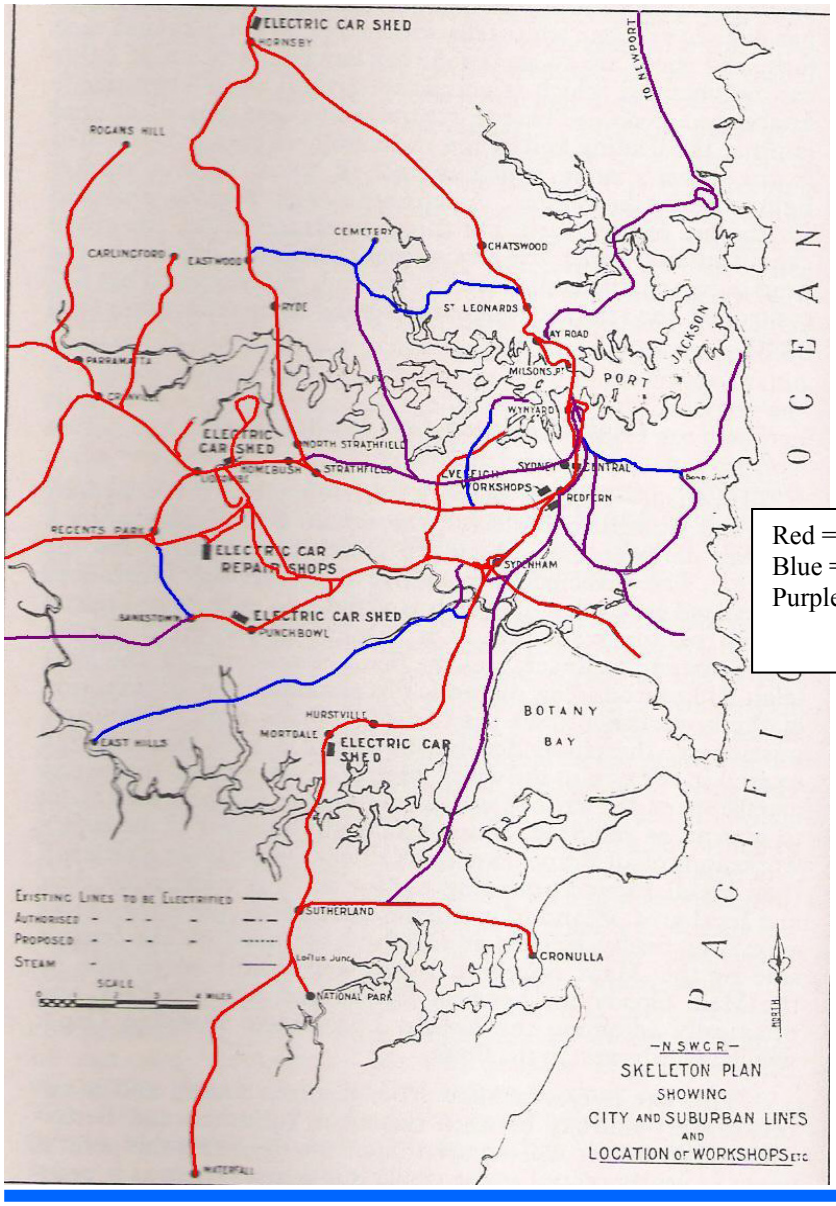
This plan shows a proposal for an extensive Eastern Suburbs railway links, as well as a Bankstown – Liverpool Link, Parramatta Road Line, Balmain Line, Northern Beaches Line, St Leonards – Eastwood Line and a new line roughly from Five Dock to the present Macquarie Park Site.

An important note of this plan is the showing, electrification and retention of the Rogan's Hill (Castle Hill) to Westmead line – a line that was ripped up in the early 1930's, leaving the Hills District without a railway line ever since and a very pricey cost to reinstate a railway line.

Generally this plan was not implemented. Three lines were constructed as part of the immediate works for this plan – the Bankstown – Regents Park connector, the East Hills line, and the City Circle line. Considerably later, and on another alignment the Eastern Suburbs Railway Line and the Epping-Chatswood Railway line were built.

This plan was highly ambitious and planned to give wholesale rail coverage to the entire metropolitan Sydney (at the time), however the Great Depression, and politics effectively confined this plan to the scrap heap.

Figure 2.8 : Bradfield Plan



Red = existing line
Blue = authorised line
Purple = future line

Source: ARHS (1987)

2.7 Previous Proposals

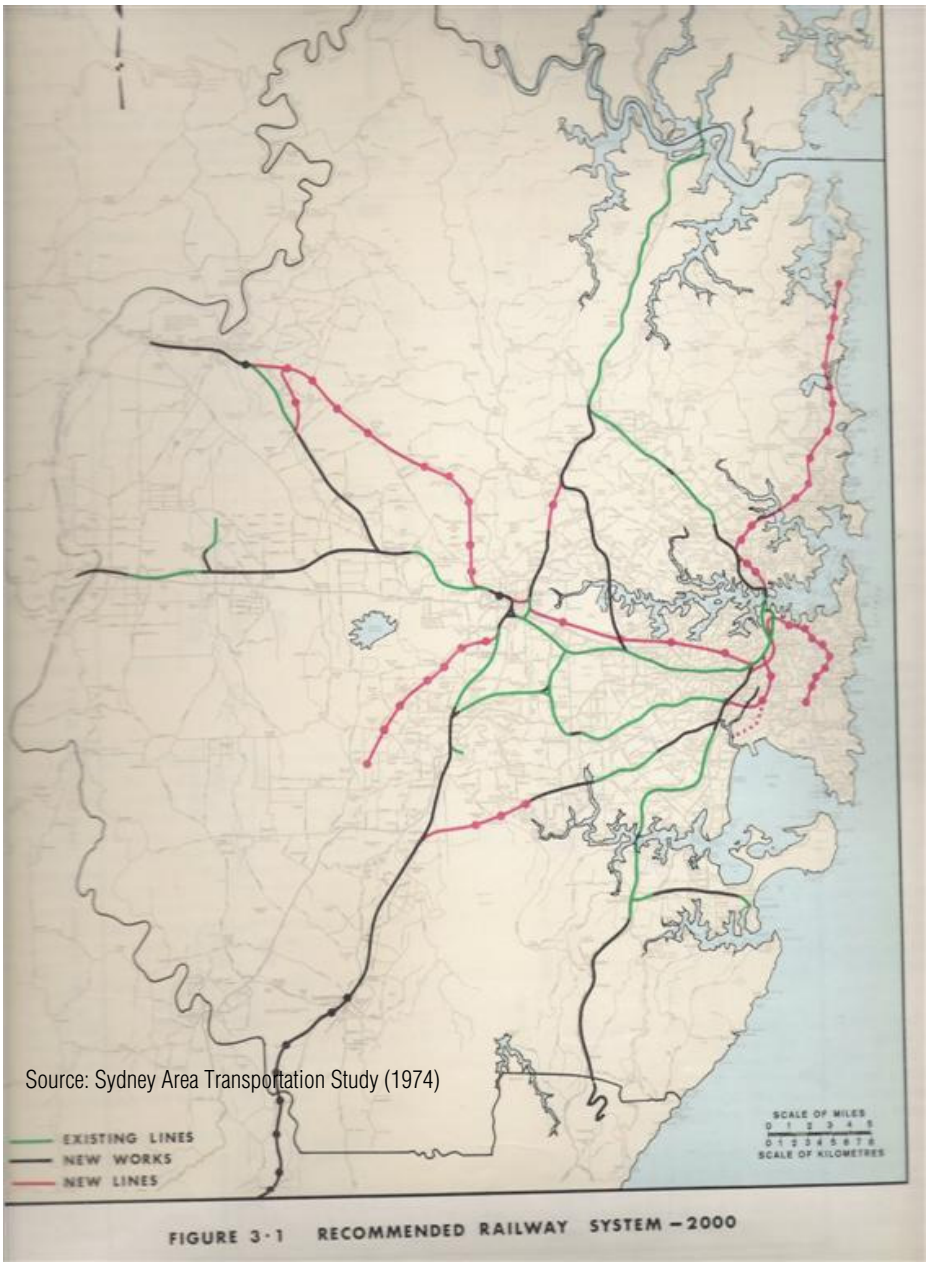
Sydney Area Transportation Study

The SATS plan for Sydney, was the first 'integrated' transport plan for Sydney, and planned for significant expansions of all transport modes within Sydney. It was highly ambitious, and as Laybutt (2008) states, overly ambitious, and was practically laughed out of Parliament, when it arrived.

This plan is effectively quite similar to that of the Bradfield plan with some notable exceptions. This plan is focused on the developing outer suburbs in Green Valley, and the Hills District, whilst ignoring the Macquarie area. The only parts of this plan that have been built are a truncated Eastern Suburbs Rail Link, and the East Hills line Extension to Glenfield. Overall this plan can be seen to be a failure, by its overambitious nature, and relative lack of construction.

This was also proposed at the time when the railway network was operating at its most intermixed. Trains from one line would have different terminal points - For example trains from Cronulla would generally continue to North Sydney, but some would terminate at St James. Trains from East Hills would start at Chatswood, but some might start from the City Circle. Every express train on the network operated to a different stopping pattern, and this combination of factors lead to the necessitation of a timetable to undertake journeys.

Figure 2.9 : Sydney Area Transportation Study



Source: Sydney Area Transportation Study (1974)

This was also at the time when the network was operating at its worst. This lead to appalling on time statistics, and the SATS plan proposed to standardise all peak and off peak trains, to the same terminal destination, and the same stopping pattern, though reducing frequency for off peak periods. This was a quantum leap in rail operations, yet was not implemented, and still has not been properly implemented in CityRail. However there was to be significant intermingling of services, with many lines converging to use the City Circle.

2.7 Previous Proposals

State Rail Plan for the Future 1994 – 2016

The State Rail Plan 1994-2016 notes that several key rail areas are reaching or are at capacity including
Homebush – City
Tempe – City
City Underground

It proposed to enable capacity relief on these lines by the following:

Construction of an airport line from Wolli Creek Junction to Central, which will then take East Hills railway line trains from the Tempe – City Section.

Construction of the Parramatta – Chatswood Rail Link to enable diversion of some Northern and Western Line trains through to Chatswood, then over the Sydney Harbour Bridge, and use up the last of the spare capacity on the North Shore Line.

The City Underground was proposed to have an additional line from Sydney Terminal/Railway Square through to Wynyard, roughly following the alignment of Kent or Sussex streets. This is known as the Metro-West alignment. This alignment was to take fast Western line trains out of the North Shore Line, and onto Metro-West, to enable more trains to run on the suburban lines between Strathfield and the City.

Of these, only one has received partial capacity relief, which is the Tempe – City which received an additional two tracks, though they still feed into the same number of tracks in the City Underground. This capacity relief essentially separated out the Bankstown Local services from the East Hills express services. The Airport Line acts as a bypass line, enabling the junction at Sydenham, where the Bankstown Line and East Hills Line meet to be used only in peak (after sustained protest by users of the East Hills Line) which increases the capacity of the line between Tempe – City, by separating out the local-express services.

The Parramatta – Chatswood Rail Link was constructed, but to an alternate, and truncated path. This line will not achieve the objective of relieving capacity on the Homebush – City segment as a result, however it will serve a large and growing region of employment of Sydney. It does enable the diversion of 4tph from the Northern Line, but this is half the original proposal of 8tph (4 Northern Line, 4 Western Line) which would have enabled more South and Western line trains into the City.

This plan mostly stated that there would be just enough capacity with signalling enhancements and new rollingstock to generally keep pace with the rail patronage demand until 2016.

Overall this plan had the absolute majority of its construction completed, and well before the 2016 deadline. However it underestimated the proposed patronage growth, which has the system reaching rollingstock capacity well before the proposed 2016 period. This is clearly evident by the removal of the Gset trains from Intercity runs back to suburban runs, and increasing the number of new trains purchased to replace the R/S sets from 62 trains to 76 trains.

2.7 Previous Proposals

Action for Transport 2010

The highly ambitious Action for Transport 2010, which proposed multiple new lines to relieve capacity constraints and enable new commuting options including:

Hurstville – Strathfield
Parramatta – Epping (thence to Chatswood)
Castle Hill – Epping
Liverpool Y link
Parramatta Y Link.

Of these links none were direct CBD links – rather they were trying to reduce the strain on the CBD radial links, by siphoning off passengers that were only heading into the CBD to head back out to the suburbs again, as there are no adequate cross-town public transport linkages. Unfortunately only the Parramatta Y Link was built, which is severely underutilised, and the Epping to Chatswood Link. These lines are valuable, but without the additional cross city lines, their effectiveness is reduced.

This plan is similar to that of SATS and the Bradfield Plan, which were highly ambitious plans, with significant levels of new railway construction. Of this plan, only the Chatswood – Epping line and the Parramatta Y link was constructed.

The Liverpool and Parramatta Y Links, though great in theory – enabling a short cut link between two busy lines, which would save considerable time, the practice has shown that these are not appropriate without further infrastructure works. The Parramatta Y link, which was the only one built, changed the Granville junction from one conflict point to three conflict points. Only one of these junctions is a flying junction, which means that trains are crossing at grade. This means that there is potential for one train crossing at these junctions to create a conflict with at least another two trains. This goes against best practice, and when the line was operating with 'real frequencies' – not five trains per workday integrated Sector 2 and 3 (South and Western Lines) far tighter than what existed previously, and enabled for a service disruption on one sector to be bounced across to the other sector.

The Liverpool Y, if built would have brought the East Hills line to capacity far more quickly than what has occurred, and would have meant that in the future that there would have been a minimum of four different lines using this track – Liverpool Y, Campbelltown Expresses, East Hills Locals, and SWRL trains, each which have competing aims, and would have diluted service frequency, and quality, as shown in the London Overground example.

2.7 Previous Proposals

Christie Report

The Christie Report was released in 2001, to provide a large scale long term plan to improve, enhance and extend the reach, reliability and network operation of CityRail. This proposal provided significant technical data on how the operation of the railway system was operation, and where the key deficiencies lay. The Christie Report is also the only report other than SATS that provides empirical data and justification for the proposals.

It also provided a clear blueprint for how the existing three sectors of CityRail could be separated out, by track amplification, additional turnbacks and the like. This part of the Christie Report provided the framework for the Rail Clearways. The Christie Report also brought forward the proposed Metro East Alignment which was a railway line roughly running underneath Pitt Street from Central to Circular Quay, then under or over the Harbour. This is in contrast to the previous plans that focused heavily on the Metro-West alignment, which was from Central to Wynyard generally following Sussex or Kent Streets.

The Christie Report provided for a long term framework to build a new metro system, consisting of three Lines

1. **River Line: Parramatta – Sydenham via City and Kingsford**
2. **Miranda – Dee Why via City, Newtown and Chatswood**
3. **Hoxton Park – Castle Hill via Parramatta**

These metros were to be completely separate or nearly completely separate from the CityRail network, and run at the traditional high frequencies that a metro suggests. However these metros generally only provide service to the inner ring suburb areas, and are predominately capacity relievers – these areas are predominately serviced by buses, and have reached or are near capacity, or provide for significant regeneration potential. The do not insofar relieve capacity constraints on the existing railway network.

The key deficiencies of the Christie Plan is that it does not provide for significant cross country links – it provides the existing Cumberland line, an enhanced Carlingford line from Parramatta to Epping and a metro line from Hoxton Park to Castle Hill through Parramatta. It also has significant intermingling of trains through the City Circle and also does not provide for capacity enhancement along the Illawarra line from Hurstville to the City, where it is required. It does separate the network out into more sectors than the existing three, but there is still significant intermingling of the various sectors proposed, albeit further out in the suburbs than at present. This could have a significant impact on the reliability and punctuality of the network.

However the use of empirical data to provide evidence and justification for the proposals is a strong step forward, enabling for clear identification of why the project received priority.

2.7 Previous Proposals

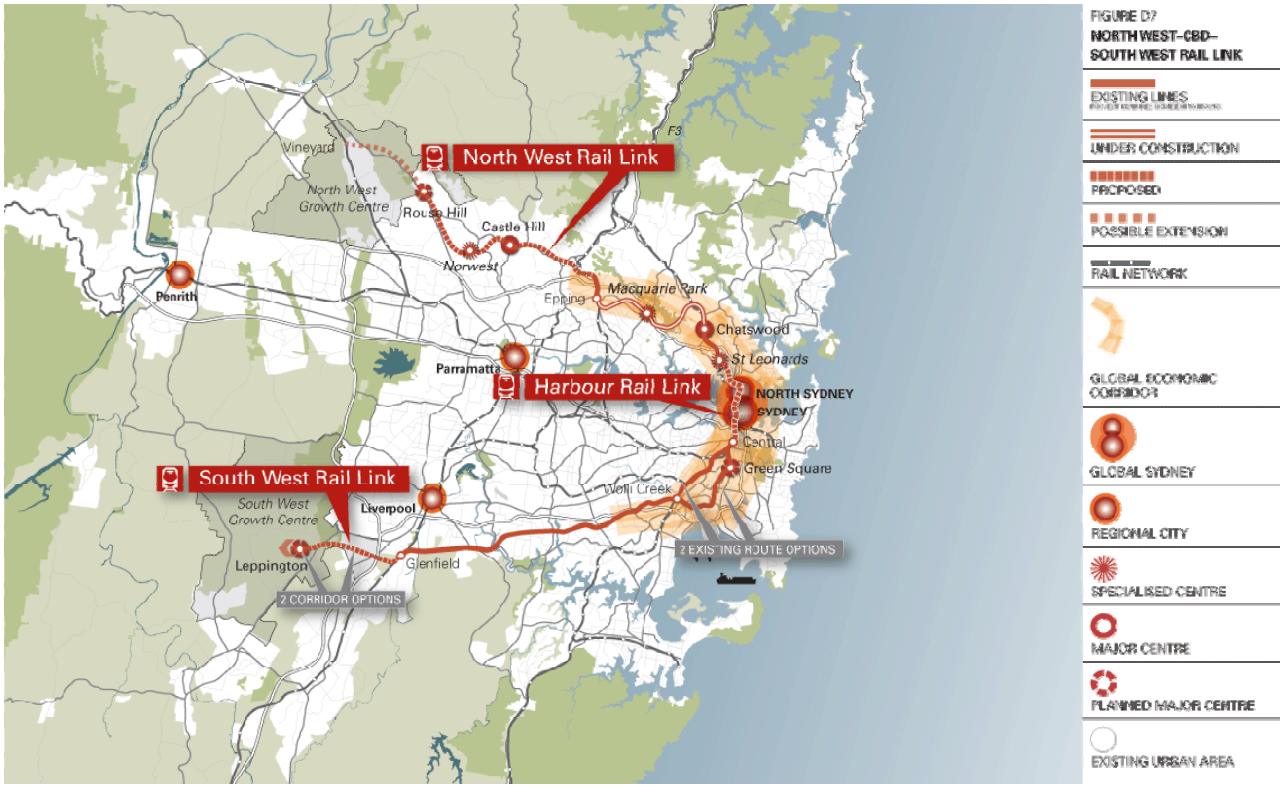
Metropolitan Strategy

The Metropolitan Strategy provided for an ambitious new line that would run from Leppington in the South West, to Castle Hill in the North West, through a new City Line, generally underneath Pitt St, and then with either new trackage, or taking over existing trackage for exclusive use of this line. This line would have run with over 20tph, in a roughly RER style format. This line has been postponed, potentially permanently due to the budget crisis in NSW.

This plan though providing ample capacity for the North and South West Growth Centres provided no relief to the Illawarra and Western Lines, where they are already at capacity. This proposal also did not provide any alternative for how frequency or capacity of services could be improved on these lines. This was the greatest failure of the Metropolitan Strategy – that it did not look at CityRail holistically and provide for overall capacity relief, let alone provides additional capacity where it generally was not needed (South West).

It should be noted however that this plan is more a land-use plan, rather than a transport plan.

Figure 2.10 : Metropolitan Rail Expansion Plan



Source: Sydney Metropolitan Strategy 2005

2.7 Previous Proposals

Clearways Projects

The clearways projects were projects that were proposed at the same time as the Metropolitan Strategy. The aim of Clearways was to separate out the existing lines of CityRail into discrete and identifiable lines and enhance capacity and reliability of the network and was broken down into three stages:

Stage 1: (cheapest)

1. New platforms and track enhancements to these platforms
2. (Cronulla line duplication was also part of this stage)

Stage 2: (moderate)

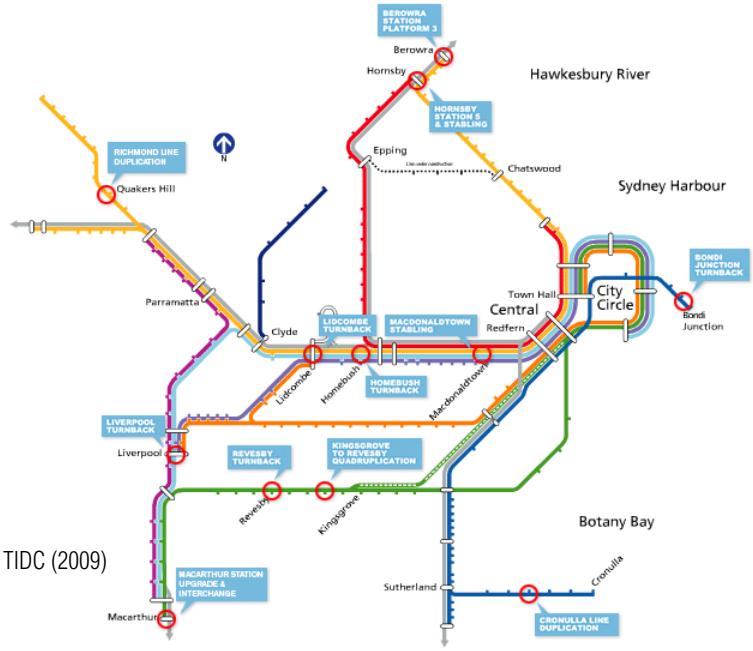
1. Difficult new platforms (Due to SSFL)
2. Track amplification (e.g. Revesby tracks)

Stage 3 (most expensive) (tentative and not funded)

1. Future Track Enhancements
2. Illawarra Junction Flyovers
3. Sydenham – Redfern track amplification etc.

At present four projects are essentially complete – Revesby Platform, Lidcombe Platform, Homebush Platform, and the Cronulla line duplication, however all other projects are in doubt due to a fiscal crisis and the desire of the state to maintain its AAA credit rating.

Figure 2.11 : Rail clearways project



Source: TIDC (2009)

These projects in general are highly valuable, as they enable greater efficiency with core junctions and increased turnback capacity. However the implementation has been poor, with all projects experiencing significant cost overruns, in some cases greater than 100% over the original proposed price, and poor and unsafe work practices in use – where equipment has been left on the running lines (where trains are operating), rail infrastructure has been installed in the wrong locations, leading to potentially dangerous intrusions into the carriage zone. This is evidence of poor project management, and not properly skilled or trained staff, or improper supervision and management by CityRail and TIDC.

The major problems with the clearways project was that it did not enhance raw capacity (with the exception of the Cronulla line duplication), rather it improved junctions and turnbacks reducing the strain on the network through late running, but did not address other issues such as city underground capacity. It did not increase raw capacity as there was the potential previously to increase frequency, through better timetabling. Signalling in general has not been upgraded, so the same capacity constraints still apply.

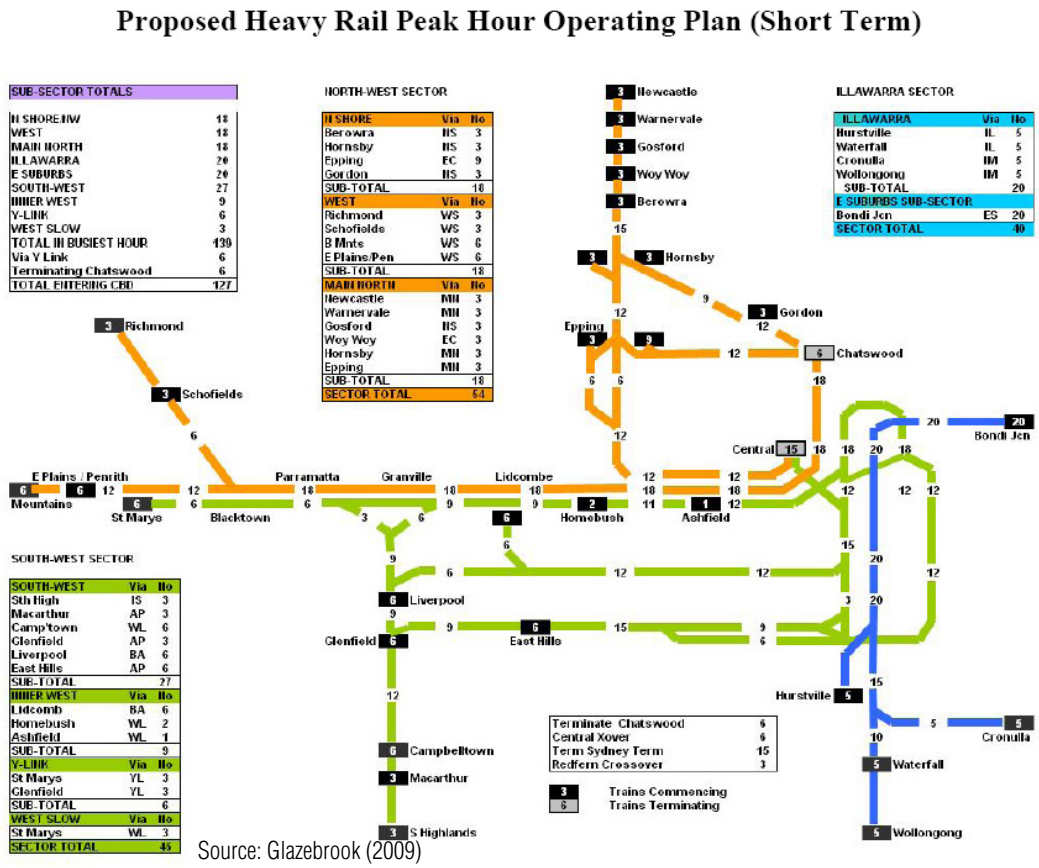
2.7 Previous Proposals

Glazebrook Plan

In 2009 Gary Glazebrook a senior academic from the Sydney University of Technology released an integrated transport plan for Sydney.

For CityRail this plan generally required the removal of the Northern Line from the North Shore Line in the short term, and excised the Epping – Chatswood Line for a metro service in the long term.

Figure 2.12 : Glazebrook plan for heavy rail in Sydney



Source: Glazebrook (2009)

In the short term he proposes a general maximum of 15tph terminating at Sydney Terminal, which is a reduction in capacity from now, as well as 18tph running along the City Circle and North Shore Lines, whilst running the Eastern Suburbs line at 20tph.

Sydney Terminal has the potential to terminate up to 30tph, using the existing track and design layout, which means that it will be operating at 50% of capacity under the Glazebrook Plan, whilst the City Circle which has 6 platforms at Central, and the greatest potential for delay recovery (as trains can sit at Platforms 20-23 for up to 5 minutes without delaying other services) is also not running at maximum capacity.

This plan has some flaws, in that there are trains terminating at St Marys – which requires a train to either run empty to Penrith, cross the two main tracks at grade to the west of the station, or cross all tracks at grade to the east of the station, which will act as a major capacity constraint on the Western Line. Creation of a Flyover here for terminating trains to enter the former Ropes Creek Line (now the terminating area for St Marys) would then remove the potential for a quad track system to Penrith, without extensive modifications to the railway at St Marys. It also appears that there are

2.7 Previous Proposals

Blacktown would be a superior terminating location, given it has platform 3 that acts as a dedicated turnback without interfering with the running lines. Furthermore the reduction in through capacity on the Western Line locals from Harris Park to Blacktown from 4tph to 3tph is significant, when the system can easily cope with up to 8tph using this section (4tph Cumberland, 4tph Western), and would most likely be heavily resisted.

This proposal also does not increase capacity on the Illawarra Line north of Hurstville, where the major demand generators reside. The Illawarra line running as a mixture of local and express services is constrained to a maximum of 12-14tph between Hurstville and Sutherland, without deliberate slowing of the express services. The Illawarra line is also the line most in need of capacity relief – at present there is unmet demand that the current system cannot supply – there is potential for at least marginal capacity increases on the Western and North Shore Lines. These lines are the top three heaviest used lines in the CityRail Network.

His proposal is also a capacity reduction between Granville and Homebush on the local tracks. It also appears that all Blue Mountains Line trains are heading through to the North Shore Line. All Blue Mountains trains that run past Springwood are of the Country train design, which have very long dwell times, due to narrow doorways, and are not appropriate for use on the city underground, on the line which has significant dwell problems now.

At present CityRail is divided up into three sectors.


