

CSELR EIS – Commentary on capacity and demand contained in the Transport Operations Report volume of the EIS

By Peter Egan 04 1450 9700 peteregan2001@gmail.com 14/26 Hampden Rd Artarmon 2064

Summary

This paper advises the operational capacity of the tram line is 3,900 passengers each direction – 20 seven-segment trams (43 metres long) carrying 195 passengers each. The capacity is slightly lower per square metre than achieved for a 12.5 metre standard bus (58 passengers) and for an 18 metre articulated bus (85 passengers) as tram passengers expect the slightly greater personal space achieved on a train. It is not possible to fit 300 passengers on the trams specified due to public order and safety concerns, the need to provide circulation space on the trams and the public's perception of needed personal space. A 66 metre, eleven-segment tram is required for a 300 passenger operational capacity.

In the constrained demand environment the tram service will experience, the operation capacity should be reduced to 3,600 for the peak hour due to the profile of Sydney's public transport AM peak provided by Douglas Economics in 2012. The capacity reduction ensures that not many people are left behind at the busiest stop at the top of the peak hour.

The EIS advises 80 seats will be provided on each tram for a seated capacity of 1,600, although a standard tram of the length specified normally has 88 fixed seats, 18 folding seats (106 seats in total), and space for 88 people to stand. An operational capacity of 194, not the 300 reported by TfNSW.

It is notable that the 60 articulated bus express services from the south-east that enter the CBD via the Cahill Expressway have an operational capacity of 5,100 (85 per bus) and a crush-load capacity of 6,600 compared to 3,900 and 6,000 respectively for the tram line. The seat comparison is 3120 on the buses and 1,600 for the trams. The express buses provide a faster door-to-door service to the northern CBD than the proposed tram service. Fortunately, the express bus services are being retained as they are a superior service.

The EIS maximum line load of 5,366 inbound at Surry Hills is based on 2010 data for the buses to be replaced by the tram service. Based on the 1.65% p.a. demand increase to 2036, demand in 2021 will be 20% larger at approximately 6,400. This is 1.65 times the available peak hour operational capacity to Central. The demand is not balanced between the two branches – the Kingsford branch has 57% of demand compared to 43% for the Randwick branch – exacerbating the overcrowding. In the outbound direction, the AM peak ratios are reversed. Even for the outbound direction, demand exceeds operational capacity on both branch lines.

Crucially, TfNSW expects only a hundred, or so, of the 20,000 