Sector 2 at Revesby

Sector 1

- Eastern Suburbs Railway Line
- Illawarra Line
- South Coast Line

Sector 2

- East Hills Line
- Main South Line
- Old Main South Line
- Airport Line
- Inner West Line
- City Circle
- Southern Highlands Line

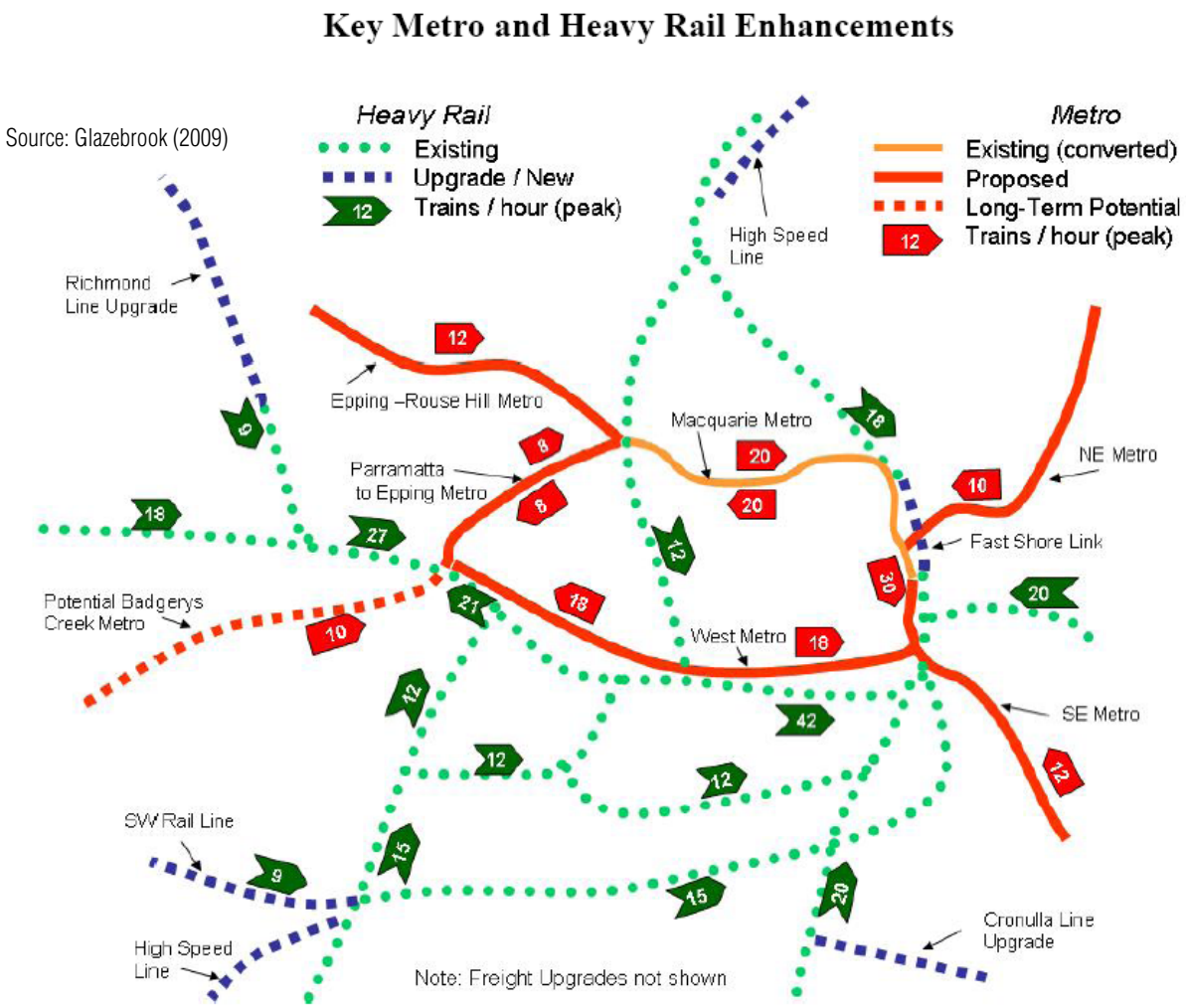
Sector 3

- Western Line
- Richmond Line
- Northern Line
- Carlingford Line
- North Shore Line
- Epping – Chatswood Rail Link
- Blue Mountains Line
- Central Coast Line

His proposal further integrates the current sectors, with the western line which is currently purely within sector 3 being also added into sector 2, which can further impede service delivery.

2.7 Previous Proposals

Figure 2.13 : Glazebrook metro proposal



Source: Glazebrook (2009)

Separation of lines out into discrete sectors is essential. This is a key flaw of the Glazebrook Metro Proposal (2009) which has too many interlinked sections/lines – which can lead to catastrophic cascade delays.

Trains will not be heading to the same termini point. The west metro running at 18tph will most likely feed the Macquarie Metro, yet the SE Metro, will also feed 2tph into this line, and the remainder of the SE metros frequency will be heading to the NE Metro. Of the original 18tph from the West Metro, potentially 12tph would then be heading to Rouse Hill, and the remaining 6 back to Parramatta. Splitting of services between termini like this is highly undesirable, as it leads to customer confusion, and the potential for wrong-routing and cascade failures increases.

TRB (2003), The Transport Modellers Handbook(2004), Timetabling for Tomorrow(1992) and general observation from cities including London (underground), Moscow, Paris, Singapore and Hong Kong, show that the highest optimised rail system, works when there is only one line with a maximum of 2 branches sharing the tracks, as this reduces potential delays through junction crossings (whether flat or flying), different stopping patterns, and the potential for one late running train to delay all others in sequence, which becomes very probable when running high frequencies, of above a train every 5 minutes (12tph).

Therefore the separation of lines into as many discrete lines is a necessity and a highly desirable outcome, which is not achieved with the Glazebrook proposal.

3. The Proposal

This proposal is designed to enable CityRail to run at maximum capacity, through timetabling, infrastructure, operational and staffing changes. These changes are necessary to bring about generational change, and to reduce the self defence of incompetence within the organisation. Changes to operational and staffing regimes could bring about significant cost savings for the network and organisation, potentially helping to fund some of the infrastructure upgrades required. This proposal identifies the following constraints to increased service within CityRail. These are listed in priority order, for stage 1 only..

Infrastructure

1. Design of Illawarra – Cleveland St Junctions (and Redfern Station)
2. Lack of track capacity Cabramatta – Liverpool
3. Flat Junction at Cabramatta
4. Cabramatta Station location.
5. Lack of track capacity Strathfield – Hornsby
6. Flat Junction at Wolli Creek
7. Flat Junction at Sydenham
8. Flat Junction between Northern Line and Main West Line at Strathfield
9. Single Track Quakers Hill – Richmond
10. Lack of track capacity Sydenham – Redfern
11. Lack of track capacity Bankstown – Campsie
12. Lack of dedicated Airport Line Platforms – Central
13. Flat Junction at Sefton Park

Hornsby Junction

System Design/Timetabling

1. Intermingling of various service types
2. Lack of 'sweeper trains'
3. All trains must go through the city underground
4. Over utilisation of Local/Express running on a single track pair
5. Underutilisation of Sydney Terminal
6. Lack of local/metro style running
7. Lack of rollingstock
8. Underutilisation of stepping back
9. Excessive delay times built into timetable.
10. Excessive turnback times at outer termini
11. Lack of cross suburban links.

Staffing/Operations

1. Increased crewing through the use of driver/guard combination, compared to the Driver Only Operation (DOO) which is world standard practice, and in use in all Australian rail systems except Sydney and Brisbane.
2. Significant staffing of railway stations above normal practice
3. An unwieldy and manpower intensive ticketing system
4. Lack of fare integration between modes and public/private operators.
5. Top heavy bureaucracy
6. Lack of modern signalling systems

3. The Proposal

The design of this proposal follows the following principles, most of which were elaborated on within the literature review.

Stage 1

- Show that there is capacity into the City.
- Minimise stopping patterns on single track pairs.
- Maximise capacity of the system
- Reduce use of junctions (especially flat) wherever possible
- Separate out freight, interurban, suburban and inner area train services, where possible.
- Maximise frequency within the inner regions of Sydney
- Provide for cross connections were possible
- Enable the conversion of short inner city lines to single deck, high frequency stock.
- Minimise expenditure

Stage 2

- Continue to separate out railway lines as per best practice
- Identify key cross-country routes
- Maximise efficiency and operation, and usability of the network

Stage 3

- Improve access for outer Western Sydney
- Improve access for the Growth Centres
- Improve access for Wollongong and Newcastle to Sydney

And identify and use best practices as identified with similar railway networks overseas, including Moscow Subway, Singapore, London's Overground and Paris's RER networks.

Vset, Mset and Sset near Redfern

This proposal also requires the construction of an additional 1420 cars to run at maximum frequency, if the S sets are not kept for an additional 6 years. (This figure includes the new Aset trains) This delivery run could take approximately 4.5-5 years from signing of the contract to delivery, however service improvements can start to occur from when the first 10 new trains are in service.

Victoria received 390 cars in 18months, with the Xtrapolis and Siemens fleet orders. The use of a mass produced train, with a minimal internal refit, from Bombardier, Siemens or Alstom will reduce the time required, due to the economies of scale.

The New York Subway received 1030 cars from Bombardier and had these new cars received within a 4 year period, which shows a 5 year period is appropriate for the size of the rolling stock order if a complete order is given. The Ssets (non-air-conditioned trains) will be required to be kept past the A set delivery times, to enable enough rollingstock to be available, but then retired as the new rollingstock arrives.

There is no need for additional drivers to be hired – rather the existing guards can be transferred into driver training and complete training at a much quicker rate than a direct hiring, as guards already have some driver training. It also increases the efficiency of trains, by only having one staff member on board, which is world standard practice.

3. The Proposal

Staffing and Operations

This will only be entered into in brief context due to space constraints.

Ticketing

The current ticketing system is unwieldy and incomprehensible to those outside the operations of the network. The current ticketing manual is 121 pages long, which is a level of complexity far beyond what the average commuter needs or wants. The basic premise of the current ticketing system is that it is a hybrid point-to-point and zonal fare along the shortest path between the two stations. Essentially the ticket has a flag fall cost, then a set fare increase for every 5-10 kilometres travelled.

This makes the existing ticketing system highly complex, and requires a large staffing level to cope with the ticketing demands. A zonal or flat fare ticketing system would enable a reduction in staff, and an increase in awareness of how the tickets price is calculated.

Flat Fare:

Flat fare ticketing means that the cost to travel on the transport system is fixed, regardless of whether you travel one station or twenty stations. The most famous example is that of the New York Subway. This system can be highly inequitable if set up incorrectly, as those travelling long distances will be paying too little, whilst those travelling short distances will be penalised with an additional fare. Flat Fares are ideal for systems that is trying to encourage large volumes of trips – i.e. provide for a single fare, and an unlimited monthly rides fare only. This system is the least complex to set up, maintain and understand.

Zonal:

Zonal ticketing means that the city is divided up into discrete zones, generally based upon radii from the CBD. This system is most equitable for those travelling into the City Centre, but can be less equitable for those travelling along cross-suburban routes, depending on the cost of crossing zone boundaries. This system is midway between the flat fare and point-to-point ticketing systems, for equitability, understanding and cost recovery.

Proposed:

The proposed ticketing system would be a two zone system, encompassing all rail, bus, ferry and tram systems. The railway boundary between the two zones would be Berowra, Richmond, Penrith, Macarthur and Helensburgh. The remaining interurban network would form zone 2. It would only provide for two ticket types, and PET, full fare and concessions. There would be an overlap of four stations (two in either direction) between zone 1 and zone 2 to enable a more equitable distribution for stations at the boundary, and partially reduce the potential for overloading of the first station within zone 1.

A six station ticket is a short distance ticket that is only valid for travel between the station you board your train at, and the next six stations in one direction. For example if you board the train at Blacktown, this ticket is valid for travel between Blacktown – Parramatta, Blacktown – Kingswood and Blacktown – Mulgrave. It cannot be used for transferring between transport modes.

The fare for zone 2 only would be set lower than that of zone 1 given the relatively little patronage that occurs in this area (see table x)

The introduction of such a fare system would enable for a reduction in the number of ticketing staff. Figure X shows the complexity of a Sydney Ticketing Machine, in comparison to one in Melbourne, showing how the Melbourne Ticketing Machine is much easier to use. This would enable for a considerable saving in staffing costs.

Assuming this ticket was introduced the following revenue per year could be expected, with the following assumptions

1. Rail receives 50% of fare revenue, buses 35%, ferries/light rail 15% (similar to existing revenue split)
2. The split between full fare and concession tickets is 50:50.
3. That the split between concessions and PET is 40:10
4. The split between daily and monthly tickets is 33:66
5. That 600,000 are buying zone 1 tickets only (63%)
6. That 300,000 are buying zone 1 and 2 tickets only (32%)
7. That 45,000 are buying zone 2 tickets only (5%)
8. That the PET is split 50:10:40
9. That there is a fare evasion rate of 15%
10. 20% of costs relate to fare collection
11. For purposes of calculation the 6 station ticket will be ignored as there is no equivalent ticket in CityRail at present.

Table 3.1 : Proposed fare structure

Zone	Full Fare Daily	Full Fare Monthly	Concession Daily	Concession Monthly	Daily PET Ticket
6 stn	$8	$50	$4	$25	N/A
1	$15	$100	$7.50	$50	$4.00
2	$10	$60	$5	$30	$3.00
1+2	$20	$150	$10	$75	$7.00

This provides for a total revenue per year of $719,184,393.27/year, which is significantly more than the 2007/2008 CItyRail fare revenue of $549,900,000; without taking into account any potential additional trips,. A simpler fare operation should enable for a less gross volume of income spent on fare collection, due to less ticket sales people, and simpler, and less prone to breakdown TVMs.

Table 3.2 : existing fare costs for selected stations Source: CityRail 2009

Station	Daily Cost (Return)	Monthly Cost	Station	Daily Cost (Return)	Monthly Cost
Bondi Junction	$6.80	$105.00	Penrith	$14.40	$199.00
Blacktown	$11.20	$172.00	Newcastle	$36.00	$320.00
Hurstville	$8.00	$125.00	Wollongong	$21.20	$230.00
Chatswood	$7.60	$117.00	Bankstown	$8.80	$140.00

This shows overall that commuters receive a significant discount by buying the proposed monthly fare, and also enable free transfer between modes, though the daily fare works out to be slightly to significantly higher than current.

Station Staffing:

It is also proposed that all stations with a patronage level of above 3,000 people per day are converted to closed/ gated stations, and staffed from the first train to the last train with Transit Officers. The additional requirement for transit officers can be sourced through some of the now redundant station staff – a swapping of roles. Stations which have a patronage above 3,000 people/day comprise 121 stations out of a total of 300, and 92% of the total patronage. This would reduce potential fare evasion significantly, whilst providing for a safer rail environment, as Transit Officers can legally intervene in altercations, whilst Station Staff cannot. This would require around 1,100 Transit Officers. Stations will less patronage than 3,000 people/day would have staff removed, except for underground, junction, safe working and regional city stations (Newcastle, and Wollongong etc). Station staff are primarily employed at low patronage stations to deal with ticketing enquiries, due to the complexity of the system, and with a new ticketing system, this would enable for a reduction in staffing levels.

Train Staffing:

Driver Only Operation (DOO) is required to enable sufficient drivers to run the proposed network. This will occur by removing guards from the trains, and training guards up to drivers. This will require a minor retrofit to trains and stations to enable this to occur. The proposed DOO system would be a leaky feeder system, where the stations closed-circuit cameras are fed into the driver through a leaky feeder cable adjacent to where the train pulls up at the station, enabling the driver to see the passengers boarding and alighting the train. DOO operation is world best practice, and it can enable for a faster operation of trains, as the driver does not have a delay between the guard closing the doors, signalling the driver, then departing the platform.

Rail Worker at Glenfield

Bureaucracy/Operations:

In line with best practice CityRail/RailCorp should be split into the service provider and the service-deliverer. The service deliverer should only provide for the day-to-day operation of the network, whilst the service provider should undertake the long term planning, upgrades, and infrastructure requirements. This split would enable the service provider portions of CityRail/RailCorp to be integrated into the Ministry of Transport, where there is already overlap, and the service provider to be the existing CityRail.

Table 3.3 : Splitting CityRail up into Service provider and deliverer

Service Deliverer (CityRail)	Service Provider (MoT)
Day to day operations	Long term planning
Required to meet benchmarks set out in contract or penalties applied	Sets out the contract as to the duties of the service provider.
Initiates upgrades as required by contract.	Plans for long term upgrades
Deals with basic maintenance to rolling stock	Purchases rolling stock for long term use
Provides feedback as to where upgrades should be targeted	Initiates upgrades

This would enable overlap in planning and infrastructure between government departments and RailCorp/ CityRail to be removed, and enable a much more holistic integration of all public transportation modes in Sydney, as well as enable a staffing reduction. RailCorp as it is providing for both the Service Provider and Service Deliverer roles, as well as planning and operations which overlap with other bodies, and has significantly more staff than is required within the bureaucracy.

3.1 Stage 1

This is a five year project.

Stage 1 proposes a continuation of the clearways project to separate all lines out as far as possible, and provide for maximum headways within the network, by timetabling changes and improvements. To enable maximum frequency and operationally of the lines the following infrastructure upgrades are required:

1. Track amplification Sydenham – Erskineville Junction, with the demolition of Platforms 1-2 at St Peters and Erskineville, and the removal of the half-built platforms A-B at these stations.
2. Upgrades to Strathfield Station
3. Flyover/under at Homebush Junction
4. Upgrades to Redfern Station (demolition of Platforms 2-3)
5. Quad track amplification Granville Junction—Fairfield.
6. Quad track amplification between Cabramatta Junction and Liverpool
7. Flyover at Cabramatta Junction
8. Upgrade of the Northern Line Strathfield – Hornsby
9. Duplication Mulgrave – Quakers Hill, and upgrades to Richmond.
10. Additional Platform at Dundas and Carlingford.
11. Quad track amplification Bankstown - Campsie

This requires the following changes to existing timetabling procedures:

1. The Western Line (Penrith) to be sent to Sydney Terminal rather than the North Shore Line (removes flat junctions at Homebush and Illawarra)
2. Diversion of South Line (Campbelltown via Granville) to be sent via the North Shore rather than the City Circle (removes flat junction at Homebush, and enables higher frequency on local lines)
3. Illawarra Line (Cronulla et al) to be diverted to Sydney Terminal (removes flat junction at Wolli Creek, and Hurstville)
4. East Hills Line to be diverted to Sydney Terminal (removes flat junction at Sydenham, and significant numbers of trains entering the city circle)
5. Northern line to be truncated from Epping to Strathfield and ECRL line to be extended to Berowra from Chatswood

Stopping patterns on the Northern Line

This proposal assumes that the North West Rail Link (NWRL) and South West Rail Link (SWRL) are under construction or constructed, as the Sydney Metropolitan Strategy, and the Growth Centres work is underpinned by these rail extensions. The NWRL is truncated to Castle Hill, where it would act as a major bus interchange, similar to Bondi Junction until a further extension occurs. This proposal also assumes that the North Sydney Freight Line and South Sydney Freight Line are or will be constructed during the life of this proposal. The NSFL would have input due to track sharing with interurban trains, as shown in figure 3.15. However the costs of NSFL are included in this proposal.

This figure 3.5 shows the CityRail network operating at maximum efficiency in the short term, with a minimum of line branching and a maximum of 2 different stopping patterns per line. This enables for a maximum opportunity for both local and distant services to receive equitable services. At present the inner local services, are disadvantaged by the requirements of the outer suburbs. This can be seen by the frequency for local trains on the Inner West, East Hills, and Illawarra lines having a peak frequency and non memory timetable of between 10-20minutes, which is generally worse than outer areas, even though these areas are experiencing significant infill development, and potentially significant patronage.

This will require 1422 new rail cars to operate.

3.1 Stage 1

Travel demand is not just commuter demand, which is what CityRail is primarily geared for. The figure below shows the timetable between 6:00am and 8:00pm, showing the number of trains running in each half hour block through Central. This shows a significant peaking effect. The peaking effect is when the frequencies are highest for a short period of the day, then rapidly drop off. The following two figures show the peaking within Cityrail.

Figure 3.1 : CityRail peaking by line

Source: CityRail 2009

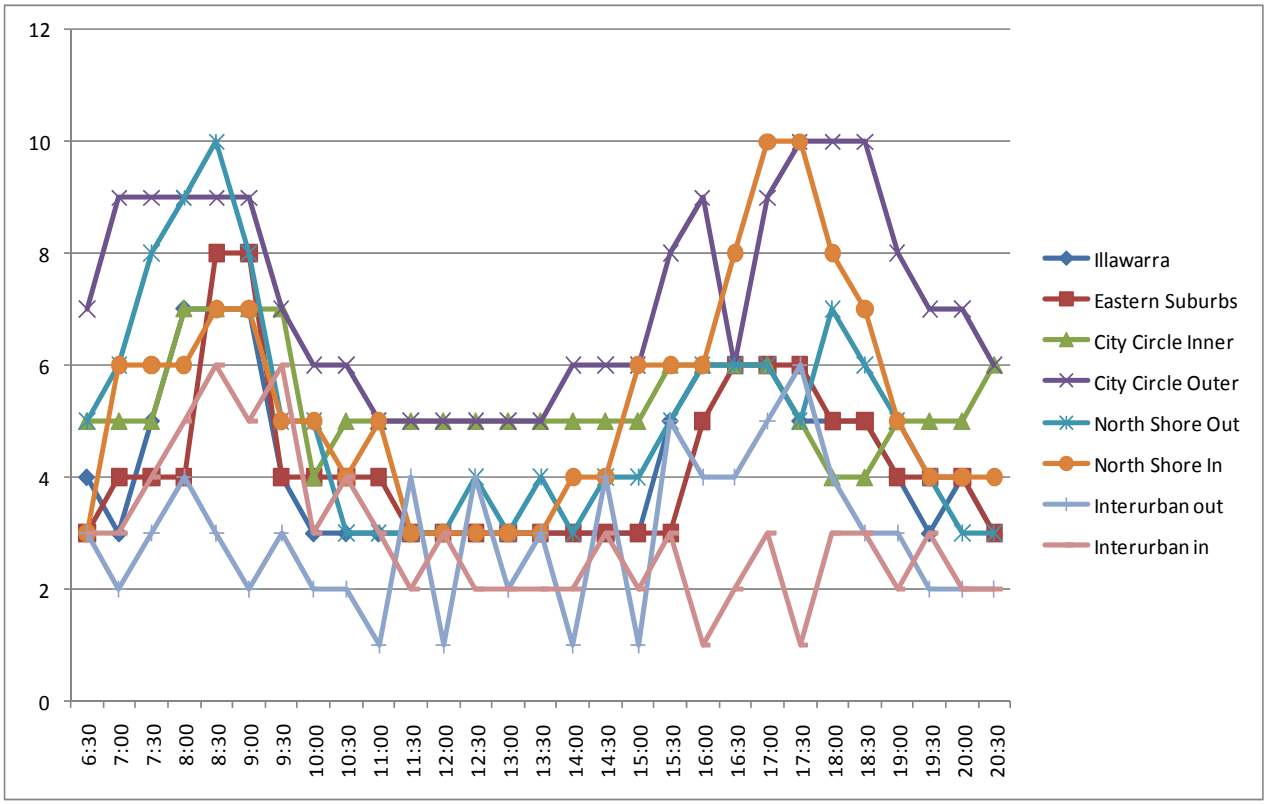
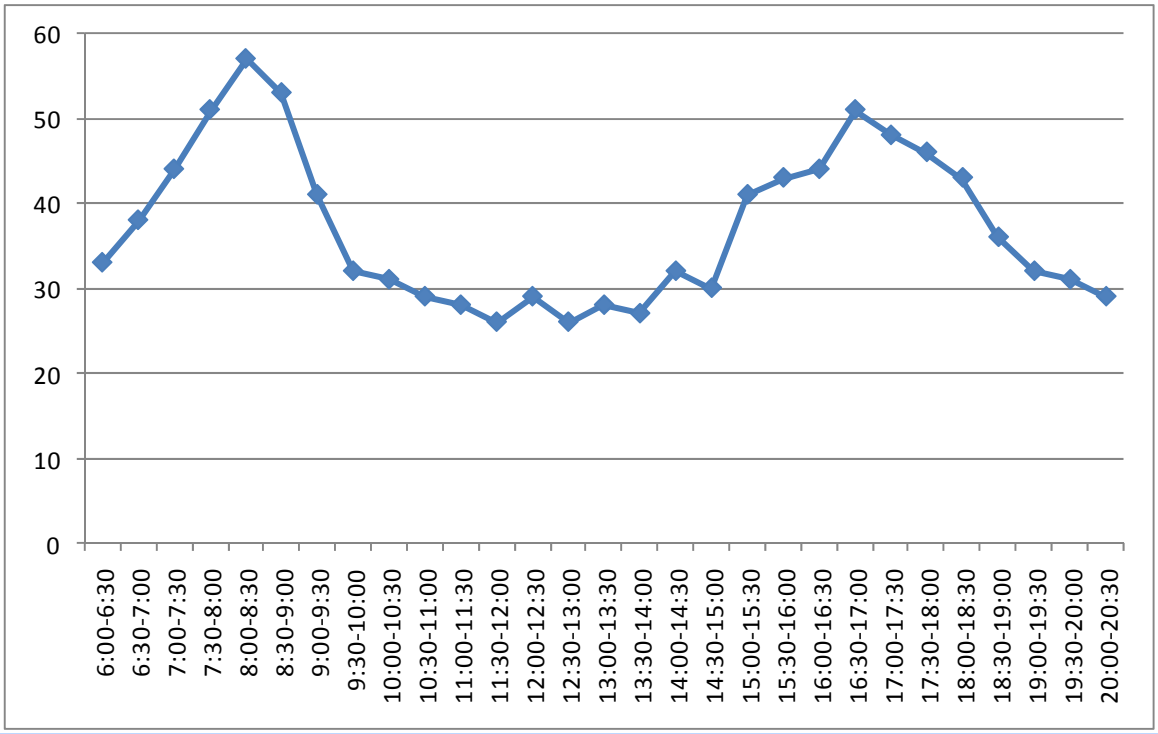


Figure 3.2 : CityRail peaking total

Source: CityRail 2009



3.1 Stage 1

These graphs clearly show a peaking occurring. In the morning peak the amount of trains running peaks between 7:30 and 8:30, whilst in the afternoon peak it peaks between 16:30 and 17:30. This means that turn-up-and-go frequencies do not exist outside this time period, which reduces the desire to use trains outside peak periods for non-commuting trips. The Transport Data Centre (2009) states that journey to work trips only make up 15.6% of all trips during the day, and as this shows it is a minority of trips. Public transportation and rail in particular needs to try and pick up trips such as social, recreation, and shopping trips—which combined make up 38.2% of all trips. To do this requires frequent, reliable and fast public transportation.

Vuchic (2007), (2004) states that even if the transport corridor will only have a maximum of 70 passengers per hour each way, per stop, it is better to run at a frequency of at least 6 vehicles per hour/direction, to enable turn-up-and-go or discretionary travel. Transport Data Centre states that 26% believed public transport was too indirect, 18% of respondents thought it was too slow, and 11% stated that timetabling constraints were severe, and 8% stated that they were too infrequent. Overall this is a 63% disincentive cost, of which the use of turn-up-and-go style services would reduce 37% of these complaints.

C set Train at Kingsgrove

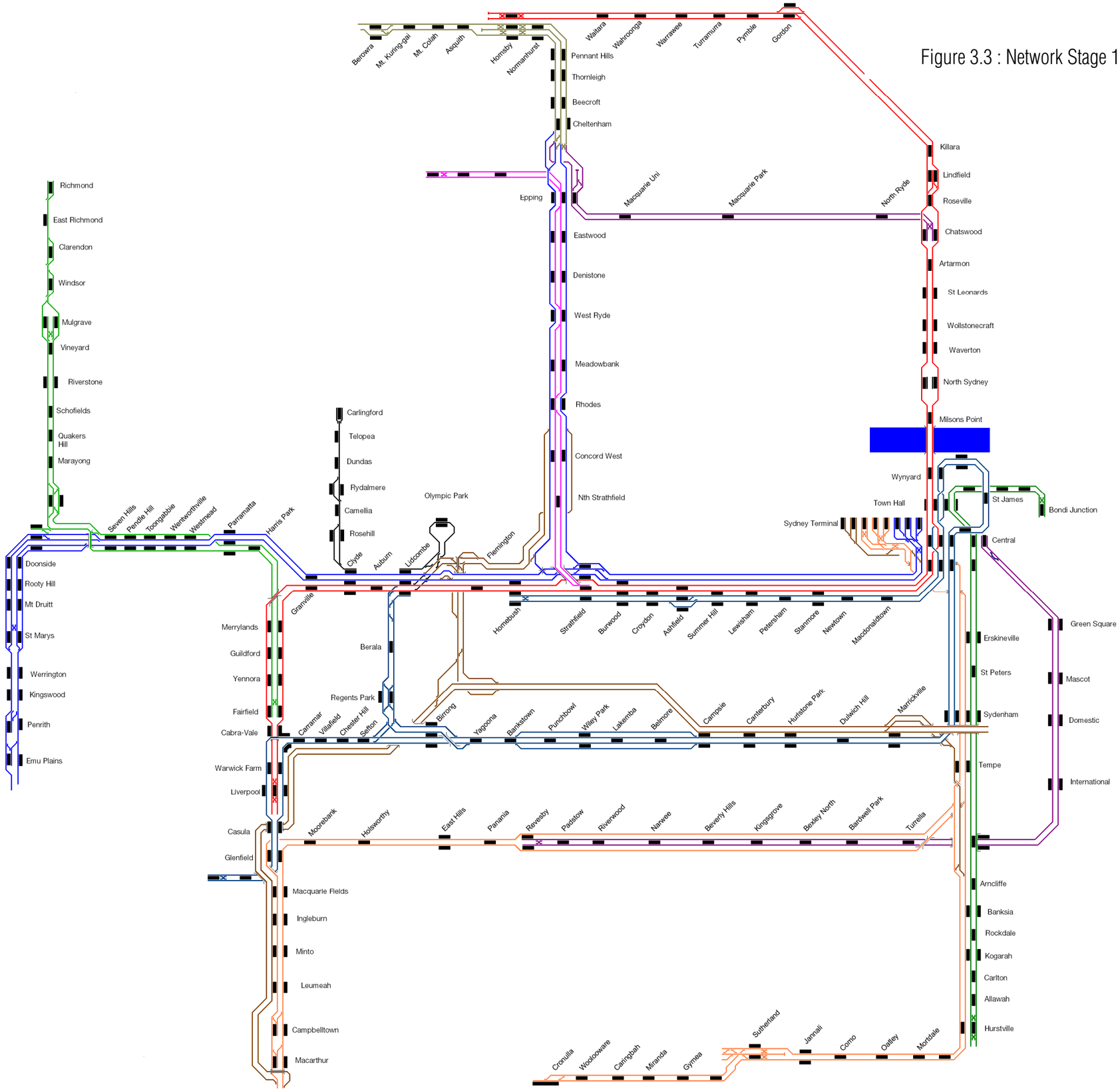
Source: Ben Chatwin (2009)

Turn-up-and-go essentially states that you can arrive at a rail station, and not have to need a timetable to know when the next train is arriving—as the services are that frequent. Chapman (2009) states that there should be a service at least every 15minutes to be turn-up-and-go, whilst Laybutt (2008) believes that it should be a service every 10 minutes or better to be turn-up-and-go. At present turn-up-and-go services only exist at CityRail at major stations, where multiple train lines converge, and stop to the city stations. Due to the use of limited stop services, and a base frequency of a train every 30minutes, or 2tph, significantly limits the appeal of railway transit for discretionary travel, especially when compared to the convenience, speed and door to door service of the car off peak.

Turn-up-and-go services are the mainstay of metropolitan, urban and in most cases suburban services around the world.

This proposal intends to increase the amount of trains stopping all stations, and also the frequency of these services, by enabling freight trains to have a relatively dedicated path through the Sydney basin, and enable proper local-express running of services. This is shown in Figure 3.5.

Figure 3.3 : Network Stage 1, showing new sectors



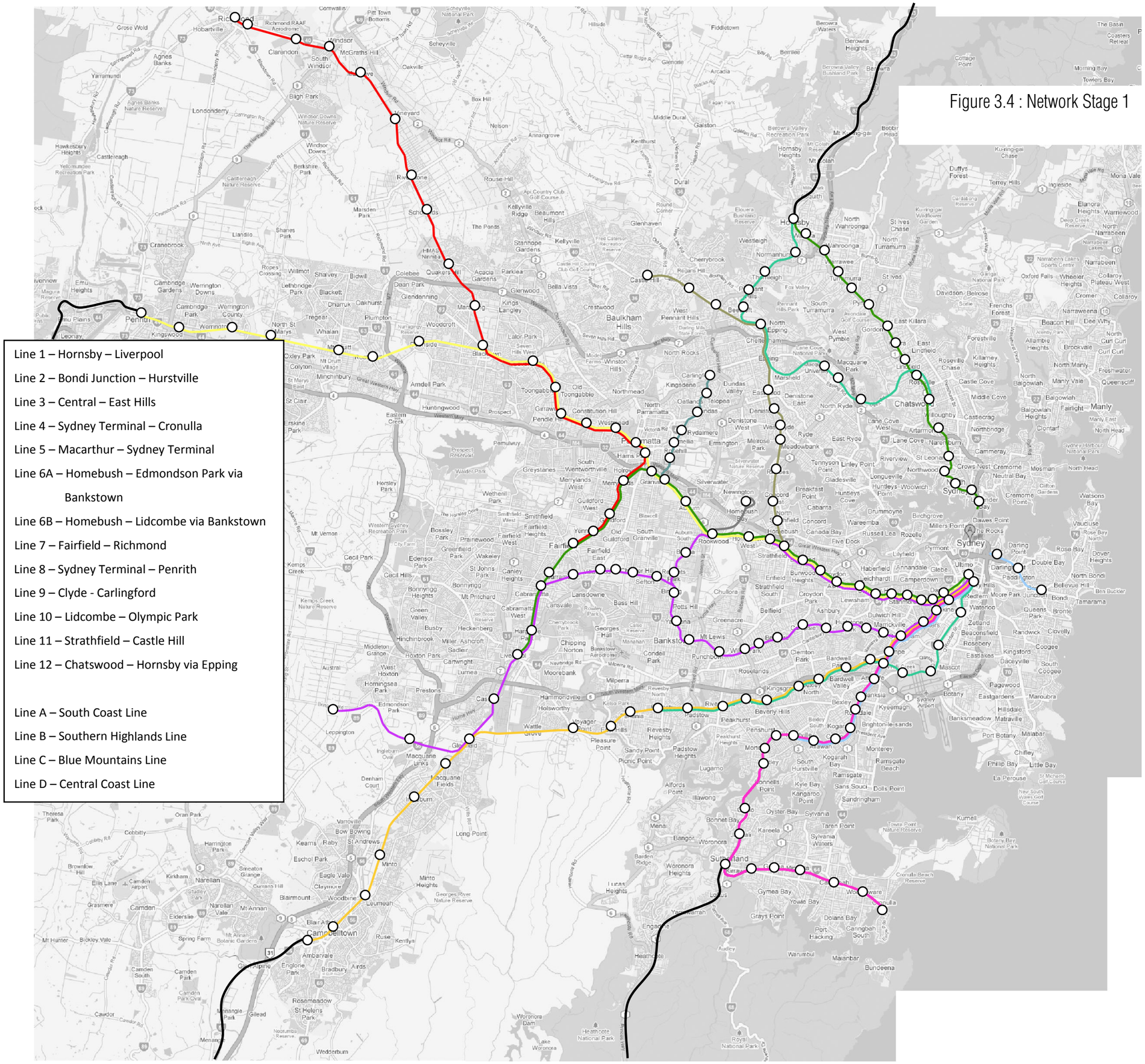
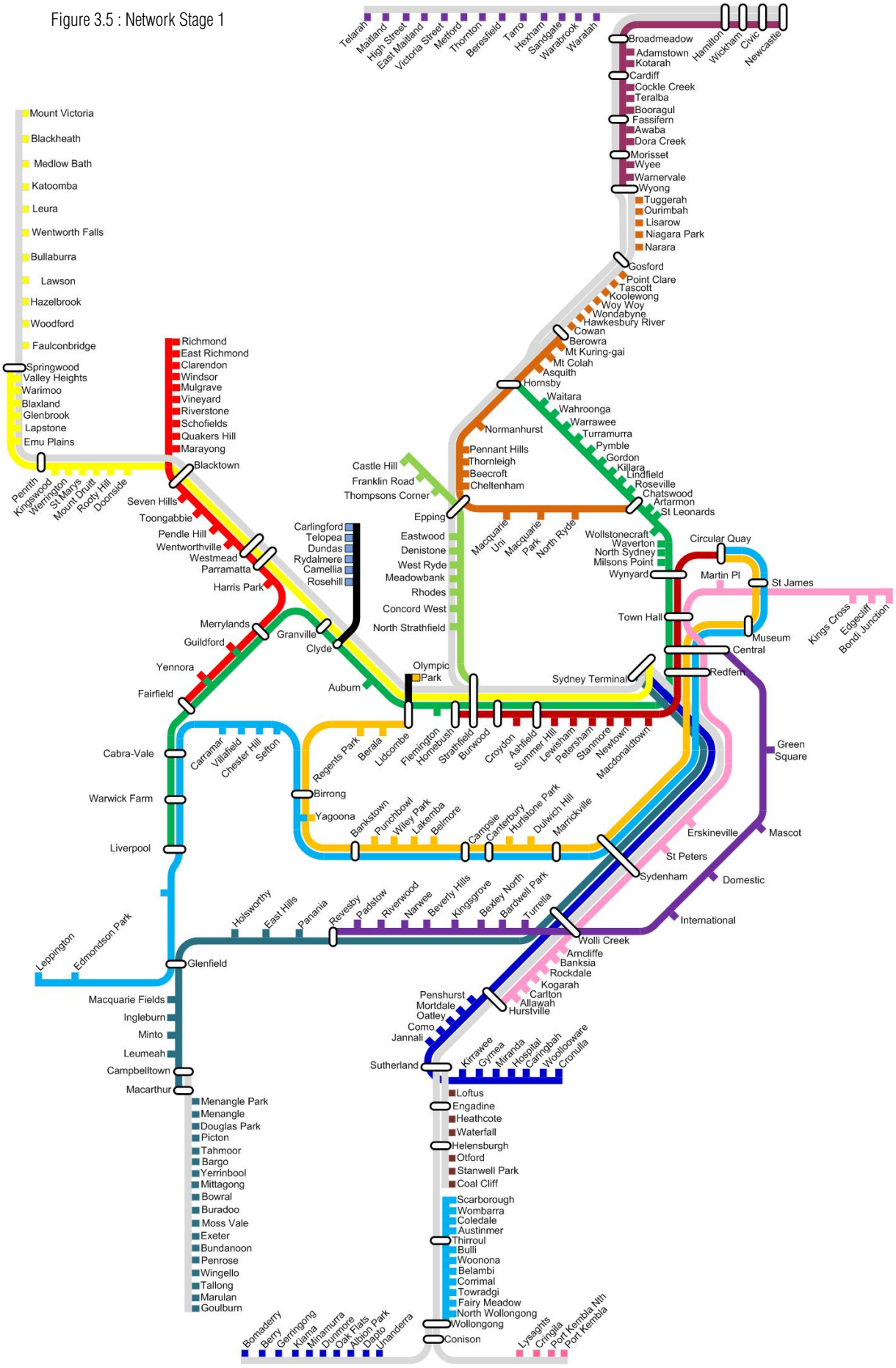


Figure 3.4 : Network Stage 1

3.1 Stage 1

Figure 3.5 : Network Stage 1



3.1 Stage 1

This sectorisation enables for local and express trains to be separated out, as well as increase capacity into the Central Complex (Sydney Terminal, Central Electric, Chalmers St) by more than 56% using double deck rolling stock only. If sectors 2 and 4 are converted to single deck, the increase into Central Complex is 186%

The table below shows a comparison of the trains per hour that can enter the Central Complex now, and what is proposed in **stage 1**.

Between the hours of 7:30 and 8:30 into the Central Complex

Table 3.4 : Capacity existing and proposed into the City Underground

Line	Existing Tph	Maximum existing	pph	Proposed Tph	Max TPH	pph
City Circle Inner	14	20	21,000	20	20	30,000
City Circle Outer	16	20	24,000	20	20	30,000
Eastern Sub-urbs (in)	16	20	24,000	20	20	30,000
Eastern Sub-urbs (out)	12	20	18,000	20	20	30,000
North Shore (in)	14	20	19,500	20	20	30,000
North Shore (out)	18	20	27,500	20	20	30,000
Sydney Termi-nal	16	20	24,000	60	60	90,000
Airport	n/a	n/a	n/a	12	20	18,000
Total	106	*140*	158,000	192	*200*	288,000

City Circle Inner = via Museum
City Circle Outer = via Town Hall
North Shore in = From North Sydney
North Shore Out = To North Sydney
Eastern Suburbs In = To Bondi Junction
Eastern Suburbs Out = From Bondi Junction

Note: This works off the maximum standard capacity of a double deck train to be 1500 people. Double Deck trains can operate with a higher level of congestion (maximum crush loading is considered to be 2000 people), but above 1500 people per train is where CityRail generally considers service quality to be compromised with longer dwell times at key stations. This can be partially alleviated through reduced stopping patterns, and allowing trains to come very close to each other again in the City Underground, as what occurs at Central.

This shows by terminating 60tph at Sydney Terminal, splitting services out of the City Circle (Airport Line – 12tph, Campbelltown Express 12tph), and running the other lines at maximum capacity (as shown in the literature review), enables for an additional 87 trains per hour to run. (44tph additional Sydney Terminal, 22tph additional City Circle, 12tph additional Eastern Suburbs, and 8tph additional North Shore Line)

3.1 Stage 1

If sectors 2 and 4 were converted to single deck trains the following tph and pph would apply.

Table 3.5 : Capacity through the City Underground if some lines single deck

Line	Maximum tph	pph
City Circle Inner	30	60,000
City Circle Outer	30	60,000
Eastern Sub-urbs (in)	30	60,000
Eastern Sub-urbs (out)	30	60,000
Total (inc other lines)	*260*	408,000

It should be noted however that the significant number of trains terminating at Sydney Terminal will place strain on Central Electric (platforms 16-23) and Chalmers St (platforms 24/25).

Congestion at North Sydney

These assumptions on maximum passenger numbers per hour are working on a wholesale change in people-use patterns of the City Underground Stations. At present Martin Place, Museum and St James Stations are used significantly below capacity (and are better located than Town Hall), Whilst Circular Quay, Central Town Hall and Wynyard are nearing capacity. This proposal assumes that the increased use will bring Museum, St James, Martin Place and Circular Quay stations to near or at capacity, through increased interchanging at stations before the City Underground, and at Redfern and Central. It also assumes that a significant proportion of the interchanging passengers will use the City Metro line.

The increase in frequency should also increase the number of seats available, which should reduce the need for passengers to use Town Hall and Wynyard to ensure that they receive a seat on City Circle line services.

The proposed solution is shown above, which is the conversion of the City Circle and Eastern Suburbs Lines to a metro style single deck rolling stock. A 164m long longitudal seating only train has a standard maximum capacity of 2,000 per train, and maximum crush loading of 2,500 per train. This is based of similar rollingstock already in use world-wide.

If this is not implemented alternative solutions will be required to reduce overcrowding here, including barring interchanging during peak, walking the remainder of the trip to the office, or an intense campaign showing alternative traffic routes (buses etc), or which platforms/lines are underutilised. Stage 2 of the network proposal should also alleviate this congestion, by enabling up to 468,000 people into the Central Complex, and up to 414,000 people per hour into the City itself.

It shall be noted that if there is delays, they would be restricted to one sector, due to the 'clearwaying' out of each sector. To stop the delays from further cascading, it would be assumed that there would be one or more trains cancelled then transposed to bring the system back into order.

3.1 Stage 1

This figure shows the number of trains into Central during the morning peak between 7:30 and 8:30am.

The darker coloured line indicates the number of trains under the existing timetable, and the lighter coloured line the number of trains running under this proposal.

This shows that overall there is a significant number of increased services operating into the City, which reduces passenger congestion.

Figure 3.6 : Overall network capacity.

This shows increased services on the Western, South, and Illawarra lines where capacity is most needed.

3.1 Stage 1

This table shows the Trains per Hour operating between 7:30 and 8:30am into the Central Complex under the current timetable and contrasted to the proposed timetable in stage 1.

Table 3.6 : Existing and proposed TPH by station

Station	Current tph	Stage 1 tph	Station	Current tph	Stage 1 tph
Allawah	4	20/30	Macdonaldtown	4	20
Arncliffe	4	20/30	Macquarie Fields	11	12
Artarmon	12	20	Marayong	3	14
Ashfield	12	40	Marrickville	4	20/30
Asquith	5	3	Martin Place	16	20/30
Auburn	10	20	Meadowbank	4	6
Banksia	4	20/30	Merrylands	6	10
Bankstown	6	20/30	Milsons Point	13	20
Bardwell Park	4	12	Minto	12	12
Beecroft	8	10	Miranda	4	12
Belmore	6	10/15	Mortdale	8	12
Berala	6	5	Mount Colah	2	3
Berowra	5	9	Mount Druitt	8	12
Beverly Hills	8	14	Mount Kuring-gai	2	3
Bexley North	4	14	Mulgrave	2	14
Birrong	6	20/30	Museum	30	40/60
Blacktown	15	38	Narwee	4	12
Bondi Junction	16	20/30	Newtown	5	20
Burwood	20	40/50	Normanhurst	8	10
Cabramatta	10	30/40	North Strathfield	4	10
Camellia	1	4	North Sydney	13	20
Campbelltown	15	12	Oatley	4	12
Campsie	6	20/30	Olympic Park	3	6
Canley Vale	4	n/a demolished	Padstow	8	12
Canterbury	4	20/30	Panania	4	12
Caringbah	4	12	Parramatta	18	38
Carlingford	4	12	Pendle Hill	6	20
Carlton	4	20/30	Pennant Hills	8	10
Carramar	4	10/15	Penrith	11	18
Casula	6	20	Penshurst	7	12
Central	109	192/222	Petersham	5	20
Chatswood	12	20	Punchbowl	6	10/15
Cheltenham	8	10	Pymble	6	20
Chester Hill	4	10/15	Quakers Hill	3	14
Circular Quay	30	40/60	Redfern	101	120/160
Clarendon	2	4	Regents Park	10	10
Clyde	4	20	Revesby	8	12
Como	4	12	Rhodes	4	10
Concord West	4	6	Richmond	2	4
Cronulla	4	12	Riverstone	2	14
Croydon	5	20	Riverwood	8	12
Denistone	4	6	Rockdale	11	20/30
Doonside	4	12	Rooty Hill	4	12
Dulwich Hill	4	10/15	Rosehill	1	4
Dundas	1	4	Roseville	8	20

3.1 Stage 1

Table 3.6 : Existing and proposed TPH by station

Station	Current tph	Prop Tph	Station	Current tph	Prop tph
East Hills	8	24	Rydalmere	1	4
East Richmond	2	4	Schofields	2	14
Eastwood	8	6	Sefton	4	10/15
Edgecliff	16	20	Seven Hills	10	20
Emu Plains	5	12	St James	30	40/60
Engadine	4	6	St Leonards	12	20
Epping	8	32	St Marys	8	12
Erskineville	4	20/30	St Peters	4	20/30
Fairfield	6	10	Stanmore	5	20/30
Flemington	5	40	Strathfield	10	70
Glenfield	16	22	Summer Hill	5	20/30
Gordon	11	20	Sutherland	14	18
Granville	10	38	Sydenham	19	58/78
Guildford	6	10	Telopea	1	4
Gymea	4	12	Tempe	4	20/30
Harris Park	4	20	Thornleigh	8	10
Heathcote	4	6	Toongabbie	6	20
Helensburgh	4	12	Town Hall	16	120/160
Holsworthy	9	12	Turramurra	9	20
Homebush	5	40	Turrella	4	12
Hornsby	21	40	Villawood	4	*Demolished*
Hurlstone Park	4	10/15	Vineyard	2	14
Hurstville	18	38/48	Wahroonga	6	20
Ingleburn	12	12	Waitara	6	20
Jannali	11	12	Warrawee	6	20
Killara	8	20	Warwick Farm	10	30/40
Kings Cross	16	20/30	Waterfall	5	6
Kingsgrove	9	12	Waverton	11	20
Kingswood	7	12	Wentworthville	6	20
Kirrawee	4	12	Werrington	6	12
Kogarah	14	20/30	West Ryde	8	6
Lakemba	6	10/15	Westmead	10	28
Leightonfield	4	10/15	Wiley Park	6	10/15
Leumeah	12	12	Windsor	2	4
Lewisham	5	20	Wolli Creek	19	50/60
Lidcombe	6	20	Wollstonecraft	11	20
Lindfield	8	20	Woolooware	4	12
Liverpool	10	30/40	Wynyard	52	80
Loftus	4	6	Yagoona	6	20/30
Macarthur	6	12	Yennora	6	10

This proposed timetable as shown above with train-station frequencies utilising the changes to operating procedures, and upgrades, enables for a very high frequency service to be implemented, as shown by the frequency chart in the height of morning peak as shown above.

3.1 Stage 1

Sydenham—Erskineville Amplification

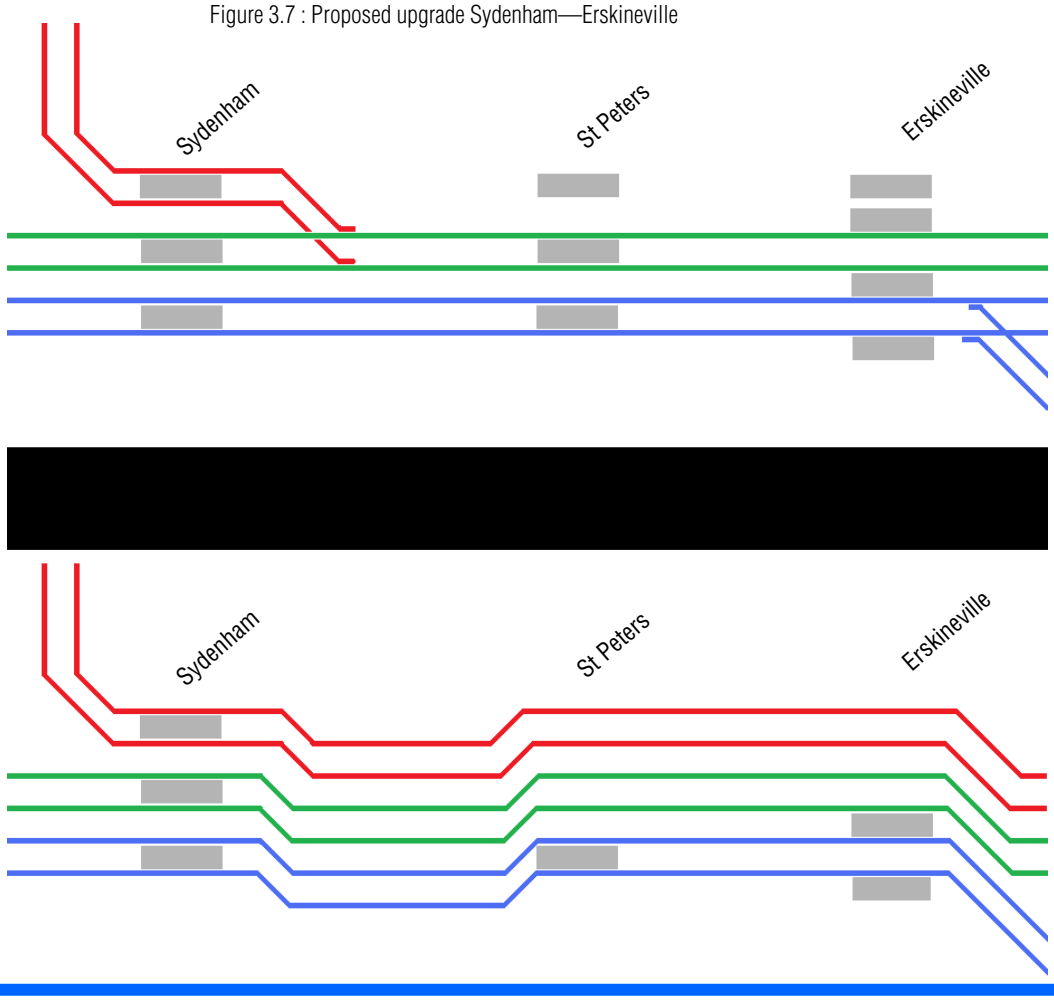
It is proposed to build the additional two tracks through this junction to separate out the two metro lines, and the suburban services. To do so will require the demolition of three platforms (2 Island platforms at St Peters, 1 through platform at Erskineville), rebuild the King Street Bridge and replace approximately 2.5 kilometres of fence as sound barriers, as trains will be operating within 60cm of a rear boundary line.

This proposal would take approximately 18 months to complete, with two significant shutdowns due to the significant realignment works required, a complete rebuilding of the overhead alignment, the replacement of one span of a very busy bridge into Newtown, as well as the demolition works.

It would be expected that the timeline for this project would operate as follows

1. Platforms A-B and 1-2 at St Peters, and Platforms A-B at Erskineville would be demolished.
2. Rebuild the third span at King St
3. Demolish existing railway boundary fencing, and replace with sound barriers, which have support posts for overhead wiring supports.
4. Install the new OH/W supports across the railway corridor (single span pieces, running from sound barrier to sound barrier)
5. realign tracks to enable the additional two tracks to be installed.
6. install two additional tracks.

Figure 3.7 : Proposed upgrade Sydenham—Erskineville



3.1 Stage 1

Redfern to Sydney Terminal Upgrade:

The following image shows the proposed upgrade to this area:

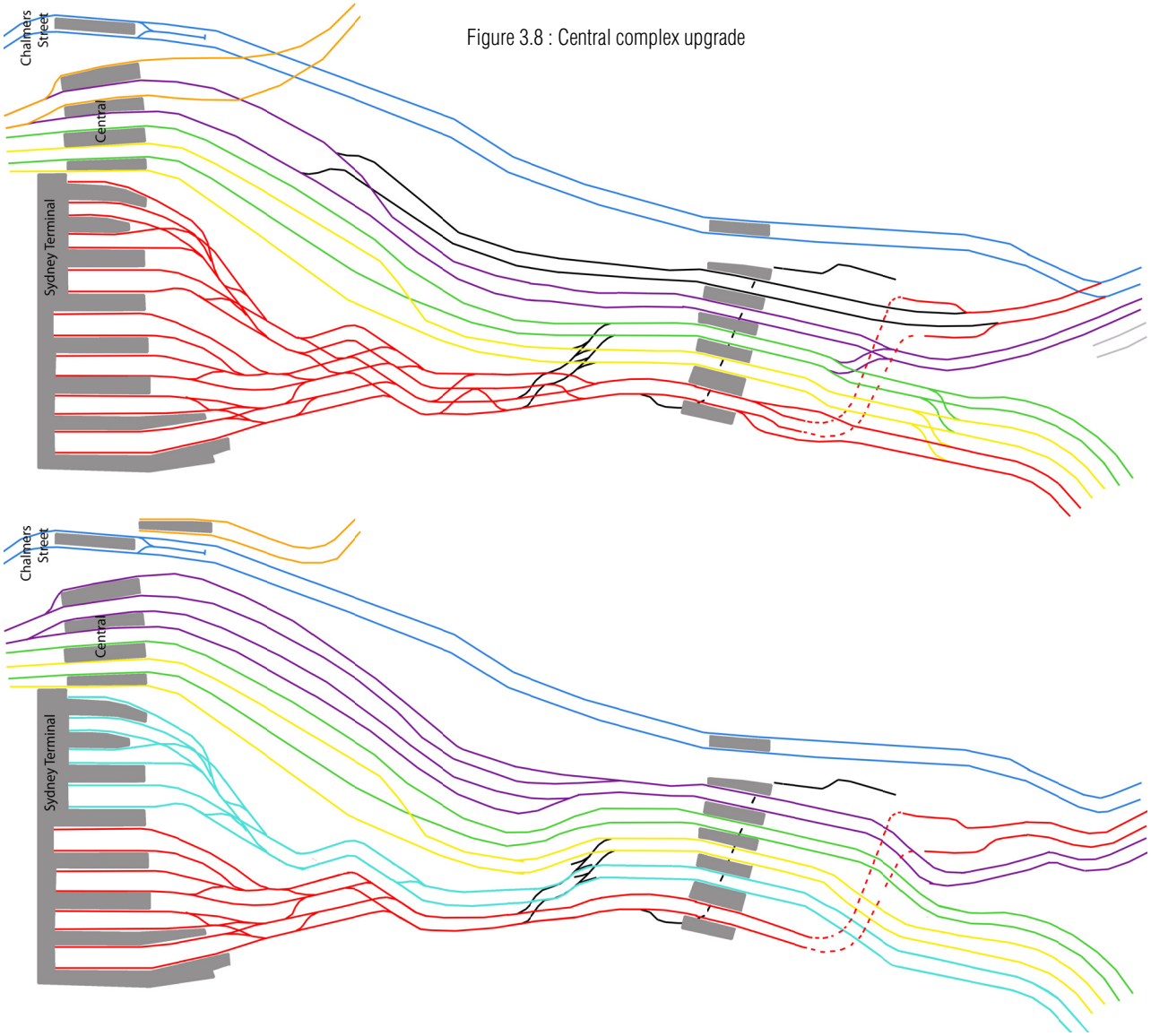


Figure 3.8 : Central complex upgrade

This shows the upgrade to Sydney Terminal to enable four tracks into Sydney terminal, by relocating the existing tracks. This proposal would take approximately 6 months to complete, with two major shutdowns. The length of this project is determined by the time it will take to build new signalling and overhead wiring structures, then realign the various tracks.

This proposal enables trains from the West and South to terminate at Sydney Terminal without conflict caused by the sharing of a dual track pair between Redfern Station and Cleveland St Junction. This realignment is necessary to enable the maximum termination of trains at Sydney Terminal, Central and Chalmers Street.

The relocation of the Airport line from Platforms 21 and 23 to Platforms 26/27 enables for the stage 2 construction from Central through to Chatswood to occur at a later date, as well as funnel these trains out of the City Circle. This would require a short dive to be built directly after the existing Airport line portal down to these platforms.

3.1 Stage 1

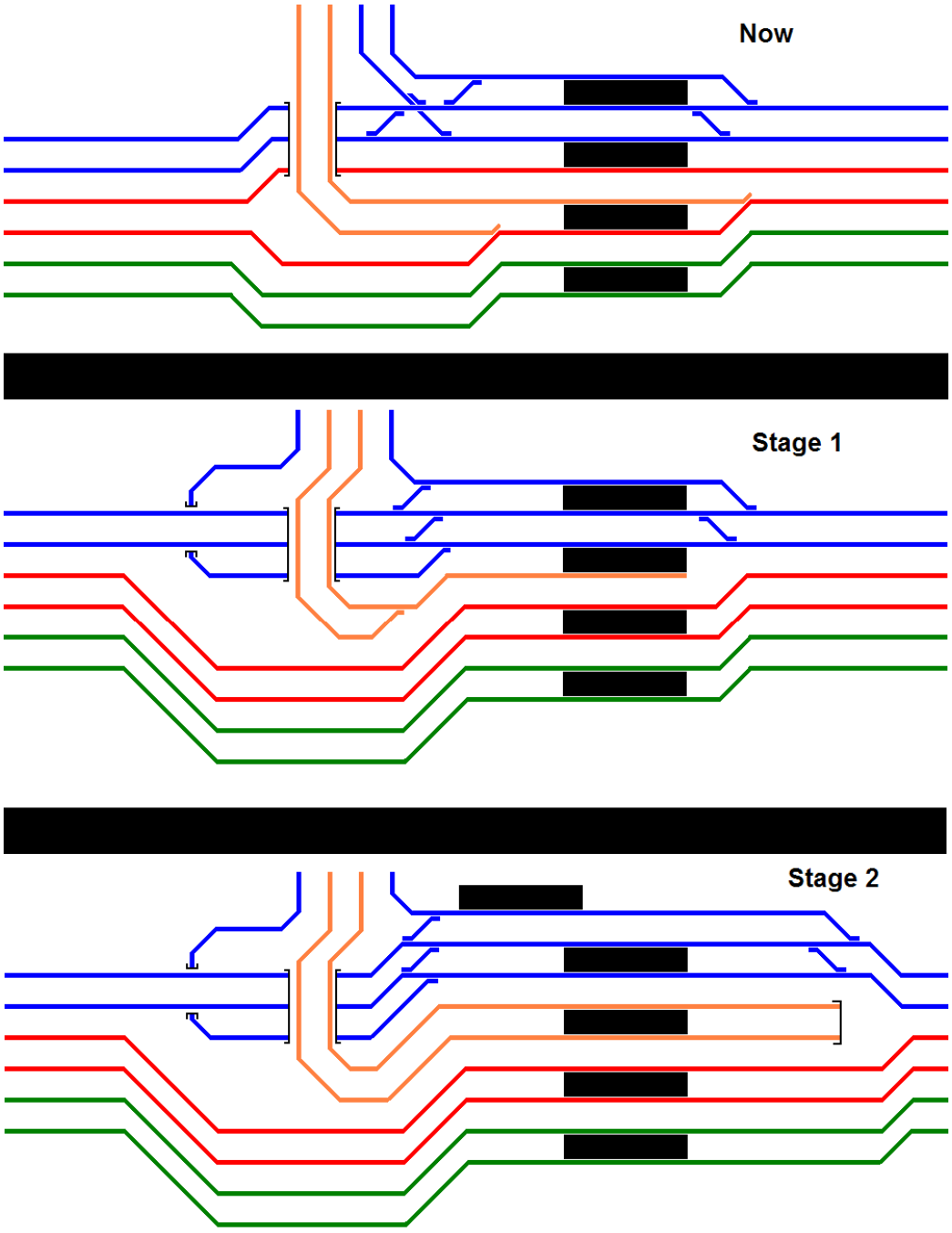
Strathfield Junction:

Strathfield Junction is to be upgraded in two stages. Stage 1 relieves the flat junctions, and separates out the shuttle Northern Line service, whilst Stage 2 builds a new platform, and enables the shuttle Northern Line service to continue into an underground portal for the connection to Campsie.

This proposal will take at least 6 months in stage 1, with two major shutdowns. This is primarily to enable the sinking of one line under the existing flyover 1m, to enable a sufficient grade to get the interurban flyunder in. It will also require piping or relocating of an existing open stormwater drain.

Stage 2 will require a similar amount of time, but will only require a minor shutdown to connect up the new point work as the new platform and track would be on a semi-viaduct over Raw Square.

Figure 3.9 : Strathfield station upgrade

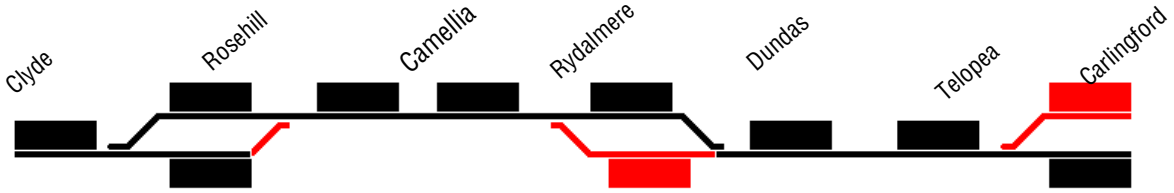


3.1 Stage 1

Carlingford Line Upgrades

The Carlingford Line Upgrade is two additional platforms, one at Rydalmere and one at Carlingford. This will enable a maximum frequency on the line of 6tph in each direction from 1tph. This line will remain designed for a maximum of 4 car long trains, but with provision for expansion if the line is extended. This will enable for a turn-up-and-go frequency service on this line, that has moderate amounts of medium and high density residential surrounding the stations.

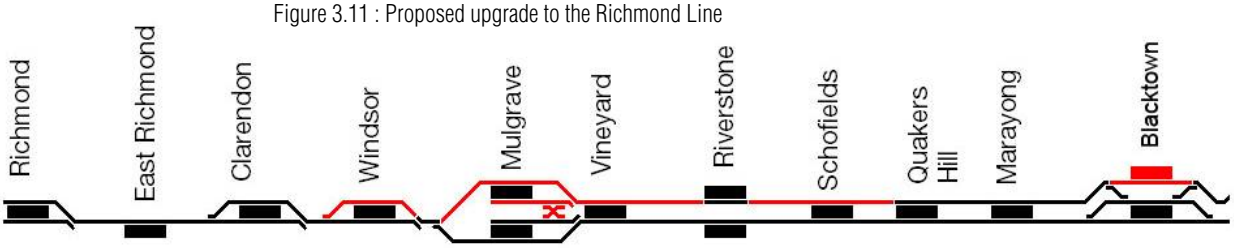
Figure 3.10 : Proposed upgrade of the Carlingford Line



Richmond Line Upgrade

The Richmond line is to be duplicated from Quakers Hill to Mulgrave, and a passing loop and platform installed at Windsor. Continuing double track past Mulgrave is considered infeasible due to excessive costs required to duplicate the existing high level, long bridges across the South Creek, and Nepean River floodplains. This will enable for a significantly higher frequency of services on this line, which can also service parts of the North West Growth Centre. Capacity is currently constrained to 2tph due to the single track. This will enable a frequency of up to 20tph to Mulgrave, and 6-8tph to Richmond.

Figure 3.11 : Proposed upgrade to the Richmond Line



Bankstown Line Upgrade

The Bankstown line is to receive a track amplification between Bankstown and Campsie to enable express services to overtake local services in this corridor. This will enable a higher frequency and utilisation of the corridor, by enabling the express trains to be separated out where they are running non-stop. This will enable for a higher frequency of services as Belmore Station acts as a capacity constraint to higher frequency trains due to its design, and also enables for high speed express services from Liverpool, as the South Line is at speed capacity, and does not have the potential for increased speed services. Stage 1 is construction of a flyover for services from Regents Park, and express tracks Bankstown to Campsie. Stage 2 is the extension of these express tracks to Sydenham, and the construction of the Regents Park—Hurstville line tracks where needed.

Figure 3.12 : Proposed upgrade to the Bankstown Line

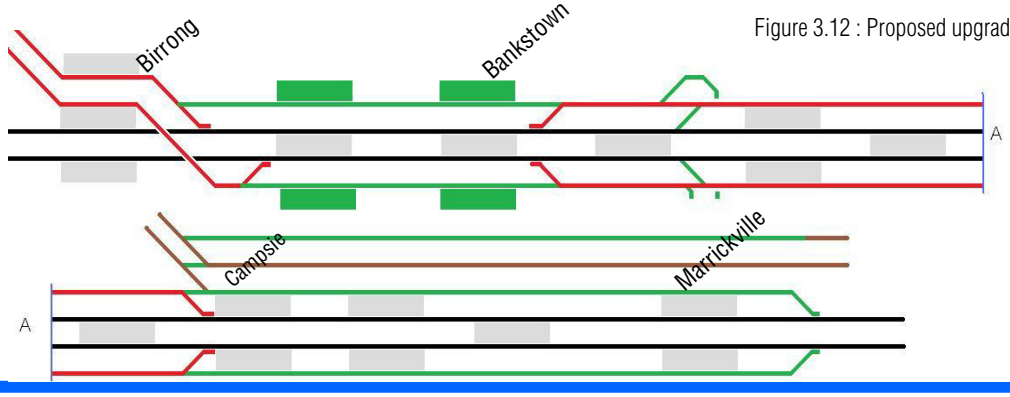
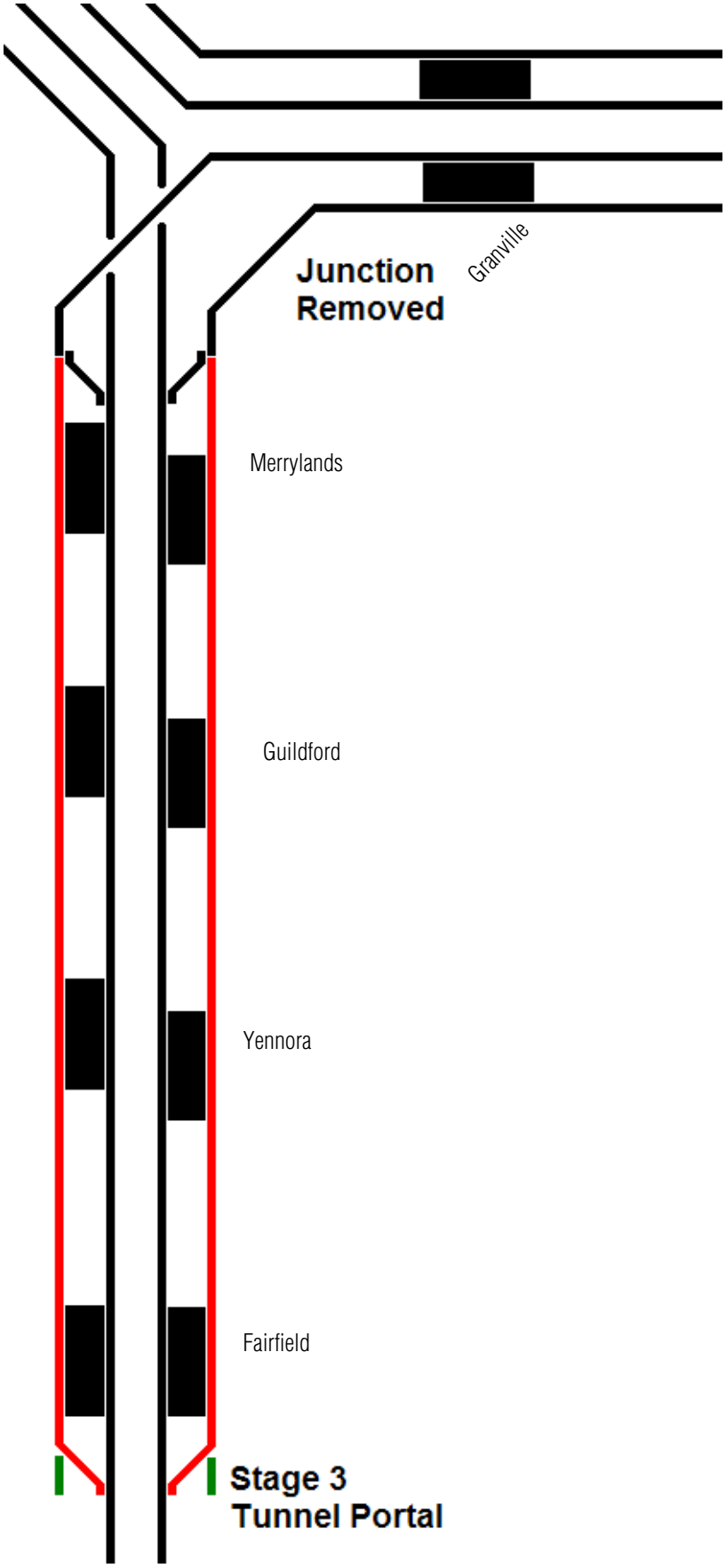


Figure 3.13 Proposed upgrade Granville—Fairfield



Track Amplification Granville Junction—Fairfield

This upgrade is one of the most critical within Stage 1.

This proposal quadruplicates the Old Main South line from the existing Junction just north of Merrylands Station to Fairfield, and provides for the portals for the Stage 2 connection to Prairiewood.

This proposal then means that a major constraint junction at Granville is eliminated, by enabling all trains on the local tracks to continue to Fairfield, and all trains from the Western Line will be on the main tracks.

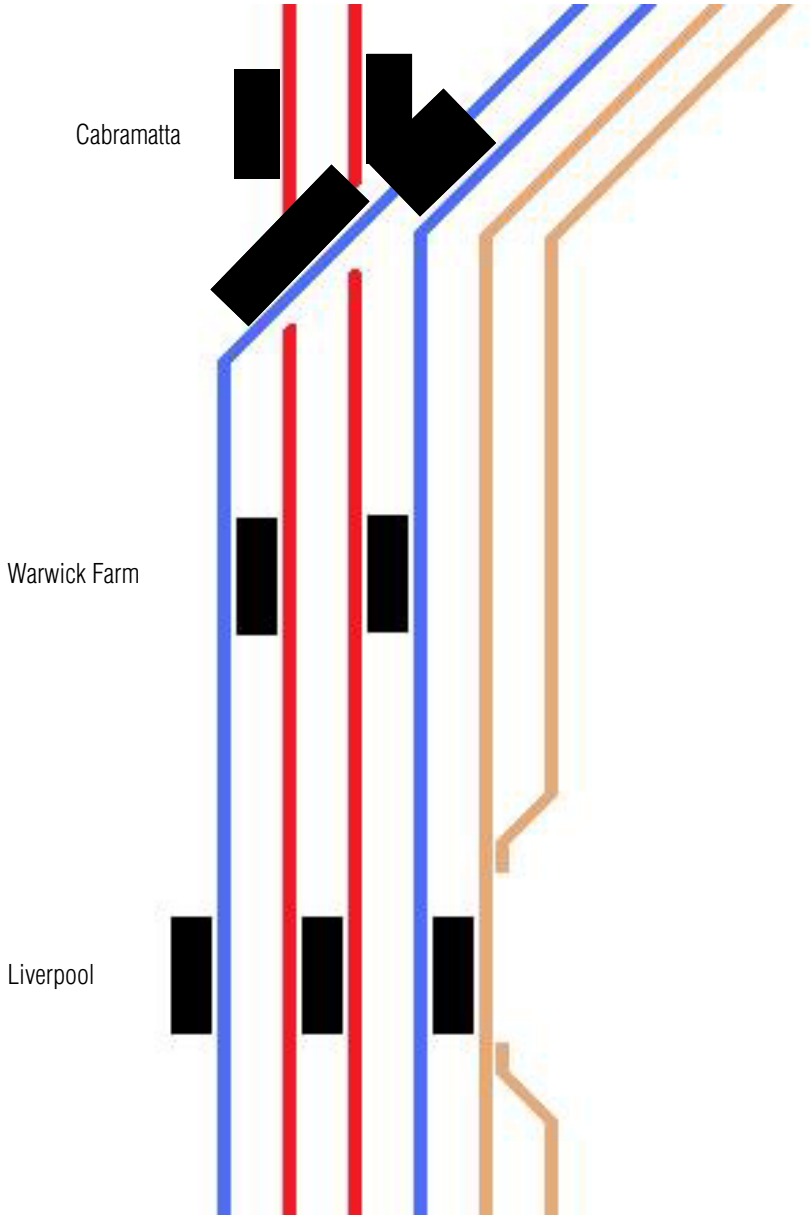
Local services that are currently serviced by the Western will instead be supplemented by a high frequency all day Cumberland Service, and east of Granville by an enhanced South Line Service, which will have all trains stop at Clyde.

The cost of this amplification is relatively minor, given that the majority of the earthworks have already been completed. The main constraint will be stations. It is envisaged that the existing stations will be reused, and in points where the corridor is particularly narrow, the track elevated over the existing footpath, or parts of the road resumed.

This amplification, with the Cabramatta-Liverpool, Sydney Terminal and Northern Line form the basis for the stage 1 improvements.

3.1 Stage 1

Figure 3.14 : Proposed upgrade from Cabramatta junction—Liverpool



This section of track is one of the largest constraints in the network.

At present four different lines and freight use the flat junction at Cabramatta, and the four tracks merge into two for the remainder of the line. This proposal separates out the two main approach lines, sextuplicatess from Cabramatta Junction through to Liverpool.

With the additional tracks through the corridor between Cabramatta Junction and Cabramatta Creek, Cabramatta Station will be demolished and relocated to the junction. Canley Vale Station will also be demolished, as it would then be too close to the new Cabramatta Station to be an effective use of resources.

At Liverpool where the track corridor narrows due to the Georges River, the freight line will have a short section of single track.

This will enable the Bankstown Line services and the South Line services to be separated out, and enable maximum capacity running.

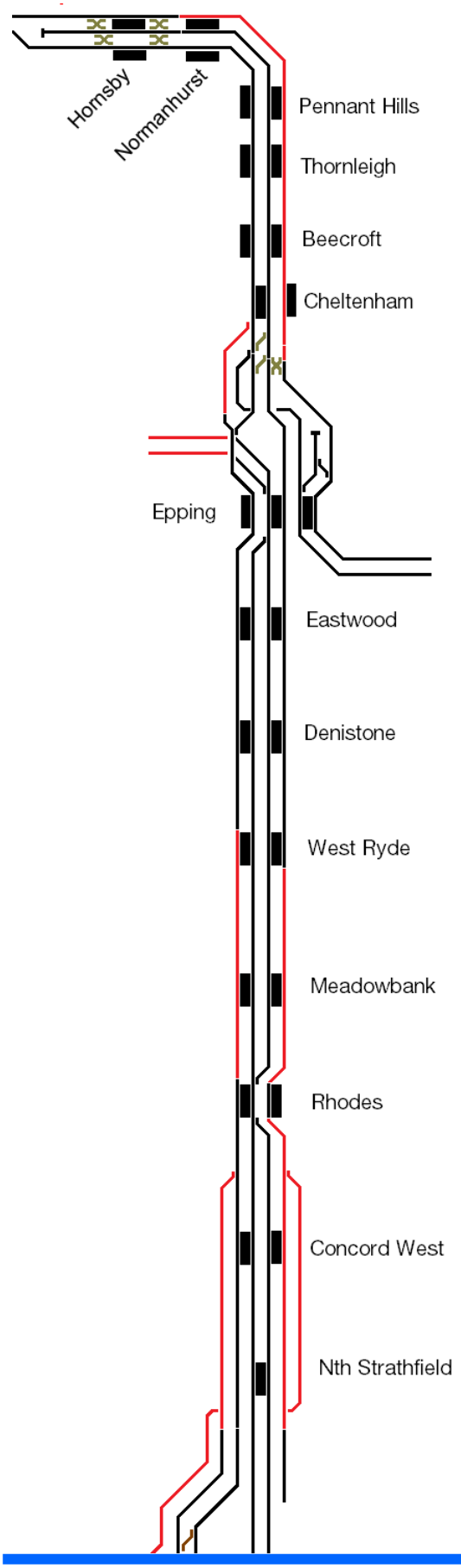
The amplification of the South Sydney Freight Line (which would occur at a later date, but need provisioning as part of this) would enable for higher frequency freight on the most important freight corridor in Australia.

Without this amplification increased services cannot be provided through most of the existing sector two network.

This is a costly amplification due to the requirement for new bridges, a complex new station and embankment rebuilding.

3.1 Stage 1

Figure 3.15 : Proposed upgrade Strathfield—Hornsby



Track Amplification Strathfield—Hornsby

This is one of the most important projects in stage 1. This project provides for track amplification on a corridor that has all stations, limited stop, express and freight services. At present there is a passing loop installed in both directions between West Ryde and Epping, and a third track from North Strathfield to Rhodes to enable faster trains to overtake slower ones. However this corridor is highly constrained, and is the third most important freight corridor in Australia.

It is proposed that the line is upgraded to six tracks from Strathfield Junction, (two freight, two intercity, two local) to near Rhodes, then generally four tracks through to Epping—there will be three tracks through Rhodes due to the constraints around the station site however. It will only the local tracks that use a single platform. From Epping to Hornsby however there will only be three tracks due to the constrained nature of the line in this area, with large cuttings, and infrastructure obstacles to quad trackage. Triple track is considered appropriate in this area, providing the third track is treated as a passing loop, with frequent high speed (80km/hr crossovers) to enable high speed passing, for intercity services.

The cost of this upgrade would mostly be borne by the Federal Government, as they have been proposing a North Sydney Freight Line, similar to that along the Main South Line, where they are currently building the South Sydney Freight Line. The construction of these freight lines, or track amplifications enables freight trains to run all day, without the current curfew that exists between 6:00am-9:00am, 3:00pm-7:00pm, where freight trains are prohibited to run (with a couple of minor exceptions) on the electrified network of Sydney.

This will also require additional tracks to be built between Gosford and Fassifern in the intercity network, however this upgrade is only considered a minor cost. The expected cost for the State Government on this project is approximately 136million, given that south of Cheltenham the earthworks, bridge foundations and major infrastructure works have already been completed. Additional funding of 136million will be required from the Federal Government for this line, as part of their contribution to the freight line.

3.1 Stage 1

Summary of Stage 1

Stage 1 operates predominately as a clearways style project—the removal of conflicts between trains and sectors, by in general removing flat junctions and conflict points. This enables a greater frequency of service to be operated across the network, and increase the reliability of freight services, by a greater separation of freight and passenger services. Stage 1 is essential to enable maximum frequency and operation of the rail network as outlined above. Without a separation of services, this cannot occur, and the rail network will remain predominately a commuter rail/suburban rail hybrid, which is incapable of moving significant volumes of people—especially as the existing network operation is reaching capacity.

A commuter rail network is a railway network which is predominately a low frequency branching service, with the absolute majority of passengers receiving a seat. A commuter railway may not operate during the peaks. This is identified by both Vuchic (2004) and TRB (2003). A metropolitan railway is a network which consists of a high frequency service, generally with few or no branches, operating on its own dedicated right of way, that is generally not shared with any other line, or freight. Vuchic (2004) states that a commuter rail service is generally designed for the peak periods of the day with minimal use outside this time, whilst a metropolitan service is designed for use for around 18 hours (or greater) a day, enabling a larger variety of trips to be undertaken, not just the journey to work.

Level Crossing

Source: Ben Chatwin (2009)

Rationalisation of the use of flat junctions, stopping patterns and frequencies is necessary to move CityRail away from a commuter rail model, towards a metro model. Without this shift rail cannot appropriately provide for off peak trips, especially as the peaking shown on figure 3.2 shows that the off peak service frequency is just over half that of the peak frequency. This acts as a major disincentive for off peak rail travel for discretionary travel, and increases reliance on the car for the majority of the trips.

Stage 1 operates as a radical rethink of how the CityRail network operates—by removing the one-seat journey modal, and reducing the numbers of stopping patterns, and standardising service levels, bringing the level of service operated from a commuter rail style service, to a more intensive, higher frequency metropolitan rail service. This will necessitate a greater interchange between services than what occurs now, but providing frequencies are increased, and the public is made aware of why these changes are being made, opposition can be reduced.

These changes enable for a potential shift in travel patterns away from the car to the more sustainable transport option of rail, by reducing confusion for infrequent travellers as to where the train is going, the frequency, and stopping patterns through standardisation, and by a wholesale increase in frequency—increase the desirability of rail for discretionary trips. Without such changes the rail network cannot accommodate more trips (both peak and off peak) limiting its role for modal shift. Rail is also seen as the most appropriate transport option to modify land-use to a higher intensity use—as it has the highest capacity of any transport system, and without such changes, greater intensification of uses (including centres, corridors and higher density residential nodes) noted within the Sydney Metropolitan Strategy are less likely to occur.

Stage 1 also provides the clear framework for expansion of the rail network as shown in stages 2 and 3, and provides the space, option and connection points to enable these expansions to occur.

3.2 Stage 2

Stage 2 of this proposal continues the splitting and sectorisation of the CityRail Network into individual lines. This part of the proposal is more concerned with cross-suburban travel, than to Sydney CBD travel to increase accessibility for the greater Sydney region.

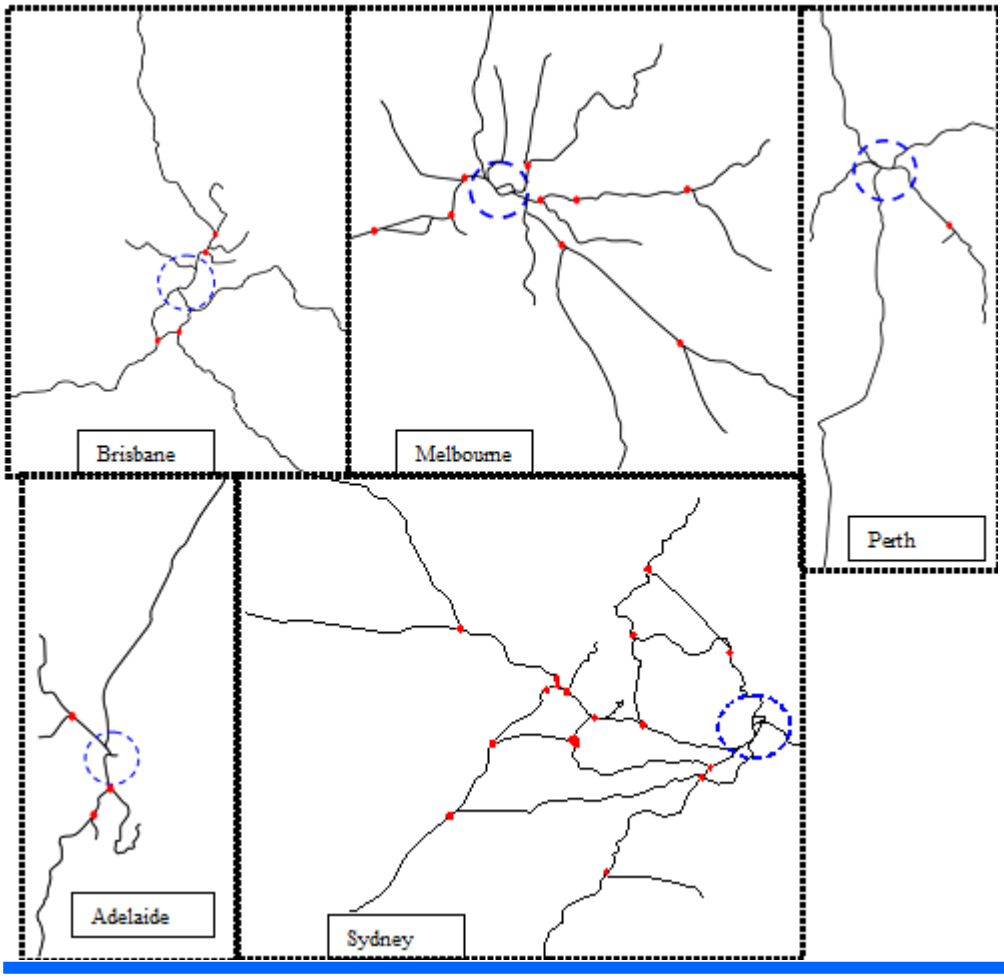
This proposal consists of more expensive works including the following new lines:

- Strathfield – Miranda,
- Punchbowl – Hurstville
- Fairfield – Prairiewood
- Central – Chatswood via North Sydney
- Revesby—Middleton Grange
- Northern Beaches Light Railway (Docklands Light Rail in London equivalent)

These lines form the core for the separation out of the CityRail network, and provide for additional cross city network amplification. It would also expect that any metro railway lines would be carried out by private enterprise, or the State concurrently to the expansion plans listed here, which is why little mention is made of these corridors. This proposal increases the maximum throughput into the City Underground to 468,000 people per hour.

Sydney in comparison to other railway networks in Australia is not particularly radial, with cross country connections possible at 18 locations, compared to 8 in Melbourne, 4 in Brisbane, 3 in Adelaide and 1 in Perth at a distance greater than 5 kilometres from the CBD. This is a historical anomaly brought about by the way the Sydney Railway System was designed. However most of these interchange points (In Sydney) only service a very small portion of the possible cross country market, and primarily exist in the west, and south west.

Figure 3.16 : cross suburban connections in Australia



This shows however that Sydney has the highest potential for cross-suburban commuting of any railway network in Australia.

3.2 Stage 2

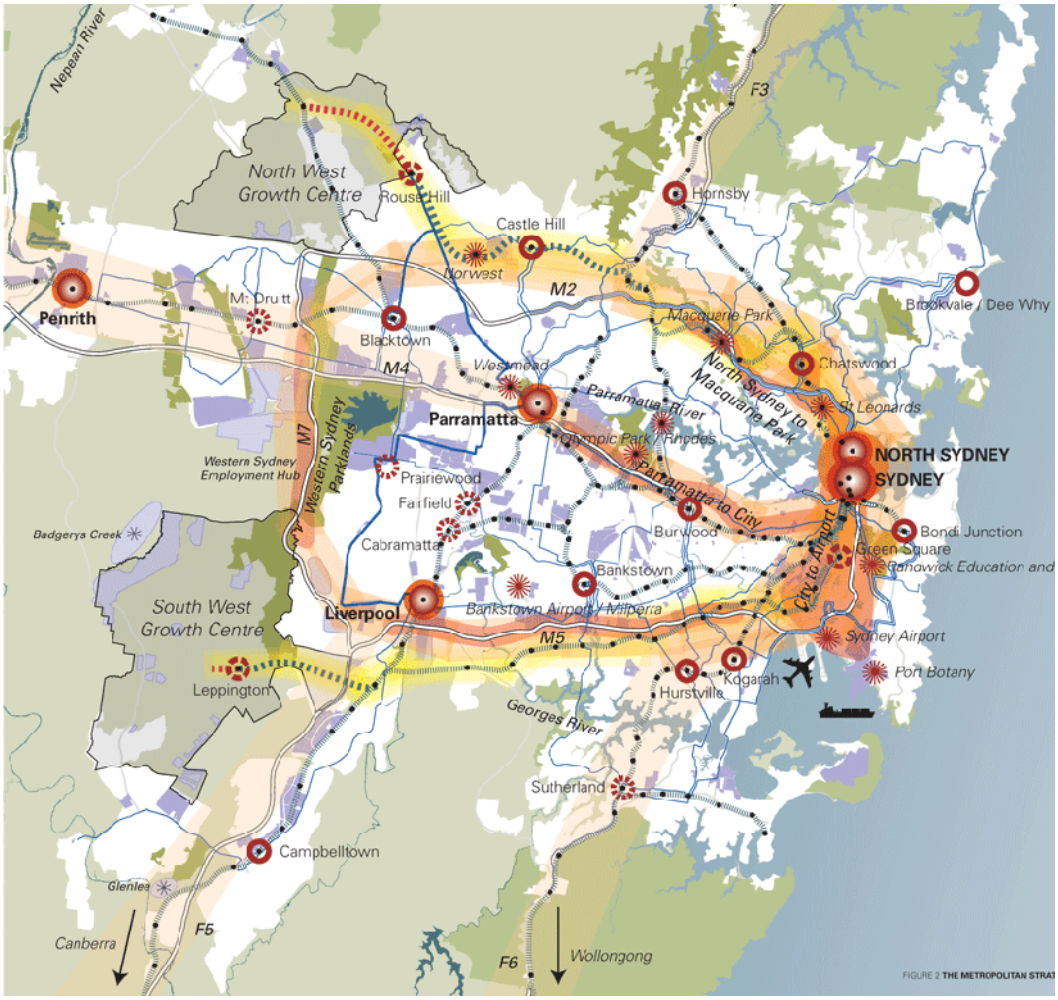
Stage 2 is a 10 year program.

As figure 3.17 below shows, the Sydney Metropolitan strategy envisages four Regional Centres (Sydney/North Sydney, Liverpool, Parramatta and Penrith), Multiple major centres consisting of Bondi Junction, Kogarah-Hurstville, Castle Hill, Chatswood, Hornsby, Dee-Why-Brookvale, Blacktown, Campbelltown, Burwood and Bankstown. These centres are expected to take the majority of retail and commercial employment.

In general the proposed cross country lines would enable for a higher connectivity within Sydney, by enabling greater numbers of cross country trips on public transport.

The TDC (2008) states that Public Transport in Sydney is only dominant to the Sydney CBD with 63% of all trips being made by PT and the PT modal share drops significantly, due the reduced accessibility, desirability and options to reach the other regional centres - down to as little as 12% modal share for Penrith.

Figure 3.17 : Sydney Metropolitan Strategy



The Sydney Metropolitan Strategy also encourages cross-suburban travel, as it continues the policy of centres—where more commercial and retail development will happen away from the Sydney CBD. This requires a non-radial network to be developed—as having centres which are located away from the dominant centre, means that there are more dispersed trips, which reduces the effective ability of a radial based system, which the Sydney system is a hybrid of, to appropriately distribute workers, without a penalty, whether time, speed, distance, or a combination of the three.

3.2 Stage 2

Looking at the proportion of all travel, not just journey to work, done internally within the subregions as shown in the table below, shows that public transport has a very low share overall.

Table 3.7 : Modal share by subregion

Sub-region	Car Share	Public Transport	Walking and Cycling
Sydney CBD	33%	18%	49%
Inner West	55%	16%	28%
East	57%	14%	26%
Inner North	60%	14%	24%
South	68%	12%	18.6%
West Central	72%	11%	16%
North	73%	11%	15%
North East	72%	9.5%	16.5%
South West	79%	8%	12.3%
North West	79%	7%	13%

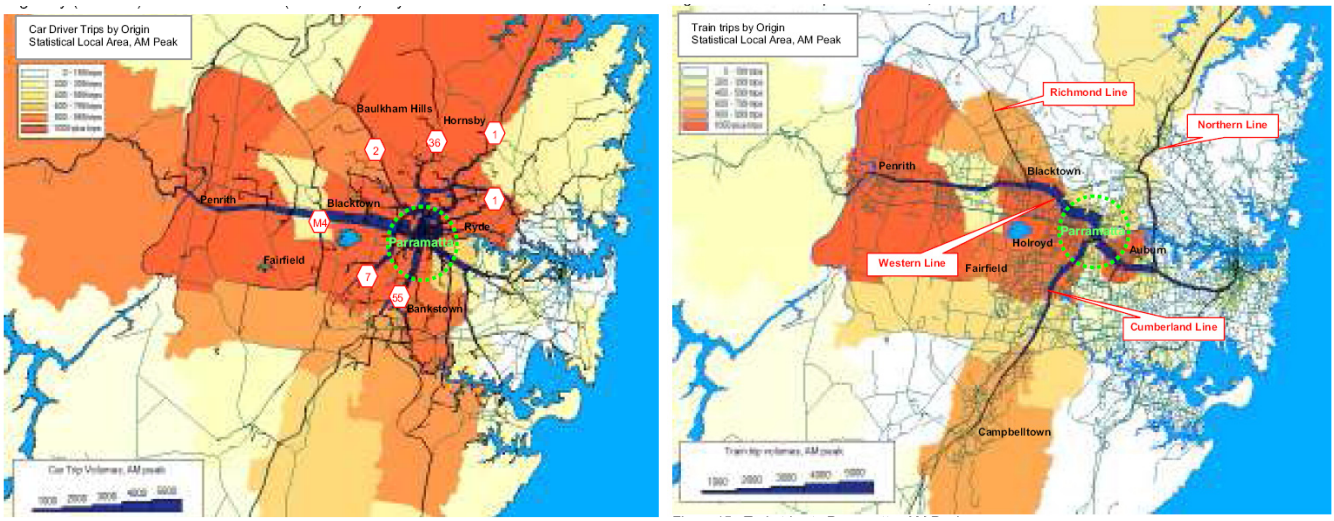
This shows that public transport use throughout all the subregions is low, showing that public transport is rarely used for most trips, except for to Sydney CBD.

Increasing the level of local trips, as well as cross country trips would enable for a significantly higher utilisation and accessibility for CityRail, and Sydney in general. This would also increase the cost-effectiveness of CityRail, by utilising more of the existing infrastructure, with the same level of staffing and minimal new rollingstock.

Figure 3.18 from the TDC (2006) shows the cross suburban and dispersed nature of commuting in Sydney for Parramatta. These images clearly show the disparity in commuting in Sydney between public transporation and the car. The car can be seen to have a highly dispersed pattern converging on Parramatta, whilst the public transportation is used a series of very fixed corridors, which limits its appeal, and usability, without further cross-suburban lines.

The Sydney Unsworth Bus Review (2004) stated that cross country travel in Sydney is difficult, and recommended that 43 strategic bus corridors be developed to redress this imbalance. However TBC (2003), Laybutt (2008) and Unsworth (2003) state that bus travel is primarily for local travel, due to low average speeds of less than 20km/hr and a low appeal rating.

Figure 3.18 Commuting to Parramatta



3.2 Stage 2

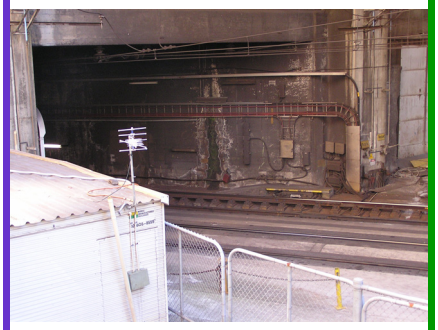
This clearly indicates that there is a lack of cross-suburban rail transport available. Stage two provides for two new cross-suburban lines; The Hurstville – Epping Line and the Miranda – Castle Hill line. These two lines will complement the existing cross-suburban Cumberland Line. These three lines will link to 2 Regional Centres, 7 Major Centres, 1 specialised centre and 2 proposed Major Centres. When linked into the existing system, it provides for an outer, middle and inner Sydney Bypass network, and provides for significantly greater accessibility to all the major and regional centres of Sydney (bar Dee Why-Warringah), by speeding up commute times as you do not have to enter the CBD to change trains (in most cases).

The proposed cross suburb lines increase the potential of more cross suburb commuting to occur by rail in Sydney, though the costs of building these will be significant. These cross country lines, especially Strathfield – Miranda, Strathfield – Epping and Punchbowl – Hurstville, have significant regeneration possibility, with high density nodal development, which would further increase desirability, and enable for greater use of these particular lines.

Stage 2 Upgrades

1. Extension of Line from Strathfield – Miranda via Campsie, Rockdale and Sandringham
2. Extension of the Carlingford Line to Epping
3. Extension and amplification Clyde – Lidcombe Junction, with Extension of Regents Park Line to Hurstville via Narwee
4. Construction of a line from Fairfield – Prairiewood
5. Quad track amplification South Glenfield Junction—Campbelltown
6. Extension of passenger Quad track amplification Campsie – Sydenham and Bankstown - Birrong
7. Extension of line Epping – Castle Hill
8. Construction of a new City Underground Line – Airport Line to Chatswood
9. Construction of a Northern Beaches Light Railway line.

Tunnel Portal to Wynyard Station



These proposed upgrades then complete the split of CityRail into 11 discrete and identifiable sectors. This also enables all lines (bar the Campbelltown/Cronulla expresses – the shared sector – a maximum of 15tph can run on each line) to run at a maximum of 20 to 30 tph (if such demand is required). It also enables each line bar the shared sector to be completely separated out, meaning no flow on delays into other sectors from problems in one sector.

This is shown clearly in Figure 3.19 shows this final configuration in a geographical format. Figure 3.20 is a schematic representation of the final network.

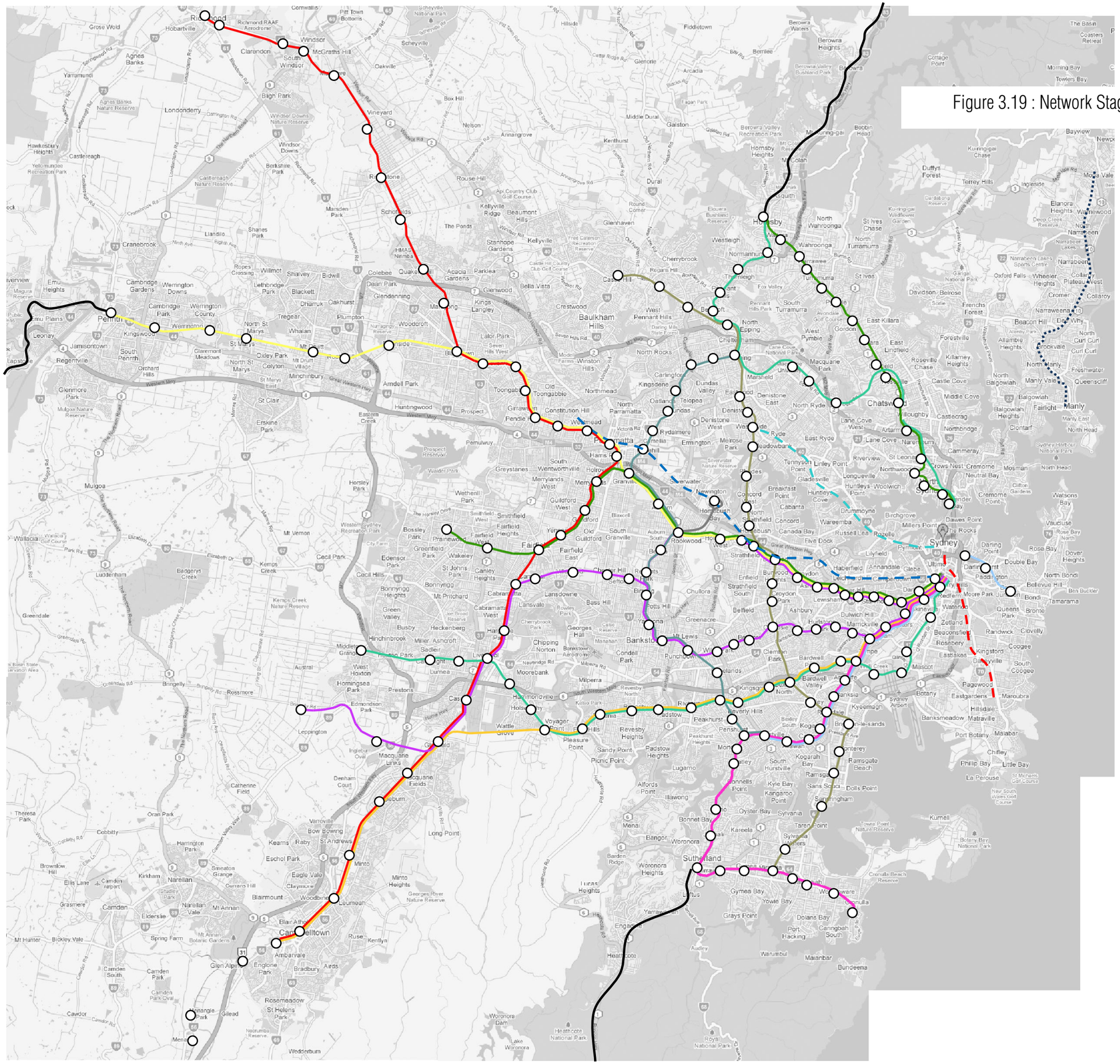
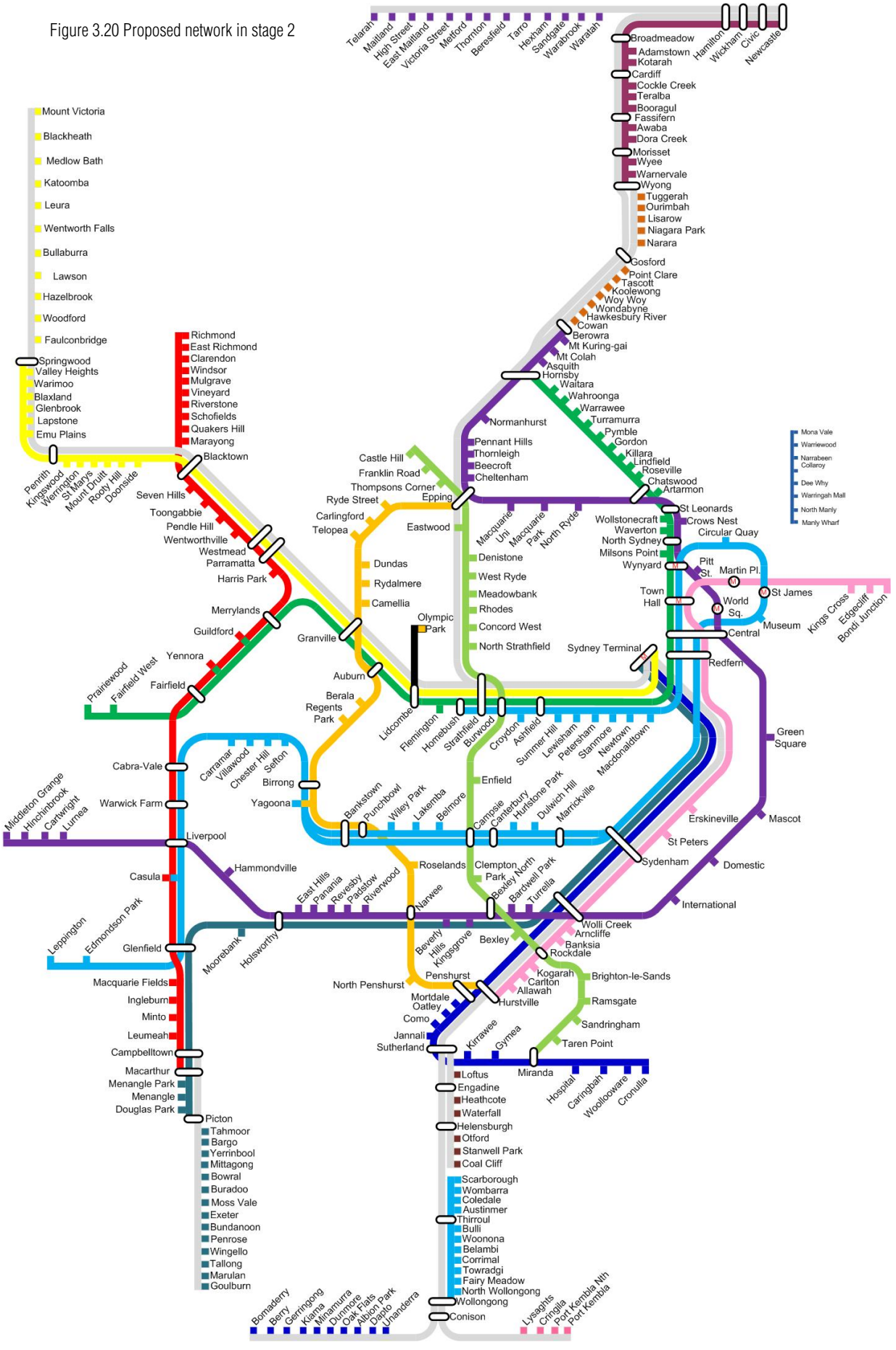


Figure 3.19 : Network Stage 2

3.2 Stage 2

Figure 3.20 Proposed network in stage 2



3.2 Stage 2

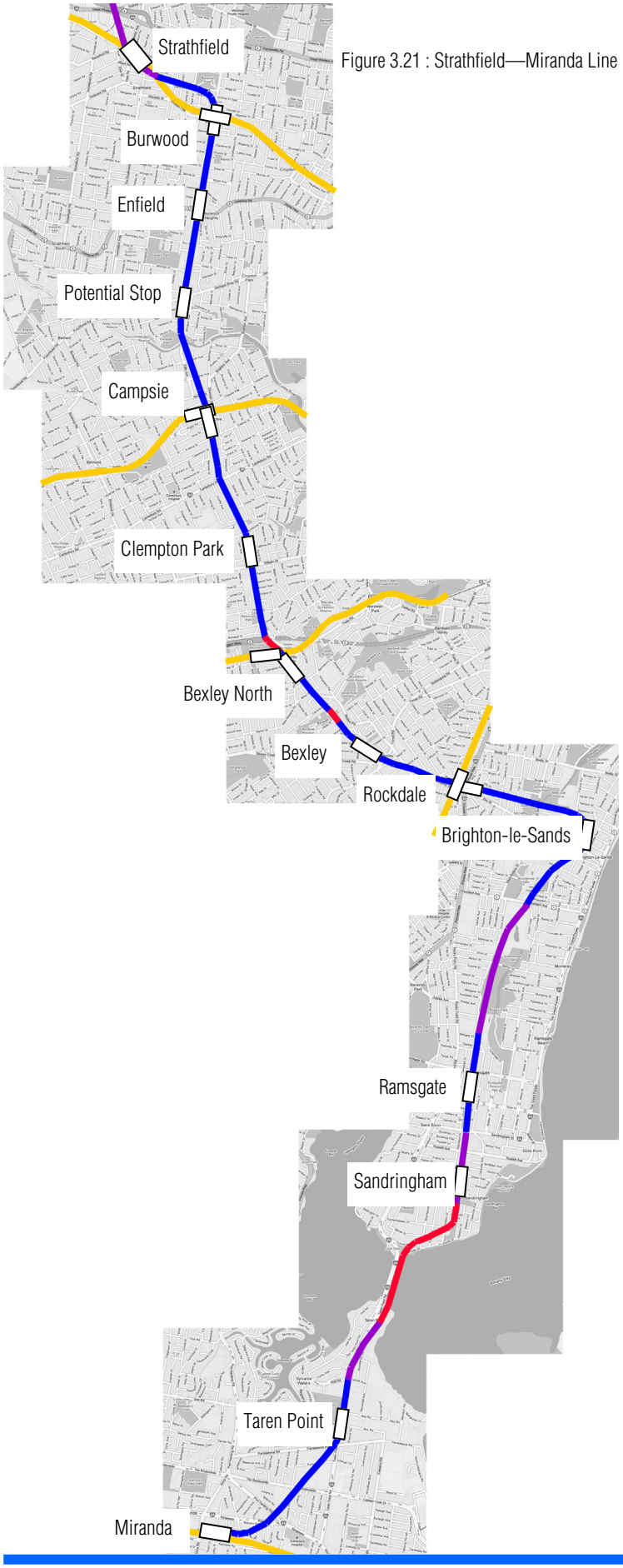


Figure 3.21 : Strathfield—Miranda Line

Strathfield —Miranda Line

This line segment is mostly tunnel with short segments of viaduct over Wolli Creek, the Bardwell Valley and the Georges River. There are at grade sections through the old F6 alignment.

This line acts as a key cross suburban line, linking up the Major Centres of Burwood, Rockdale-Kogarah and Miranda and with an interchange Hurstville. It also provides for a major redevelopment corridor between Miranda and Burwood for higher density housing.

This line also provides a faster link into the Sydney CBD (with an interchange at Rockdale) from the Cronulla line, as well as serving the Rocky Point Peninsula an area of poor accessibility with low frequency buses.

Cross Suburban travel in this area is difficult, with bus routes such as the 400 (the major cross -suburban route in Sydney), overloaded, slow and due to the length of the route, severe bunching of buses, making the route highly unreliable.

This line in conjunction with rezoning to enable high density transit orientated development along its path would provide a major new cross suburban line, which provides connections with 9 lines (Cronulla, Hurstville, Revesby, Bankstown, Inner West, Western, Blue Mountains, Central Coast and Macquarie Lines), enabling greater accessibility through the regions.

There is currently significant traffic volumes along State Route 64, 66 Bexley Road, and Metroad 3. This line has the potential to capture some of this traffic.

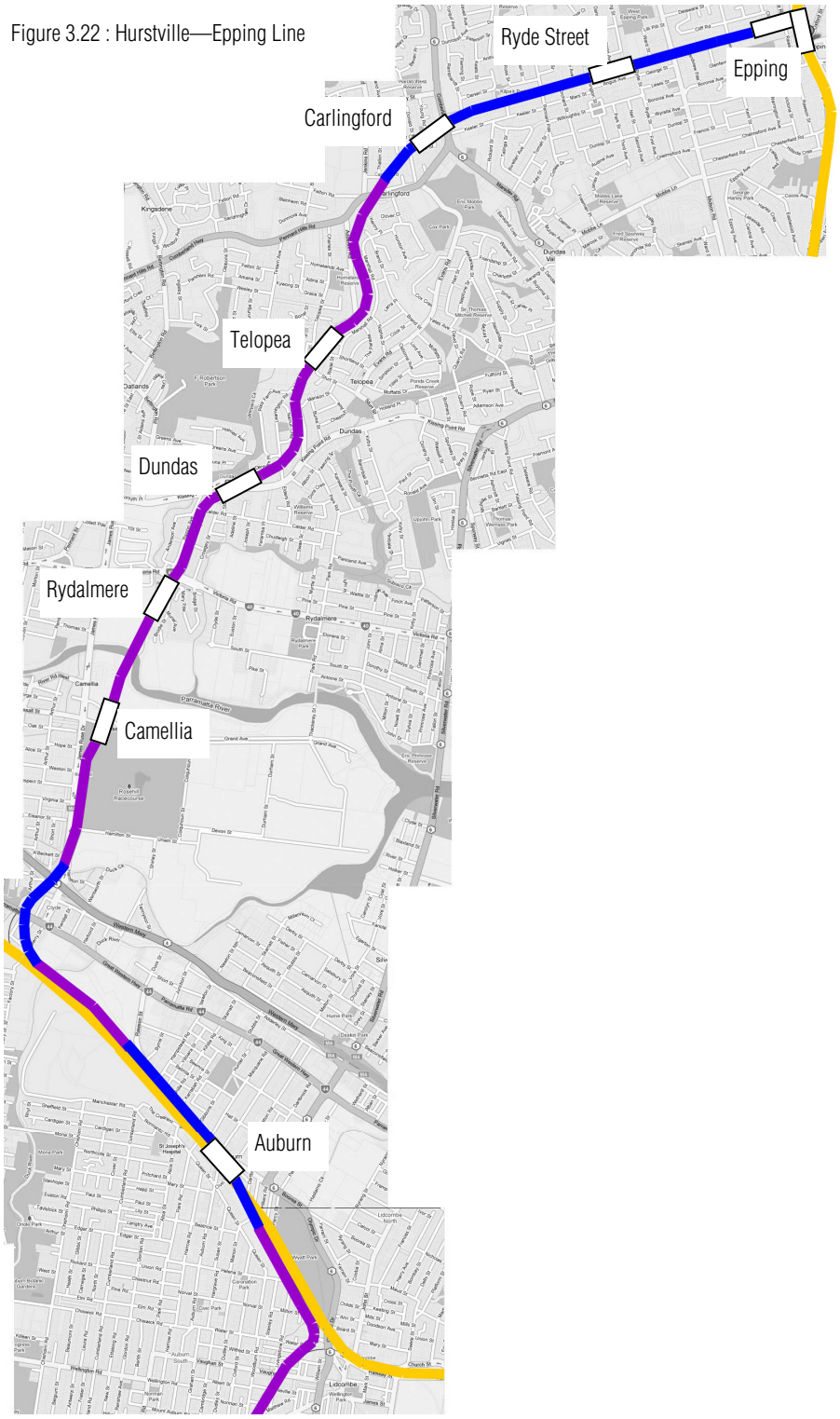
3.2 Stage 2

Epping—Hurstville Line Section 1.

This line provides for a cross-suburban service connecting the major centres of Epping (Proposed), Bankstown and Hurstville. With an quick interchange, the major centres of Kogarah-Rockdale, and the regional centre of Parramatta. This line utilises significant levels of existing infrastructure, and requires only tunnelling at the extremities of the line.

It provides for a valuable cross-suburban link through the middle ring suburbs, and connects with Bankstown. Bankstown is a key focal point for local transport infrastructure (both public transport and roads) and would become a valuable node and transfer point in the future, and is also one of the most centrally located major centres in Sydney..

Figure 3.22 : Hurstville—Epping Line



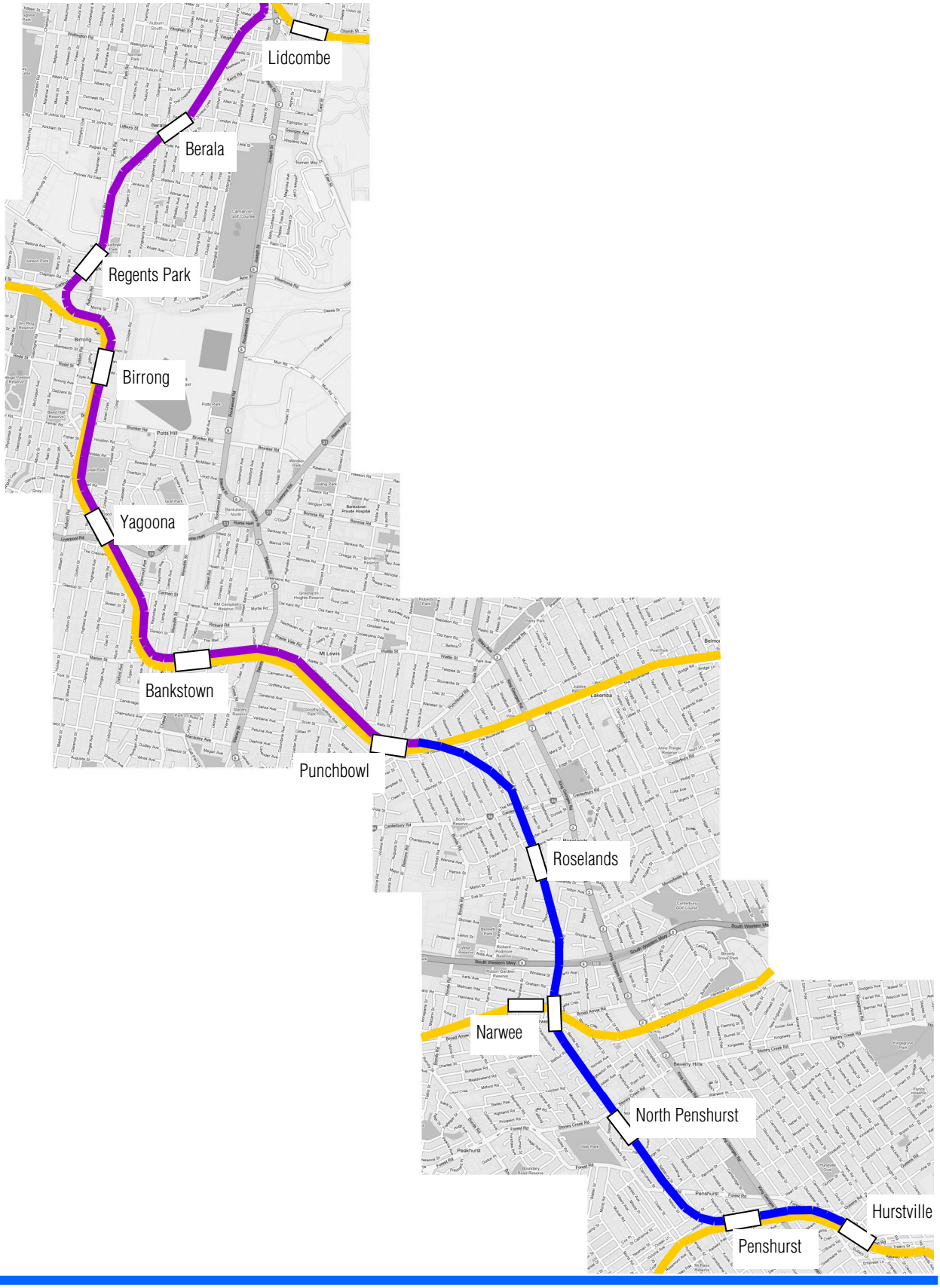
Bankstown is also shaping to be a major commercial and residential hub, with significant numbers of residential flat buildings constructed in the last decade.

This corridor also comes with significant development potential, with much of the line from Clyde to Epping, and Hurstville to Bankstown low density suburbia. This line again has the potential to form a nodal transit oriented development line, providing for significant density increases, and opportunities.

There is also significant traffic flows along Metroad 3 and Metroad 6 that could potentially be captured by this railway line.

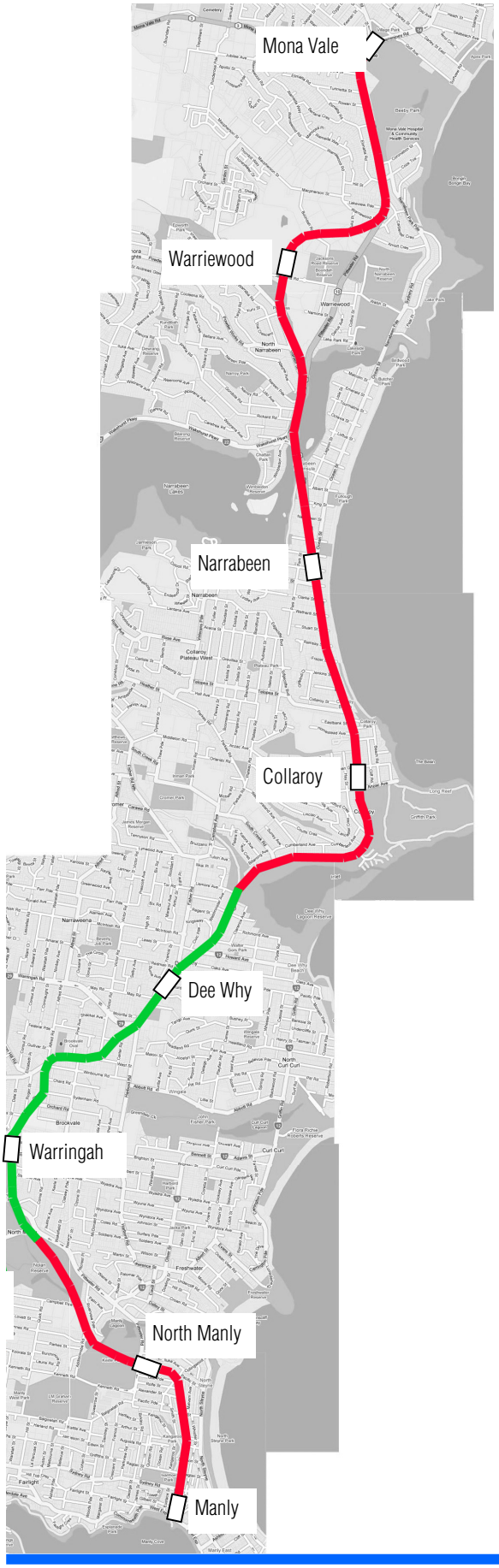
Epping—Hurstville Line Section 2.

Figure 3.23 : Hurstville—Epping Line



3.2 Stage 2

Figure 3.24 :Northern Beaches Light Rail



Northern Beaches Light Rail Stage 1

The Northern Beaches Light Rail is a Docklands Light Rail (DLR) in London Style Line. It would run on its own right-of-way, generally elevated, or trenched along Pittwater Road, servicing the main development spine of the Northern Beaches, from Mona Vale to Manly Wharf.

It is proposed that an upgrade to the ferry service will provide the major public transportation link to the Sydney CBD. The use of Staten Island style ferries, which have very high capacities, sea-going capability, with rapid embarking/disembarking, running at a minimum frequency of 4-6 ferries per hour all day, would provide enough citybound capacity for the foreseeable future.

A DLR style solution is envisaged for the Northern Beaches as it has a higher capacity than the traditional light rail network, and also can traverse steep gradients easily, as well as tight radius curves.

The need for this line to be elevated from roughly Collaroy to Mona Vale is that Narrabeen area is predominately low lying, already effected by erosion and king tides, and the hillier nature of the northern beaches to the north of Narrabeen. Running elevated enables this line to be protected from impacts of Global Warming, as well as service the Warriewood Shopping Complex.

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3.2 Stage 2

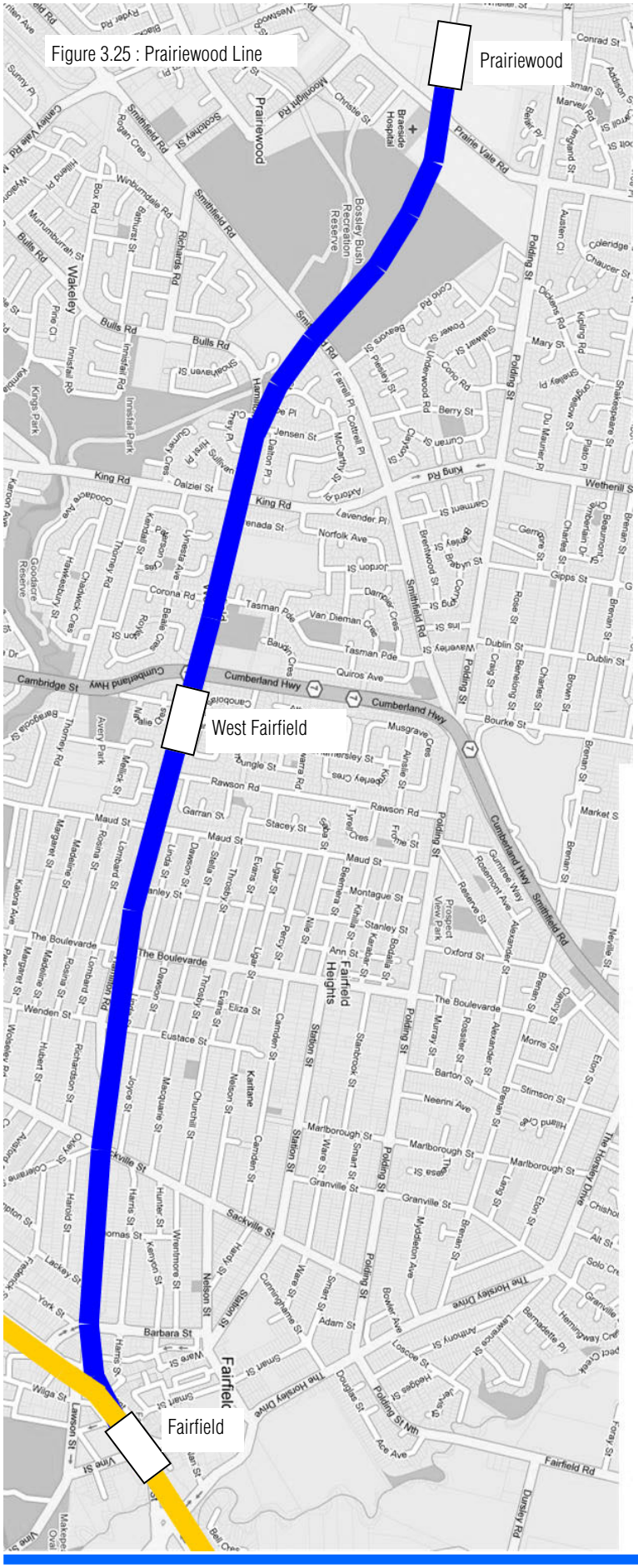


Figure 3.25 : Prairiewood Line

Fairfield– Prairiewood Line

The Fairfield-Prairiewood line provides for a major increase in accessibility to the Green Valley release area of Sydney that developed in the 1960's. This was the first area of Sydney to be developed without major public transportation networks to be built in. A line to service this area has been around since the 1970's Sydney Area Transport Strategy.

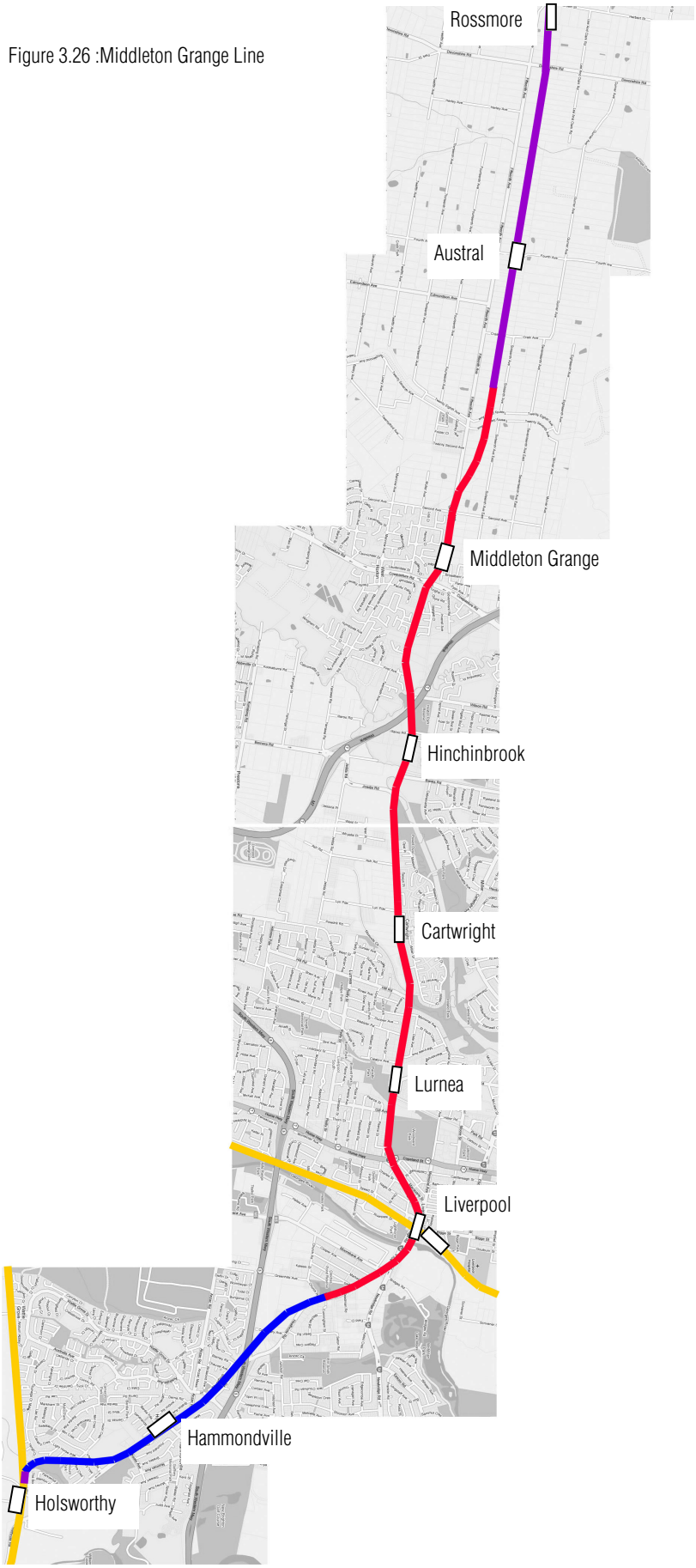
This line would be an extension of the South line from Granville, branching from the Cumberland line at Fairfield. There would be one intermediate stop at Fairfield West. This line would then form a major bus interchange role at Prairiewood shops, with local bus services and the Tway.

This line would provide for urban renewal and increased densities in an area of Sydney where the majority of the housing stock is reaching the end of its usable life span.

This line is required operationally to provide for the outer track South Line trains to terminate elsewhere, as the Fairfield Road overbridge constrains the rail corridor to a maximum of two tracks through this area, and this then enables the Cumberland line, South Line and Bankstown (with other enhancements) to run at maximum capacity required.

3.2 Stage 2

Figure 3.26 :Middleton Grange Line



Revesby—Middleton Grange Line

The Revesby—Middleton Grange line provides for a major transport corridor through the Green Valley release area, a area of Sydney that was the first to develop without any major public transportation node.

This line provides for a link from the regional centre of Liverpool to the East Hills line and to Kingsford Smith Airport, and the southern section of the Sydney Metropolitan Strategy's 'Global Arc'.

This line provides for increased accessibility from the northern section of the South West Growth Centre, by providing for three new stations roughly along the Fifteenth Avenue transit Boulevard, which can then have significantly increased densities proposed, enabling a high density transit oriented development node, surrounded by the lower density suburbia of the South West Growth Centre.

This line improves the accessibility for the southern suburbs of the Liverpool LGA, increase the potential trips that the regional centre of Liverpool can accommodate, as well as provide for increased density in a linear urban renewal corridor situated along Hoxton Park Road, Fifteenth Avenue and parts of Heathcote Road.

Operationally this line is not the most necessary, as appropriate facilities exist at Revesby, but this line provides for a significant capacity boos to the South Western region of Sydney, as well as service a large portion of the South West Growth Centre.

3.2 Stage 2

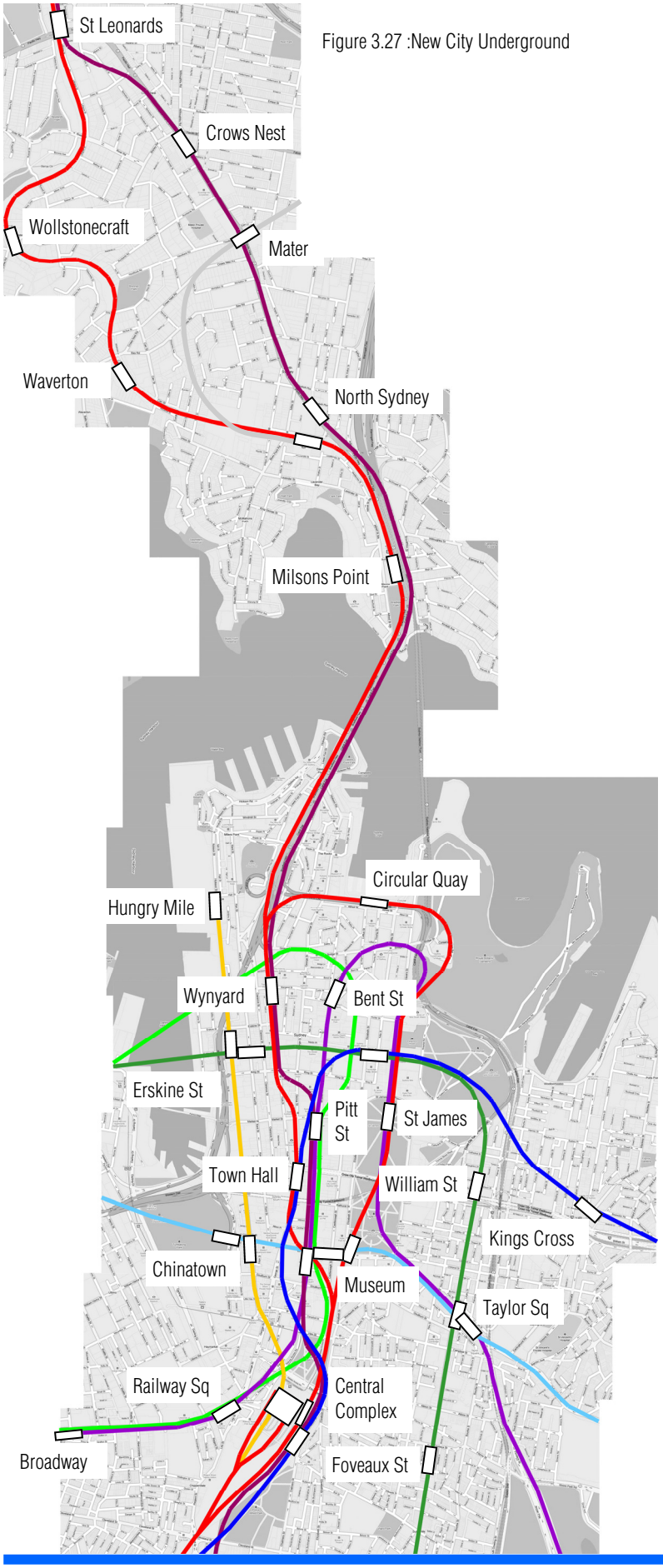


Figure 3.27 :New City Underground

New City Underground

The Red and dark Blue lines indicate the existing City Underground network, and the lime green line indicates the Proposed Sydney Metro Line.

It is recommended that as part of this thesis that the Sydney Metro Line **does not go ahead** in its current form.

The Brown line is the proposed extension to the City Underground, by providing a new line through from the Airport Line portal to St Leonards, utilising the existing eastern two lanes of the Sydney Harbour Bridge.

The Purple line indicates the preferred alignment of the Anzac Parade line, and the orange line a proposed Metro West line.

All other lines indicate possible very long term alignments for rail corridors within the City, and should be safeguarded.

The grey line indicates a possible Mosman Metro link—a short line between Spit Junction and North Sydney Station along Military Road. This however is outside the scope of this proposal.

It would be expected with the exception of the Airport—St Leonards only a maximum of three additional lines through the city will be constructed in the next thirty years.

The preferred lines would be the Purple line and the Yellow Line as this would provide for the greatest connectivity with the remainder of the lines, and increase rail coverage through the suburban areas of Sydney.

The Victoria Road Metro Could be replaced by either the dark green or light blue lines

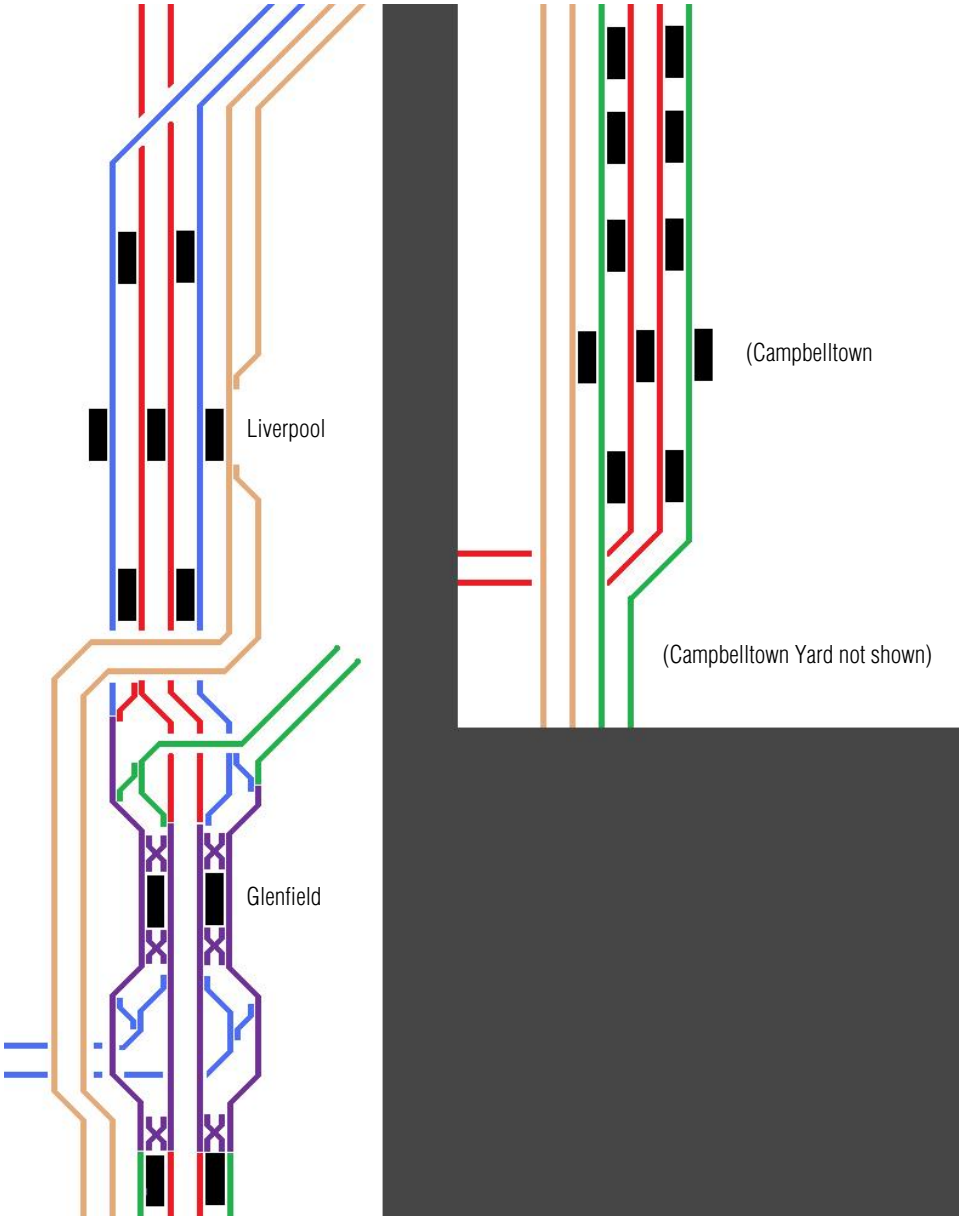
3.2 Stage 2

Track Amplification and Junction enhancement Liverpool—Campbelltown

This image shows the proposed redevelopment of the South Line between Liverpool and Macarthur, showing the Cumberland line (from Parramatta) going to Camden, the Bankstown Line going to Leppington, and the Campbelltown Line to Picton. The only pinch point that is left with this design is that of Glenfield station, where 60tph (at maximum capacity) will be sharing 4 platforms. This design constraint occurs due to the design of the proposed Leppington line flyunder, and the cost to build Glenfield station to 6 platforms and 8 tracks is considered poor value on a cost-benefit ratio.

This line provides for 6 tracks (with a small section of 5 tracks where the corridor is too narrow through Liverpool) from Cabramatta Junction to Glenfield, where the Campbelltown Line merges. The line then has six tracks to Macarthur, enabling a complete separation of freight, local and express services, which will provide for the best split between capacity, and speed in the South West. This proposal is also assuming that the Macarthur South land development will happen in the long term future, and the capacity of the lines will be able to take this additional population.

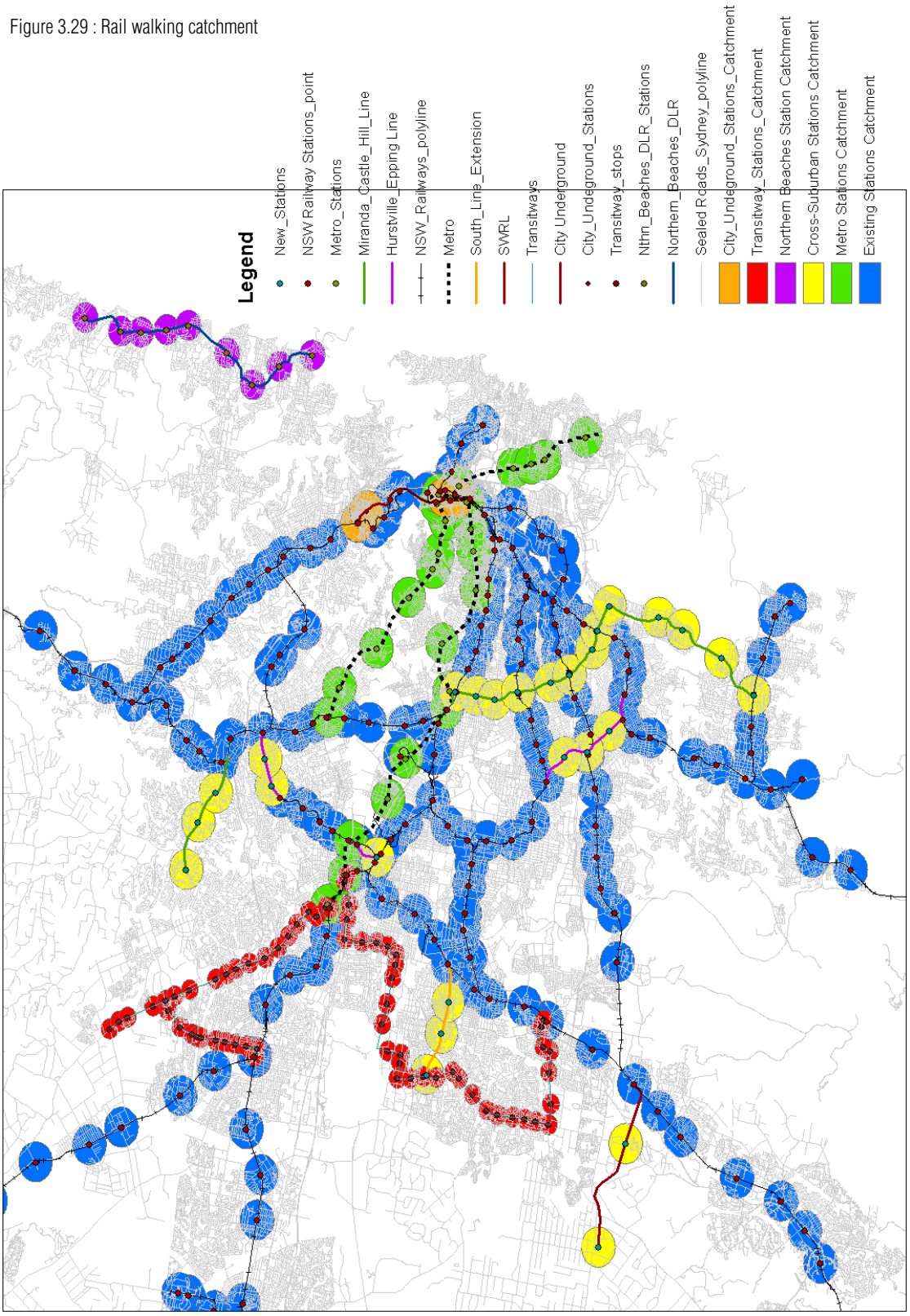
Figure 3.28 : Upgrade Liverpool—Campbelltown



3.2 Stage 2

The Figure 3.29 shows the walking distance to each station in the network, once Stage 2 is complete. This shows that a significant proportion of the Sydney Metropolitan Area is within a 1km radius of a railway station (750m Northern Beaches DLR, 500m Transitways), and the remainder within relatively easy bus commute to a station. Station radii shown in yellow have significant redevelopment potential, as they are generally low density residential at present, enabling a higher proportion of the population to live within easy distance of a high frequency public transport node.

Figure 3.29 : Rail walking catchment



3.2 Stage 2

Summary

Stage 2 provides for the essential framework to completely revamp CityRail away from a commuter style network, to a high frequency metropolitan network, by completing out the separation of the existing lines into discrete independent lines. This separation is what enables for high frequency service as the lines are independent and not sharing track space with other lines. This then gives the capacity to enable line expansions. These expansions are generally cross-suburban and are not focused upon the Sydney Central Business District, though there is expansions through there, to enable greater capacity in the City Underground.

Cross suburban links are required to enable a greater public transportation share. The proportion of trips (and employment) in the Sydney CBD is declining with the increase, dominance and hierarchy of centres, requiring alternative transport solutions, though generally the car. As buses are generally significantly slower, and with greatly reduced capacity compared to a heavy rail system means that buses cannot effectively provide for the needs of a large centre, or a centres based city, which necessitates cross-suburban rail links.

Clyde Junction

Source: Ben Chatwin (2009)

Cross suburban links need to be considered carefully, given the high capital costs especially when being constructed through existing urban areas, although this can lead to significant urban renewal and higher densities. Cross suburban links become more important as a city has more primary employment centres as this enables links that are non-radial and provide for greater accessibility into these centres.

These cross suburban links, especially within the middle ring suburbs also enables for large scale urban renewal corridors. Rail based transit has the highest capacity of any mechanised transport mode, which means that higher densities can be sustained. The areas that these cross suburban lines run through (Campbelltown– Richmond, Hurstville—Epping, Miranda—Strathfield) have housing stock that is reaching the end of its useful life, means that there is great potential for a revamp in density to medium—high density consisting of terraces, townhouses and medium and high rise apartments.

This meshes well with the Sydney Metropolitan Strategy by providing for linear corridors where density can be increased, rather than in a more ad-hoc fashion as occurs now. This enables for high density corridors which are serviced by a frequent rail service.

This should also enable for a more sustainable Sydney by providing for appropriate cross country links from Centre to Centre, not well serviced by public transport at present. By providing these links a modal shift should occur away from the motor car to public transport for these trips.

3.3 Stage 3

Stage 3 is a 15 year program.

Stage 3 continues the expansion of the network, especially as the sectorisation of all lines is complete. This stage again focuses on expansion of the cross suburban commuting, as well as an additional City Underground line, bringing the capacity of the network up to 528,000 people per hour into Sydney CBD.

1. Extension of the Northern Beaches DLR from Warringah Mall – Chatswood via Castlecrag
2. Extension of the Castle Hill line to Richmond Road via Norwest
3. Line from Ashfield through to Macquarie Park via Abbotsford and Gladesville
4. New line from Camden to Penrith via Leppington, Badgerys Creek and Erskine Park
5. Construction of a new underground line from Tempe to Sydney Terminal then through to Barrangaroo via Sussex Street. This will enable the Cronulla and Campbelltown Lines to be separated out, increasing the maximum frequency on each line to 20tph.
6. Construction of a high speed link between Wollongong and Sydney Terminal, following the F6 Alignment
7. Construction of a high speed link between Gosford and Hornsby

These lines provide for a backbone expansion of the network. The Western Sydney lines increase the connectivity into the South West and North West Growth Centres, providing for significant opportunity for increased densification of suburbs, and increased accessibility to the rest of Sydney. The Northern Beaches Light Rail expansion provides for a high capacity link out of the Northern Beaches into Chatswood, which enables an increased accessibility into the northern end of the "Golden Arc" of high value employment in Sydney. The Camden – Penrith line also provides for major accessibility into the proposed employment hubs at Badgerys Creek, and to the Western Sydney Employment Hub. The Ashfield – Macquarie Park opens up additional cross-suburban commuting links, whilst providing for transit orientated development, and increased density in a lower density area of Sydney.

ESR Railway Viaduct Woolloomooloo

Provision for new high speed lines from Newcastle and Wollongong will continue to link the Newcastle-Sydney-Wollongong conurbation, supported by a local high frequency service in the Wollongong and Newcastle Cities.

The line from Gosford should consist of a long tunnel through from Gosford proper, linking to a high level bridge over the Hawkesbury River, then a short tunnel through to the existing railway line near Berowra.

The line from Wollongong will face significant challenges. This proposal assumes that tunnelling for lengths longer than 500m is infeasible given the need for extensive support due to the large amount of mining in the area, and the subsidence that this area has, from both the mining and the Narrabeen Talus layer. It is proposed that this line remains on the plateau for the majority of its journey, then using viaducts and small tunnels will descend the escarpment and finish its descent somewhere near Mount Ousley Road and Princes Hwy.

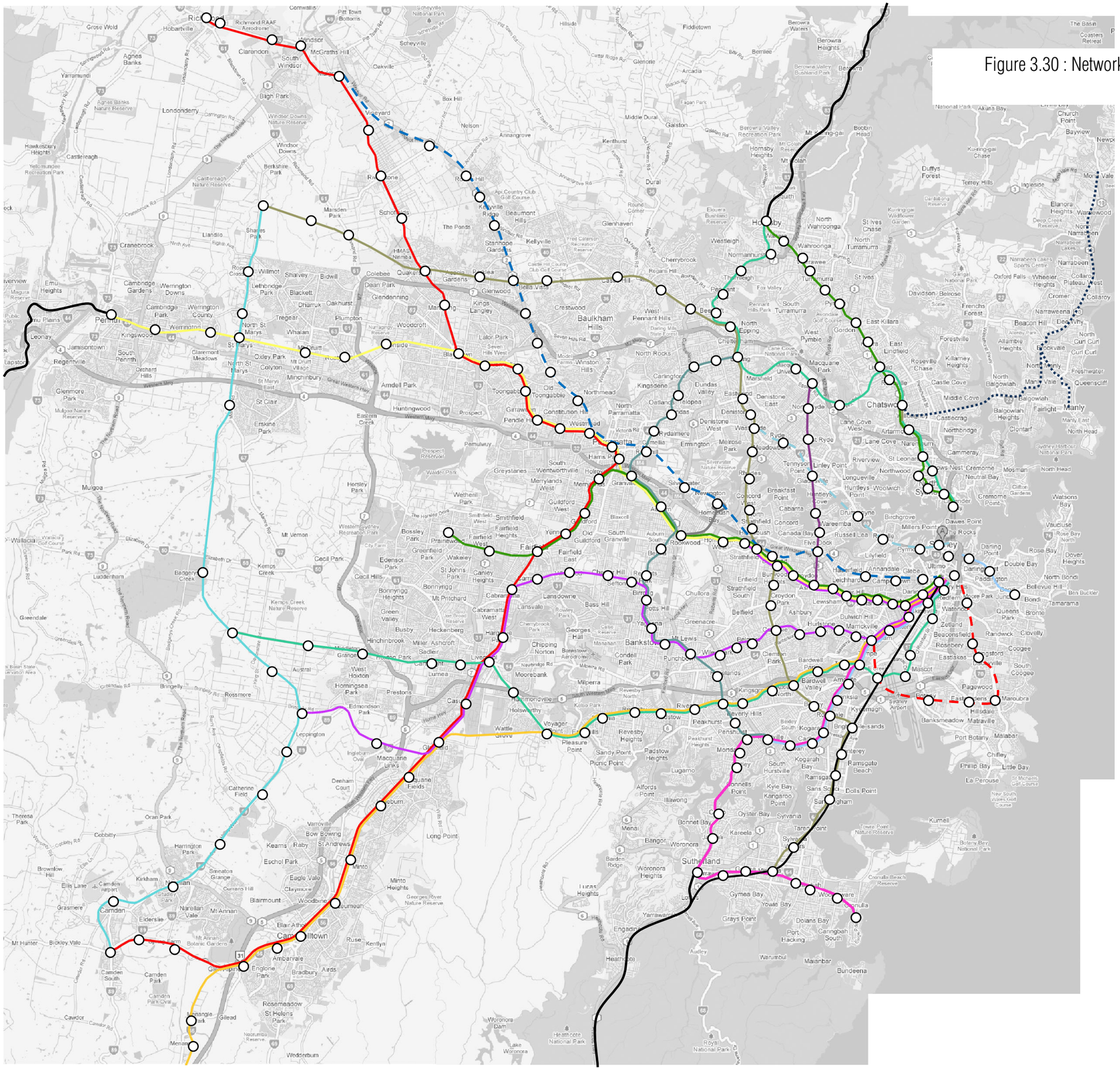


Figure 3.30 : Network Stage 3

3.3 Stage 3

Figure 3.31 : Proposed stage 3 network

3.3 Stage 3

Hawkesbury River Deviation

The Hawkesbury River section of track from Gosford to Berowra acts as a considerable constraint to high speed services on the Central Coast Line. This section of track winds its way down 400m in elevation on tracks where speeds are as little as 50km/hr and can take up to 47minutes to travel from Gosford to Hornsby, a distance of 37 kilometres. This deviation would halve the travel time between Hornsby and Gosford.

This deviation is necessary to improve journey times between Sydney and Newcastle—to be competitive with the road, as well as reduce grades, and reduce North Coast freight travel times. It is assumed that this deviation is four tracks, two passenger and two intercity.

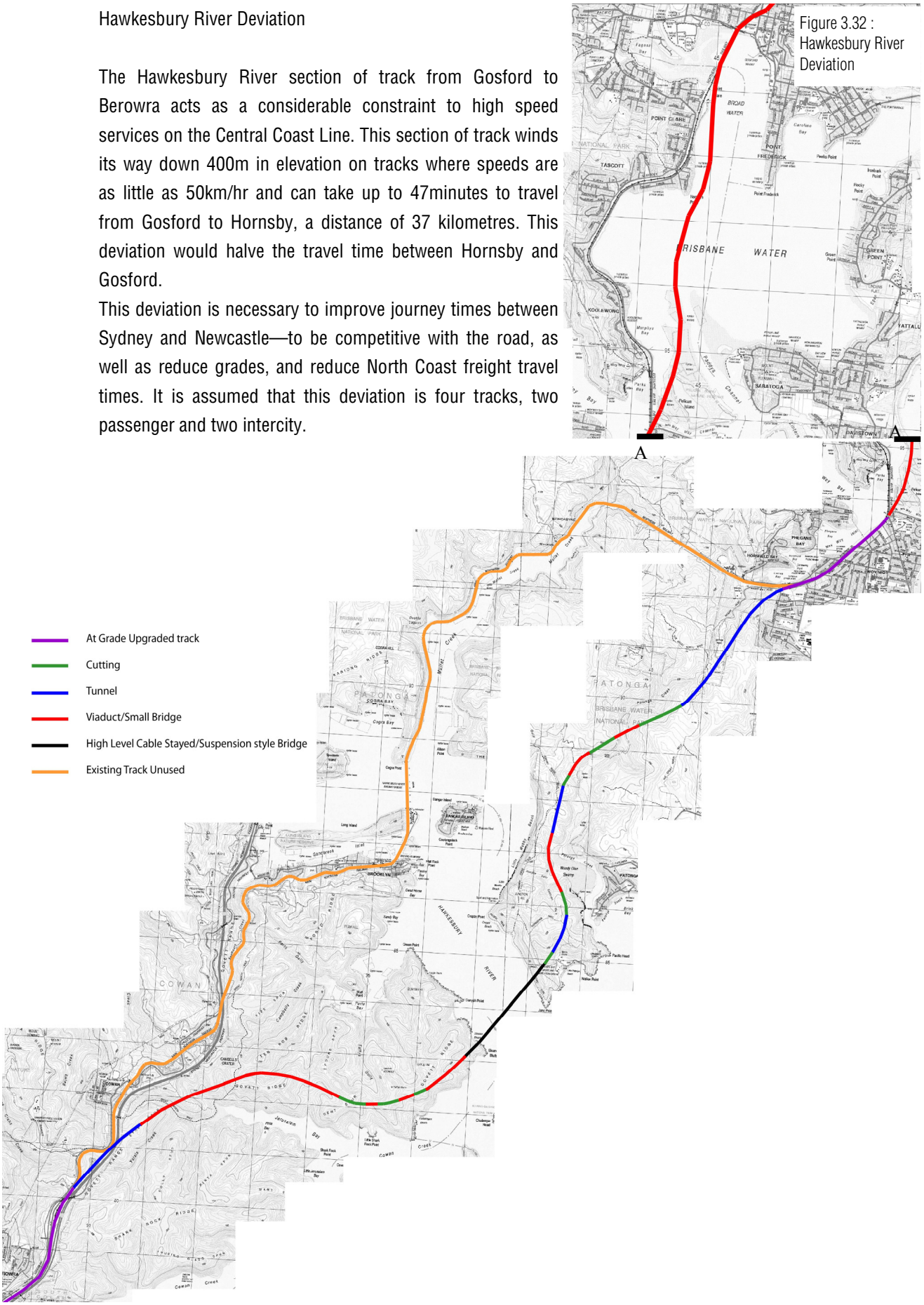


Figure 3.32 : Hawkesbury River Deviation

3.3 Stage 3

Wollongong Line Realignment.

The line into Wollongong is highly constrained, slow and has infrastructure that is reaching the end of its life expectancy. Any line into Wollongong is highly constrained by a 400m escarpment and significant coal mining in the area. It is proposed, given that a tunnel would generally be considered infeasible due to the coal mining, that a long viaduct is built along the escarpment and then follow the Woronora plateau roughly alongside the Princes Hwy.

Figure 3.33 : Wollongong Link Realignment

This deviation would be two tracks. It would be expected that freight would use an expanded and enhanced Maldon-Dombarton Link which would have significantly less grades, and will link into the Sydney Freight Lines.

The Maldon-Dombarton Link would be built to a standard of two tracks for its entire length, rather than the proposed 1 track, with passing loops.

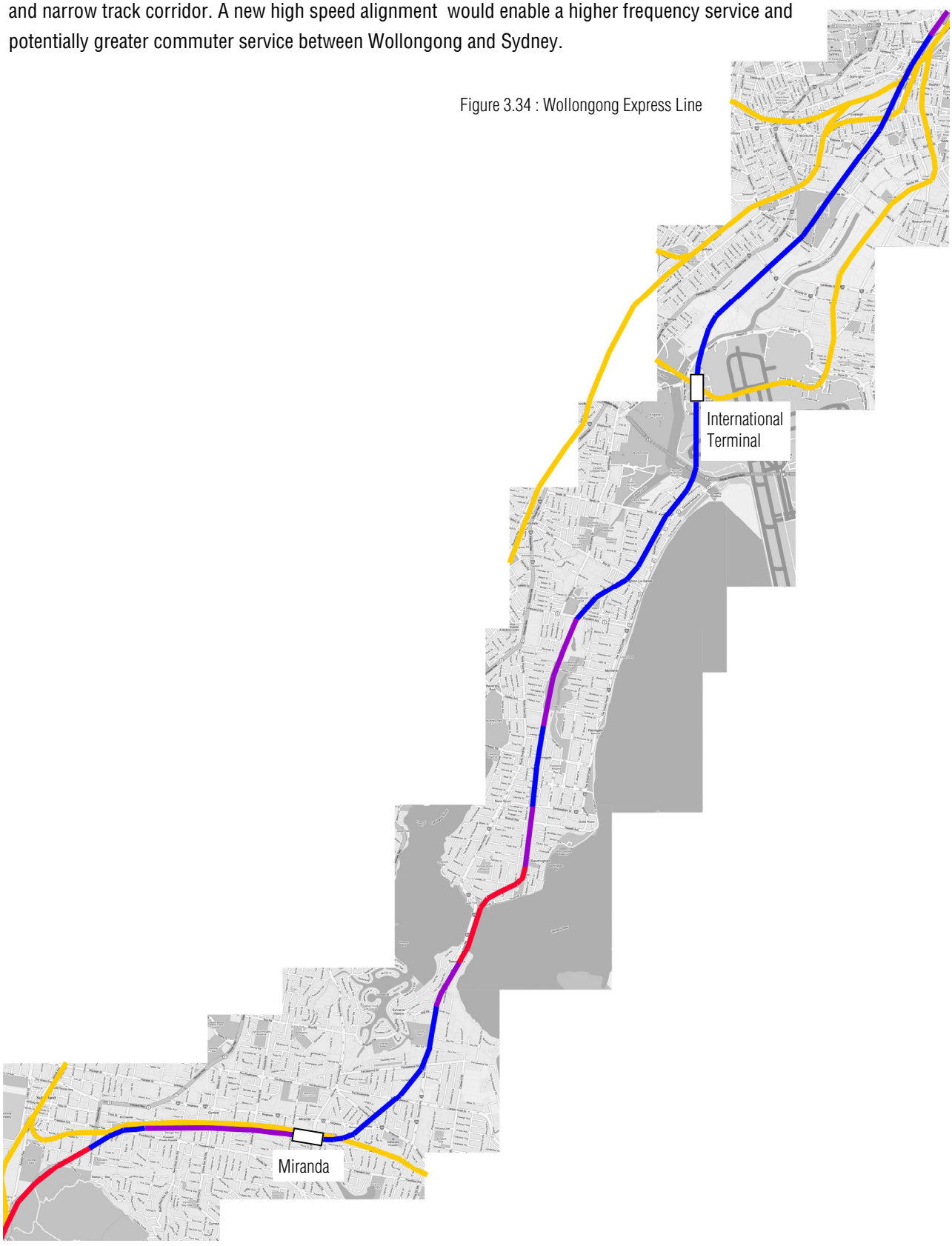
The railway lines north of Waterfall will not be able to support any more freight due to increases in passenger services.

Both the Wollongong Rail Realignment, and the Maldon-Dombarton Link will be required to be constructed to improve railway capacity, speed and frequency in the Illawarra Region.

3.3 Stage 3

The Express line for Wollongong Intercity Services would reduce journey time to Wollongong. This line will be needed in the medium-long term future to remove traffic conflicts with the Cronulla line, and enable the Cronulla line to run at maximum capacity between Cronulla and Sydney Terminal via Sutherland and Hurstville. Track amplification of the line between Sutherland and Hurstville is considered infeasible due to the steep topography, large deep cuttings, and narrow track corridor. A new high speed alignment would enable a higher frequency service and potentially greater commuter service between Wollongong and Sydney.

Figure 3.34 : Wollongong Express Line



3.3 Stage 3

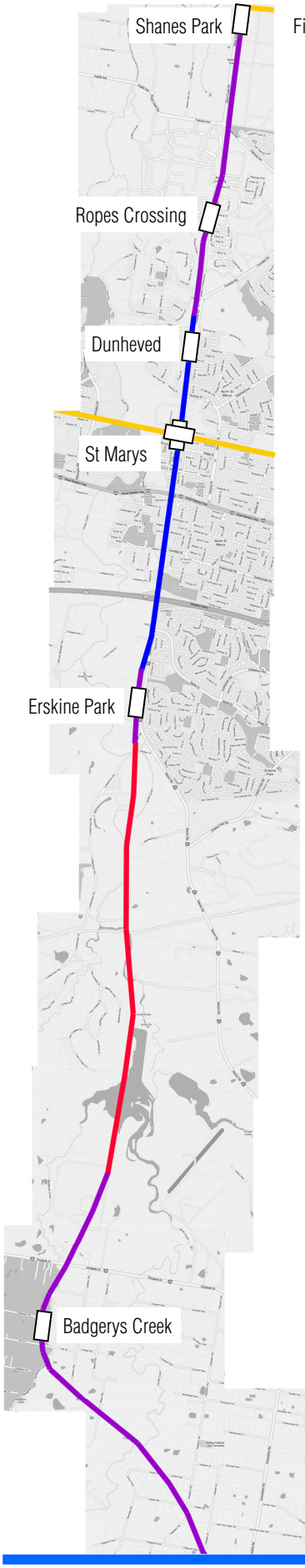


Figure 3.35 : Shanes Park—Camden Line

This line provides for a major cross suburban connection between the North West and South West Growth Centres. This line runs predominately through the residential and employment areas of these Growth Centres and would provide with interchanges, connection to all the major centres proposed, including Penrith, Norwest, Blacktown, Leppington, Liverpool and Campbelltown-Macarthur.

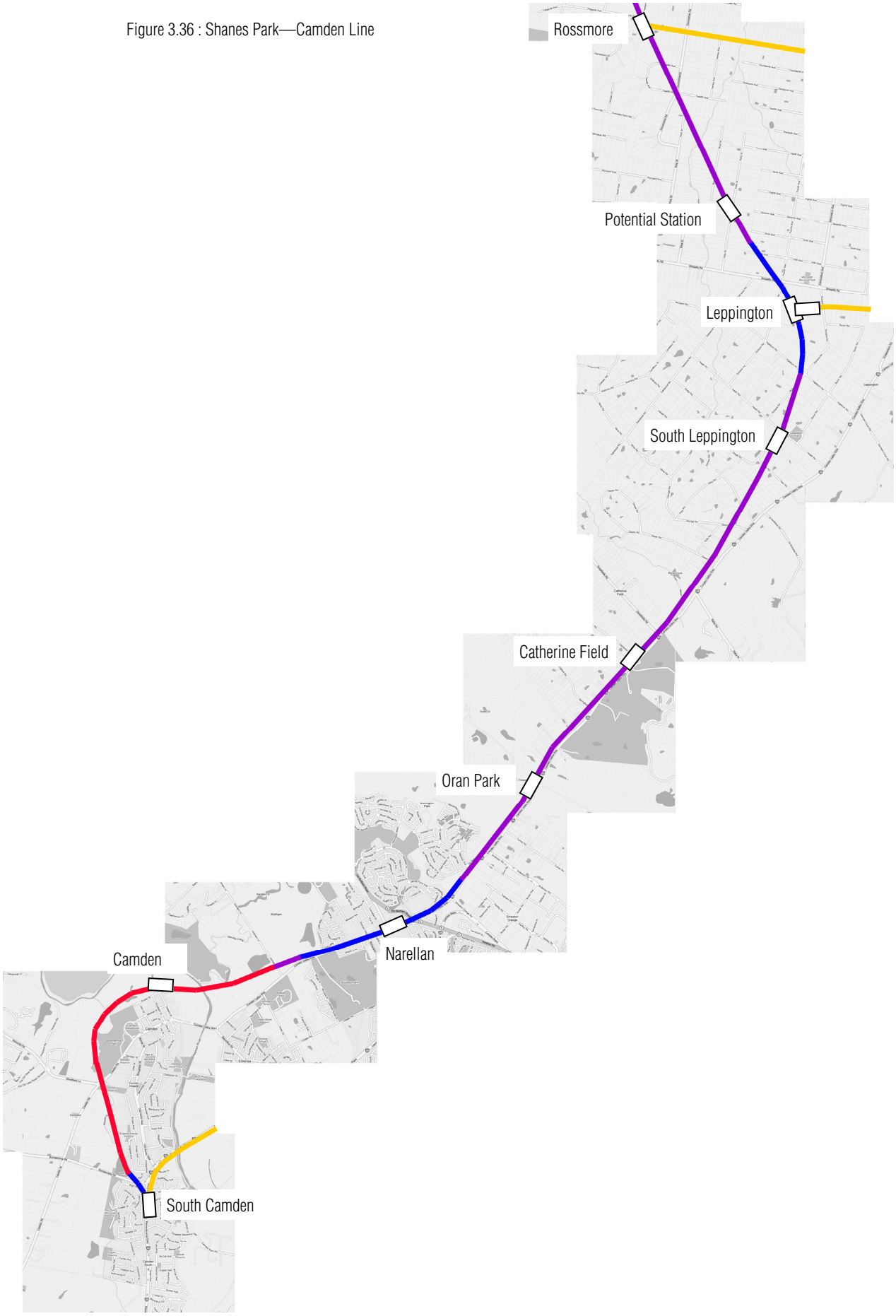
As this line runs through or near the major employment lands of the area—Western Sydney Employment Hub, South West Growth Centre Lands, Badgerys Creek (whether used as an airport or employment lands) and the Marsden Park employment lands, it will provide for significant accessibility for these areas. It will also connect with five rail lines, providing for considerable increases in accessibility to the Growth Centre, and provide for connections to the rest of the city, as this line is a pure north-south route.

This line is a continuation of the 1988 Sydney's Third Century's planning guidelines, which proposed a south creek railway line. This line would also provide for significant increases in density within the North West and South West Growth Centres, by providing for a major linear transit oriented development corridor, which is also directly linked to the major employment lands.

Although this line is to be constructed as part of Stage 3 works, reservation of the corridor is required from stage 1, to ensure that the majority of this line can be at grade, with only tunnel sections through the existing built up areas.

3.3 Stage 3

Figure 3.36 : Shanes Park—Camden Line



3.3 Stage 3

The Stage 2 of the Northern Beaches Light Rail provides for a new line from Warringah Mall to Chatswood following Burnt Bridge Deviation and Victoria Street, with a medium level bridge over Middle Harbour. This provides a direct link into the Metropolitan Network at Chatswood, enabling a direct link to this major centre, and an interchange to 6 others. This line would mostly be trenched or in tunnel given the highly built up area that this line traverses, though it will be on a bridge across Middle Harbour due to construction costs required for a tunnel under the harbour. This line primarily is designed to link into Chatswood and the northern end of the Global Arc, enabling for greater accessibility to the northern regions of Sydney from the Northern Beaches.

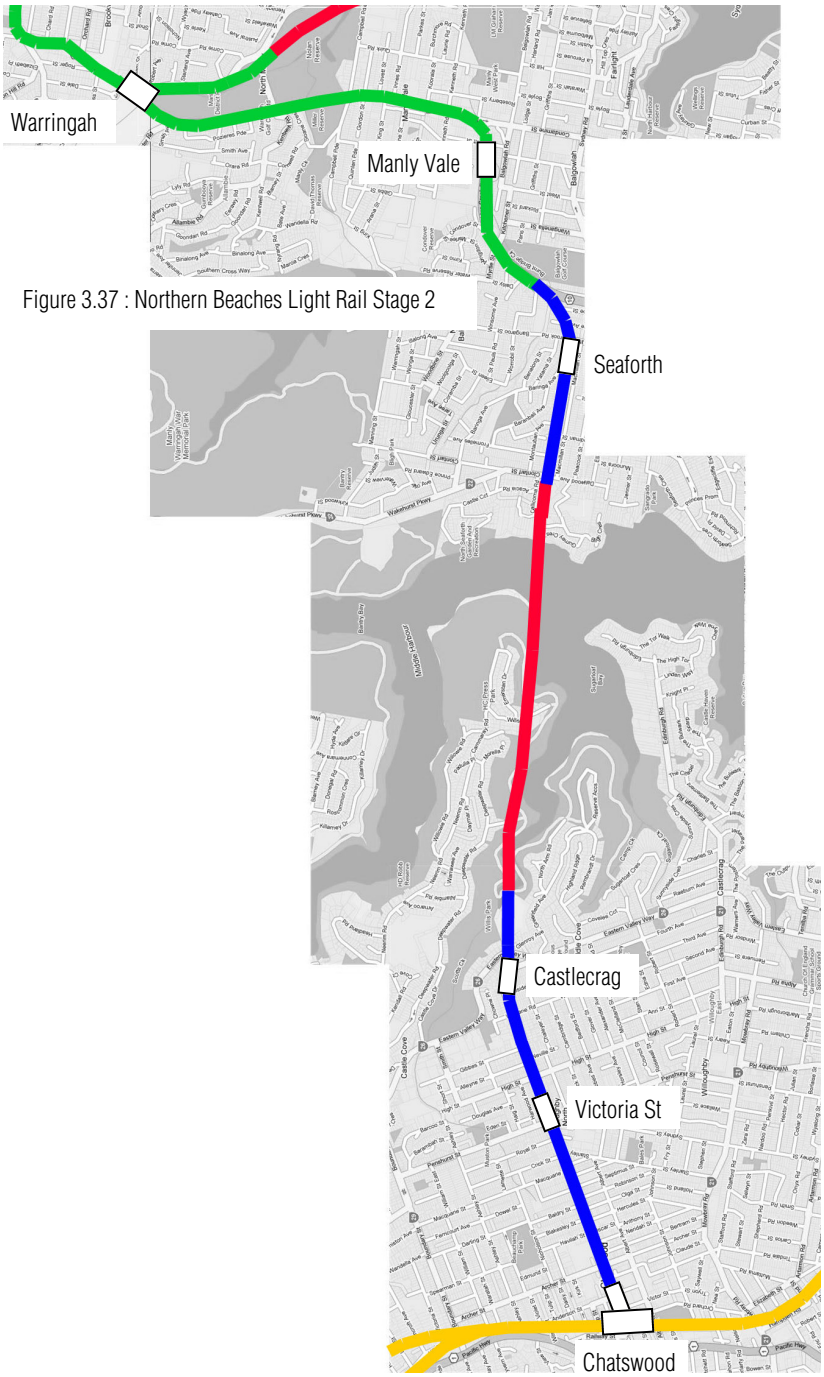


Figure 3.37 : Northern Beaches Light Rail Stage 2

3.3 Stage 3

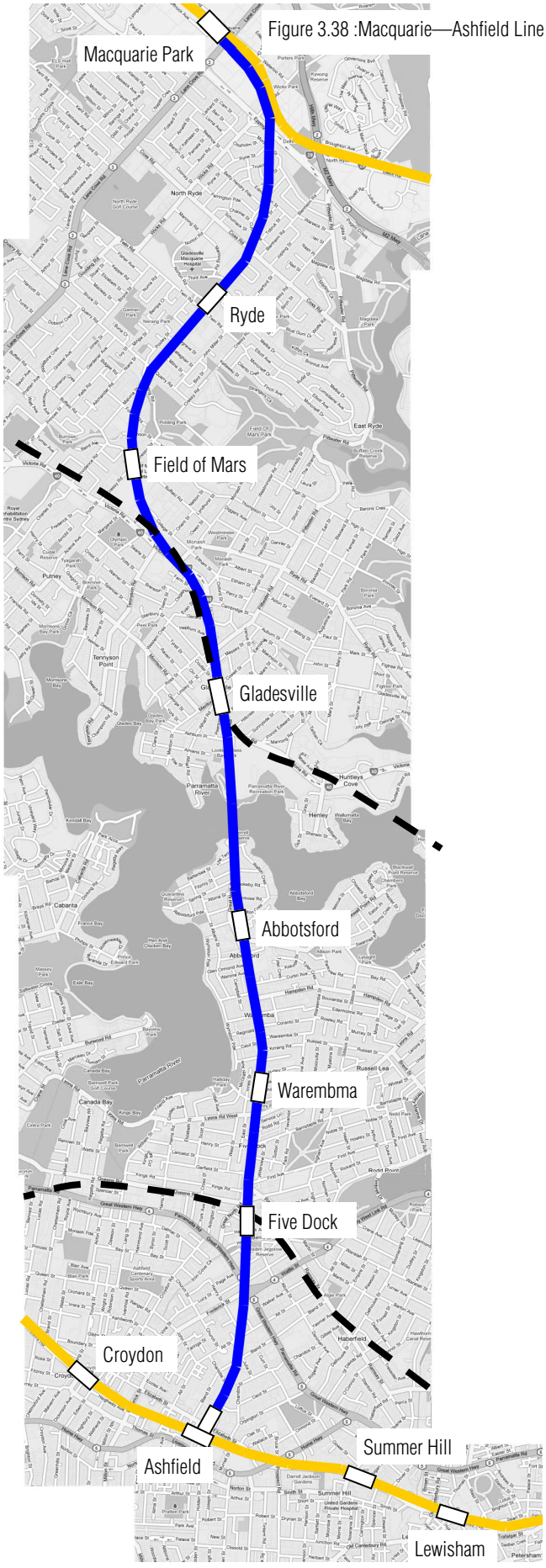


Figure 3.38 :Macquarie—Ashfield Line

The Ashfield—Macquarie Park line provides for a very valuable cross-suburban inner city link. This line connects two peninsulas and connects an area of higher order employment to the inner west, which has a high proportion of white collar workers.

It also enables for redevelopment and potentially higher densities in the northern suburbs from Gladesville to Macquarie Park.

It also provides an area of Sydney which has moderately high population densities access to a high capacity transit system.

This line would connect two existing heavy rail lines, and two metro lines, enabling valuable interchange between these transit links..

3.3 Stage 3

Figure 3.39 :Shanes Park—Castle Hill line

The Castle Hill to Shanes Park line acts as a major transit corridor through the North West Growth Centre, and connects to the existing network at Quakers Hill. This line would enable for a high density transit oriented development to be constructed along its route within the Growth Centre, and for the potential for the low density existing suburbia that it passes through to have increased densities, to enable greater urban renewal prospects. This line connects Castle Hill to the Richmond Line, the NW Metro along Old Windsor Road and the line to Camden at Shanes Park. This provides for greater accessibility within the North West region of Sydney.

3.3 Stage 3

Summary

Stage 3 provides for high speed connections to the Central Coast, Newcastle and Wollongong, of which house the majority of the population in NSW. At present the alignment to both Newcastle and Wollongong are a steam age alignment, which is slow, circuitous, and unsuited to the needs of a modern megalopolis, which requires fast, frequent and accessible services.

These deviations will significantly reduce the time required to travel between the three most populous cities in NSW, and can potentially encourage further decentralisation from Sydney into the Central Coast, Newcastle and Wollongong, by providing for greater accessibility to the main CBD, it may enable for greater white collar employment decentralisation, along with housing decentralisation outside the Sydney basin.

Stage 3 also provides for a major cross suburban link from Shanes Park in the North West Growth Centre to South Camden through the South West Growth Centre. This linear corridor connects to the major industrial employment lands of the South West including Badgerys Creek (whether an airport or employment lands), Western Sydney Employment Hub, and Leppington Town Centre. This line provides for a major Transit Oriented Development corridor through both Growth Centres, as it connects to all the major employment areas, which means that a significant modal shift could be expected. This line would then be able to be the backbone to the Growth Centres.

Kirrawee Station

Source: Ben Chatwin (2009)

The continuation of the Northern Beaches Light Rail from Warringah Mall to Chatswood enables for a rail line to exit the Northern Beaches Peninsula and access the northern section of the Global Arc, especially Macquarie Park.

4 Conclusion

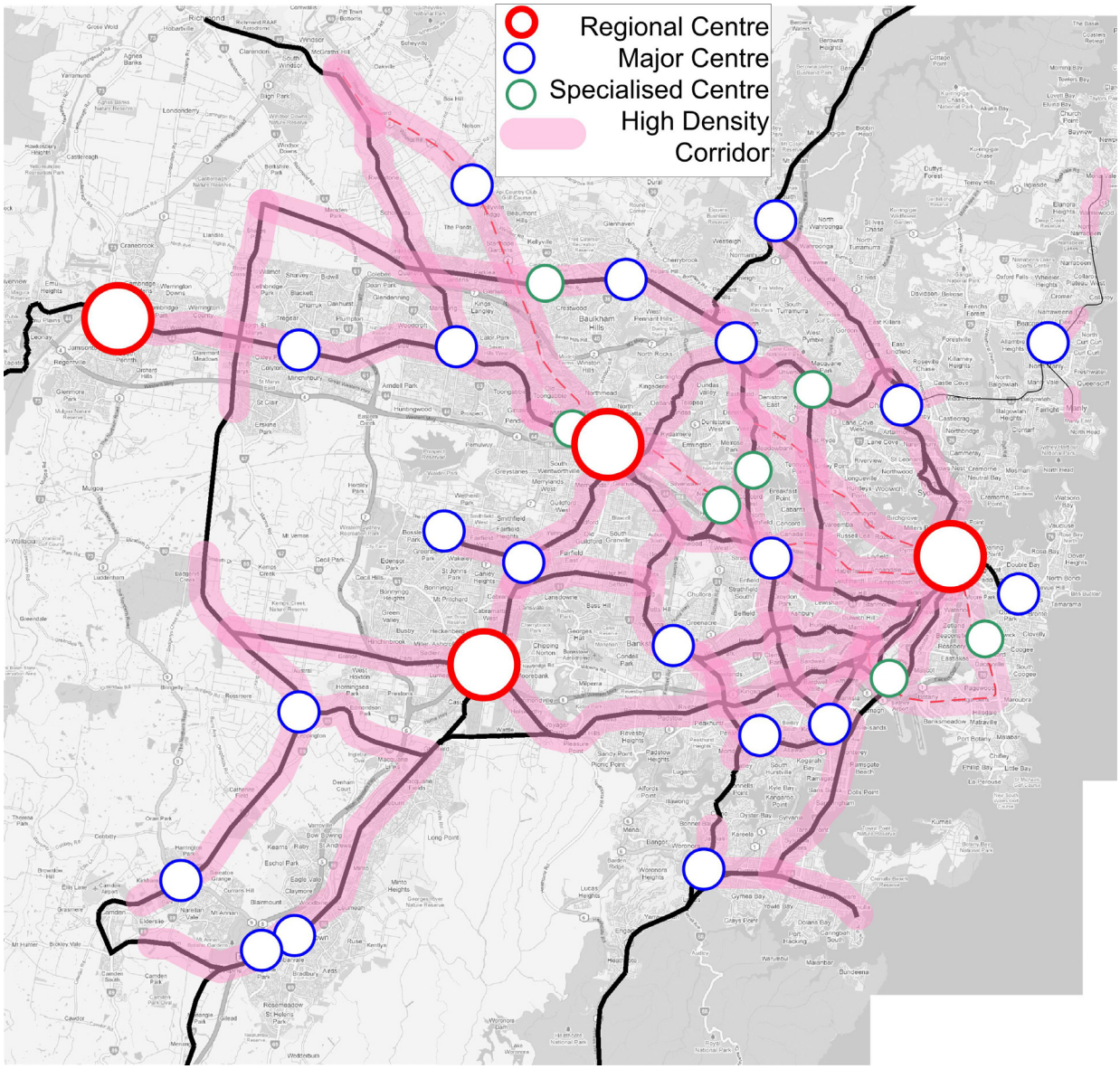


Figure 4.1 shows the completed railway system (including the three proposed metro lines) in 2040, in relation to the major employment centres of Sydney (with the inclusion of Epping), as shown in the Sydney Metropolitan Strategy. This figure clearly shows that with the cross suburban railway lines, accessibility to the centres is greatly increased.

This also enables for the creation of high density Transit Oriented Development (TOD) corridors following the railway lines. Utilising a mixture of high density housing types including high rise, and medium rise apartments, terraces, townhouses and small lot housing, the majority of Sydney's infill growth could be accommodated within these TOD corridors, which provides for greater public transportation use, and environmental outcomes, which strengthens the Sydney Metropolitan Strategies aims of the majority of new development to be infill development. This also enables areas outside the TOD corridors to remain at a much lower density—a true suburban location, enabling the character of most of the existing areas to be maintained.

The grid network that is formed especially in the inner and middle ring suburbs will improve the ability of Sydney to grow as a world city in more sustainable way by increased utilisation of the railway network.

4 Conclusion

This thesis and the proposal mesh strongly with existing State planning documents, most notably the State Plan and the Sydney Metropolitan Strategy, both of which provide the guidance and direction for long term planning in Sydney. It is briefly outlined below, the specific targets and how this plan helps meet them.

The State Plan

This thesis meets the following requirements of the State Plan

S6—Increasing share of peak hour journeys on a safe and reliable public transport system

- By improving the level of accessibility to the rail network across Sydney and increasing frequency of service, the level of journeys will increase, not just peak hour journeys.

P2—Maintain and invest in infrastructure

- This proposal updates and invests in the rail infrastructure, by providing a long term investment proposal.

E3—Cleaner air and progress on greenhouse gas reductions

- Increasing the proportion of trips undertaken by public transport will reduce the amount of vehicular greenhouse gas emissions.

E7—Improve the efficiency of the road network

- Increasing the proportion of trips undertaken by public transport will reduce the number of vehicular trips, increasing the efficiency of the road network, and enabling greater volumes of commercial traffic to use the road space.

The Sydney Metropolitan Strategy

This thesis meets and undertakes the following requirements of the Sydney Metropolitan Strategy

B2—Increase densities in centres whilst improving liveability

- This proposal reinforces the proposed centres within Sydney, and provides for TOD renewal corridors.

B4—Concentrate activities near Public Transport

- By reinforcing the Centres strategy linking all major centres to rail transport, and increasing rail coverage, activities will be concentrated around public transport

B5—Protect and strengthen the primary role of economic corridors

- By reinforcing the global arc corridor through public transport the role of corridors in enhanced

B6—Focus development in renewal corridors to maximise infrastructure use

- By providing for linear TOD corridors, clearly defined renewal corridors are identified for higher density.

C2—Plan for a housing mix near jobs, transport and services

- By providing for TOD corridors and greater rail coverage, greater housing densities can be sustained around rail corridors and railway stations

D1—Improve transport between Sydney's centres

- By providing a grid network of railway lines to all of the major centres, transport is improved to them.

D2—Improve the existing transport system

- The existing rail transport system is updated and enhanced under this proposal.

D3—Influence travel choices to encourage more sustainable travel

- By enabling greater accessibility by linking centres and TOD corridors, more trips can be undertaken by rail transport, increasing the proportion of public transport trips, and therefore more sustainable travel.

D4—Improve transport decision making: planning, evaluation and funding.

- By providing for a concrete long term and fundable transport plan, which meshes strongly with the Sydney Metropolitan Strategy, this enables for greater transparency in the decision making process by enabling the community to see the long term proposals for rail transport in Sydney.

4 Conclusion

This thesis has clearly shown that there is spare capacity within the existing network, and it is other reasons than the primary infrastructure as to why there is a capacity crisis. A lack of rolling stock, poor timetabling procedures and a necessitation of the one seat journey to the City, has caused the capacity crisis within the CityRail Network, and are all areas which can be improved at relatively little cost. Streamlining train operations enables for a higher frequency of service to be run in the central sections of the network, as there are less conflicts between services, and a reduction in the use of flat junctions.

By reducing the varied and numerous stopping patterns and train frequencies to one or two, enables the infrequent user to readily understand where and when the train will arrive and go, without the need for a timetable. The use of turn-up-and-go frequencies and more regular local services would enable the rail network to be used for non-discretionary travel trips, which are currently done by the car. This enables for higher utilisation of the rail network inter peak which is one of the lowest utilisation periods on the network.

Utilising appropriate rail stock for the various operations including high speed and frequency whilst low seated capacity single deck trains for inner suburban runs, medium distance high seated double deck trains for suburban runs, and all seated, high comfort and speed intercity stock, enables appropriate targeting of the various travel types, which is lacking at present. The splitting of the system is shown in figure 4.1.

New infrastructure at Revesby

This plan links into urban planning heavily, primarily for providing corridors of high density Transit Oriented Development. This enables for a greater density and utilisation of the railway line, whilst confining significant population growth to these corridors. By confining growth to certain corridors, it enables greater utilisation of public transport, and also enables most of the suburb area to keep its existing character.

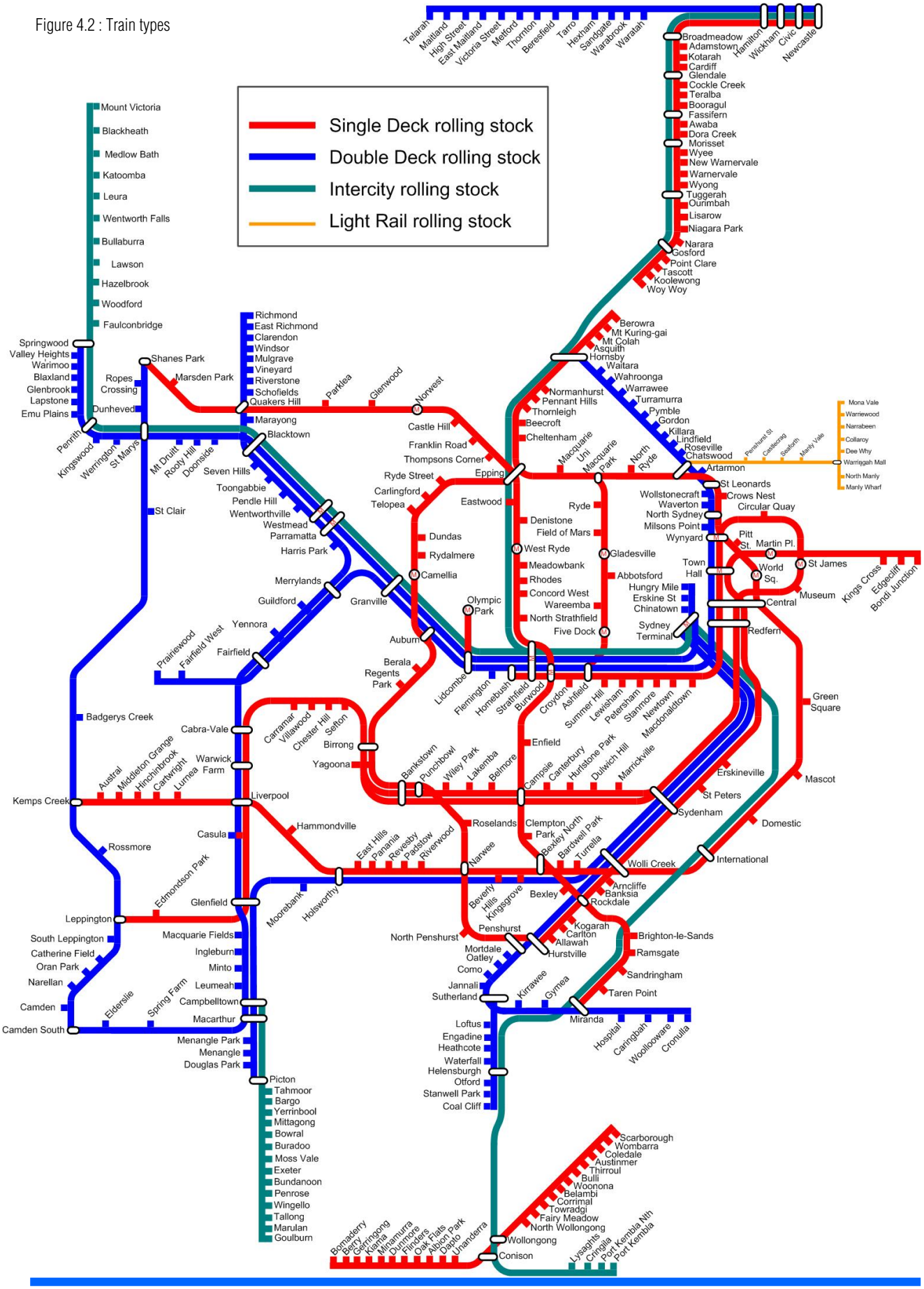
It also links into the developing suburban areas of the Southwest and Northwest Growth Centres, providing for large scale public transportation. The linkages both radial, and cross-suburban throughout the system helps to link the major employment centres of Sydney. Sydney as a decentralising city is creating a more dispersed trip city, which requires such connections to maintain a higher public transportation usage.

This plan is fundable from the existing capital expenditure within CityRail without large scale intervention from the State. It does assume however that the proposed metro system will be funded through private funding or additional funding however. This plan abides by and improves the Sydney Metropolitan Strategy, as well as the State Plan, by improving public transportation and reinforcing the centres and corridors strategy within the Metropolitan Strategy. It enables for a greater diversity in housing stock, as well as increased accessibility to the major employment centres which is increasingly important in a city that has dispersed travel patterns.

This shows with targeted planning, and capital improvements that there is considerable potential and improvement within the existing network, which will provide for Sydney's transport needs now, and into the future.

4 Conclusion

Figure 4.2 : Train types



Appendix 1

The costs of the railway upgrades are listed here, and are an amalgamation of costs found within the following sources, which are the most up to date sources for rail construction costs in Australia. These costs can be used as baselines to indicate cost of the proposed infrastructure needed for this plan.

The costs work out as follows: (all costs in millions)

Infrastructure	NCCCS (2002)	Epping-Chatswood Link (2002)	Delhi Rail (2004)
Surface Track per km	1.9	n/a	4.35
Overhead per km	0.8	n/a	n/a
Signalling per km	0.8	n/a	n/a
Elevated Track per km	n/a	n/a	25
Underground Track per km	40	68.8	118.29
Underground station	50	355 (includes tunnel fit out)	n/a

Standardised to 2008 costs

Infrastructure	NCCCS	Epping-Chatswood Link	Delhi Rail
Surface double track per km	2.27	n/a	**4.94**
Elevated double track per km	n/a	n/a	**28.38**
Underground double track per km	47.76	**82.14**	134.28
Underground station	**59.7**	423.85	n/a

Note: the use of the ECRL underground cost without the fitting costs better reflects shallow tunnelling costs, of which recent projects and proposals including the Airport Line (NSW), Action for Transport 2010 (NSW), New MetroRail (WA) and the Eddington Plan (Vic)

The highlighted figures, are the costs being used for the upgrades, as they are closest to the approximate reality in RailCorp as they combine realistic figures for construction with relatively recent costings.

The investment made into CityRail over the last several years has been significant. Clearway's has cost approximately 360million per year, (1.8billion total cost, spread out across 4 1/2 years) and the overall cost of the new Asets (Waratahs) is approximately 612 million per year. (This is assuming that the Aset delivery contract is spread out over 6 years from the contract signing date in 2006, to the last delivery in 2013) This means that the government has generally invested 972 million each year into CityRail, over the existing operational budget. It would be expected that as part of this project, that the investment will be 1billion/year.If this additional funding level was maintained, this means that there is approximately 30billion dollars in 2009 money over the next 30 years for capital improvements available., which is what this plan proposes to maintain, to enable construction of the proposal.

This is coupled with the additional fare revenues of at least $169,284,393/year additional, (as shown on page 38) indicates that there is potential to fund significant improvements to the railway network, only utilising the existing capital works budget and a potential enhancement through increased fare collection. This would assume however that running costs remain fairly static, as the main price increase would be the wear and tear on infrastructure, as no new station, or on-train staff are needed as part of the enhanced system in stage 1. In Stage 2 and 3 additional drivers will be required. The additional staffing costs in stages 2 and 3 are assumed to be covered by increased fare revenue.

This will provide for an annual capital works budget of $1169 million per year. $169million will be used for contingencies. Or a total of $35.070 billion over the life of the project in 2009 dollars.

Appendix 1

Stage 1 is a five year project that aims to increase capacity by reducing existing train conflicts. It is essentially an enhanced clearways project.

No.	Project	Segment Length	Grade	Cost	Total Cost
1	Redfern—Central Complex Redevelopment	1600	At grade	80	80
2	Erskineville—Sydenham track amplification	2520	At grade	80	80
3	Flyover at Wolli Creek	920	Flyover	26	26
4	Carlingford Line Duplication	600 n/a	At grade Station	3 12	15
5	Flyover at Cabramatta Junction	870	Flyover	25	25
6	Merrylands—Fairfield track amplification	8000	At grade	80	80
7	Cabramatta—Liverpool track amplification	3700	At grade	37	37
8	New Cabra-Vale station	n/a	Station	50	50
9	Bankstown—Campsie track amplification	6870	At grade	35	35
10	Richmond line track amplification	16140	At grade	80	80
11	Strathfield—Hornsby track amplification	16800	At grade	236	118 (ARTC pay 1/2)
12	Strathfield Junction flyunder	2000 700	At grade flyunder	10 58	68
13	Signalling upgrade Lidcombe—Merrylands	7970	n/a	8	8
14	Third platform at Regents Park	300 170	Cutting station	9 15	24
15	Track amplification and flyover at Yagoona	700 600	Flyover At grade	20 3	21
16	Diversion of Airport line to platforms 26/27 at Central	1000	transition	83	83
17	Purchase of 1422 new cars	n/a	n/a	2.8 ea	3982
18	Miscellaneous minor works	n/a	n/a		188
	Total				5000
	Total including Contingency funding				5845

The total cost of the short term improvements over the 5 year timeframe is approximately 1000million per year. This includes the total cost of the Northern Line amplification, which will be partially funded through the Federal Government, through NSFL.

Appendix 1

Stage 2 is a 10 year project.

No.	Project	Segment Length	Grade	Cost	Total Cost
1	Strathfield—Miranda Line	2900 2730 17971 12 1	At grade Elevated Under- ground U Stations A Stations	15 78 1477 720 20	2310
2	Epping—Hurstville Line	7368 12980 8 4	At grade Under- ground U Stations A Stations	37 894 480 80	1491
3	Northern Beaches Light Rail	13000 4460 2 6	Elevated Under- ground U station E station	375 337 120 300	1132
4	Prairiewood Line	5520 2	Under- ground U stations	380 120	500
5	Middleton Grange Line	9760 9700 3800 1 3 5	At grade Elevated Under- ground U station A station E station	50 276 315 60 60 250	1011
6	New City Underground Line	1920 5030 4	At grade Under- ground U station	10 805 480	1295
7	Macarthur—Liverpool track amplification	20 5	At grade elevated	100 142	242
8	New carriages required (est)	1000	n/a	2.8 ea	2800
	Total				10781
	Total including contingency				11690

Note: The new city underground line has had its construction costs doubled due additional constraints of construction in the City.

Appendix 1

Stage 3 is a 15 year project.

No.	Project	Segment Length	Grade	Cost	Total Cost
1	Hawkesbury River Bypass	5000 11520 13360	At Grade Elevated Underground	50 692 2200	2940
2	Wollongong Line Realignment	18000 16800	At grade Elevated	90 1200	1290
3	Wollongong Express Line	1780 4160 19120 2	At grade Elevated Underground U station	9 120 1571 120	1820
4	Track Amplification Wolli Creek—Sydney Terminal	6540 2	Underground U station	538 120	658
5	Northern Beaches Light Rail stage 2	7963 2690 5	Underground Elevated U station	655 76 300.	1031
6	Castle Hill—Shanes Park Line	7510 13950 4 2	At grade Underground U station A station	40 1174 240 40	1494
7	Shanes Park—Camden Line	20240 12000 17280 5 8 1	At grade Elevated Underground U station A station E station	101 347 1420 300 160 50	2378
8	Camden—Macarthur Line	1880 3100 2440 1 1	At grade Elevated Underground U station E station	10 90 201 60 50	411
9	Macquarie—Ashfield Line	12220 8	Underground U station	1004 480	1480
10	Sussex Street Line	2700 4	Underground U station	444 480	924
11	Additional rolling stock	200	n/a	3	600
	Total				15026
	Total including contingency				17535

Note: Construction costs for the Sussex Street line have been doubled given its city location, and additional construction costs.

Note: The Hawkesbury and Wollongong Deviations construction costs have been doubled given their remote location, and extensive constraints to construction

References

Asia Pulse (2009) *NSW Premier denies Sydney metro plan is impossible to realise* 14/04/09

Ausway (2009) *Sydway Maps* http://www.street-directory.com.au accessed 15/08.09

Brown, J (2009) *Discussion about London Transport*

CityRail (2009) *CityRail Map and Timetables* Accessed 10/7/09

Chapman, R (2009) *Discussions on Sydney Rail Network*

Google (2009) *Google Maps* http://maps.google.com.au

Harrod, S (2009) *Capacity factors of a mixed speed railway network* Transport Research Journal E pp 830-842

SMRT (2009) *Singapore Metro Map* http://www.smrt.com.sg/trains/network_map.asp Accessed 4/7/09

Sydney Buses (2009) *timetables* http://www.sydneybuses.info Accessed 4/8/09

Sydney Morning Herald (2009a) *Metro line hits the buffer hitch with Central station changes* Accessed 14/04/09

Sydney Morning Herald (2009b) *And now: A metro without passengers* Accessed 6/05/09

Sydney Morning Herald (2009c) *Minister changes the model to make project viable* Accessed10/09/09

The Daily Telegraph (2009) *CityFrail : $1.8bn plan to untangle train delays hits buffers* Accessed 2/02/09

TIDC (2009) *Transport Infrastructure Development Corporation* http://www.tidc.nsw.gov.au/ Accessed 4/6/09

UK National Rail (2009) *London Connections Map* http://www.nationalrail.co.uk/tocs_maps/maps/LondonConnections.pdf accessed 10/7/09

UK National Rail (2009) *UK rail timetable* http://www.networkrail.co.uk/browse%20documents/eNRT/May09/CompleteTimetable.pdf Accessed 1/10/09

CityRail (2008) *Rail Timetables at www.cityrail.info* Accessed 3/10/08

CityRail (2008) *CityRail Compendium of Statistics 2008*, NSW Government

Cooper. D (2008) *Discussions about transport modelling, capacity, and timetabling*

Eddington Report (2008) *East-West Transport Analysis* Vic Government

Hensher, David (2008) *The Handbook of Transport Modelling* 2nd Ed. Elsevier UK.

Ison, Stephen (2008) *The Implementation and Effectiveness of Transport Demand Measures: An international Perspective,* Ashgate, England.

Knowles, R (2008) *Transport Geographies : Mobility's, Flows and spaces* Blackwell Publishing, Malden USA.

Laybutt, S (2008) *Discussions on Sydney Rail Network*

Mees, P (2008) *Does Melbourne need another central city rail tunnel* RMIT University Victoria

Moscow Metro (2008) *Metro Map* http://www.wtr.ru/moscow/eng/metro/metro.html Accessed 4/7/08

References

Rail Employee 2 (2008) *Discussions on Sydney and Melbourne Rail Network*

Sydney Morning Herald (2008) *CityRail on the brink of collapse* Accessed 18/12/08

The Daily Telegraph (2008*) What you stand to lose :Eric Scissorhands slash and burn—the mini budget* Accessed 12/11/08

Transport Data Centre (2008) *2006 TDC JTW Summary Tables by Local Government Area* Ministry of Transport NSW

Transport Data Centre (2008) *Employment and Commuting in Sydney Centres* Ministry of Transport NSW

Transport Data Centre (2008) *Serving Passengers: Are you being served?* Ministry of Transport NSW

Transport Data Centre (2008) *2006 Employment and Commuting* Ministry of Transport NSW

Abril, M (and others) (2007), *An assessment of Railway Capacity* Transportation Research Journal E pp 774–806

Flamini, M (2007) *Real Time management of a Metro rail terminus*, European Journal of Operational Research pp 746-761

Rail Employee 1 (2007) *Discussions on Sydney Rail Network*

Vuchic, Vukan (2007) *Urban Transit Systems and Technology* Wiley Publishing US

CityRail (2006) *CityRail Compendium of Statistics 2006,* NSW Government

Schobel, Anita (2006) *Optimisation in Public Transportation: stop location, delay management, and tariff zone design in a public transportation network*, Springer New York.

Rodrigue, Jean-Paul (2006) *The Geography of Urban Transport Systems*, Abingdon, England

Transport Data Centre (2006)

Burdett, R.L. (2005) *Techniques for absolute capacity determination in railways*, Transportation Research Journal B pp 616-632

Carey, M (2005) *Scheduling trains on a network of busy complex stations*, Transport Research Journal B pp 159-179

CityRail (2005) 2005 *Rail Timetable* at www.cityrail.info downloaded 10/08/05

Connex Melbourne (2005) *Timetabling Handbook* MELBOURNE

NSW Government (2005) *Sydney Metropolitan Strategy : a city of cities*, Department of Planning NSW

Badami, S (2004) *The Metro Rail for Mumbai – the realistic cost estimates* http://personal.vsnl.com/aspirations/The_Metro_Rail_for_Mumbai_the_realistic_cost_estimates.htm Accessed 20/09/09

Vuchic, Vukan (2004) *Urban Transit : Operations, Planning and Economics* Wiley Publishing US

Department of Infrastructure (2003) *Northern Central City Corridor Study* Victorian Government

References

Konstadinos, Goulias (2003) *Transportation Systems Planning : methods and applications*, CRC Press, Boca Raton, Florida

Transport Data Centre (2003) *JTW summary tables Home SLA* Ministry of Transport NSW

Transport Research Board (2003) *Transit Capacity and Level of Service* Transport Research Board Washington DC

Unsworth B (2003) Ministerial *Review into Bus Services in NSW* Ministry of Transport NSW

Carey, M (2002) *Scheduling and platforming trains at busy complex stations* Transport Research Journal A pp 195-224

Button, Kenneth (2001) *Handbook of Transport Systems and traffic control*, Pergamon, London

Christie R (2001), *The Christie Report*, NSW Government

Mees, P (2000) *A very public solution : Transport for the dispersed City* Melbourne University Press Vic

Eliyahu M. Goldratt (1999) *Theory of Constraints* North River Press Massachusetts USA

Cervero, Robert (1998) *The Transport Metropolis : A Global Enquiry*, Island Press Washington DC

NSW Government (1998) *Action for Transport 2010* NSW Government

Burke, D (1997) *Juggernaut : a story of Sydney in the wild days of the steam trams* Kangaroo Press Sydney

Australian Urban and Regional Development Review (1995) *Timetabling for Tomorrow: an agenda for public transport in Australia*, Australian Government Canberra

State Rail Authority (1994), *State Rail strategic plan 1994-2016 : CityRail* NSW Government

Carey. M (1993) *Stochastic approximation to the effects of headway on knock on delays of trains* Transport Research Journal B pp 251-267

Australian Railway Historical Society (1987) *Electrification of Sydney and Suburban Railways* AHRS NSW

NSW Government (1974) *Sydney Area Transportation Study*, NSW Government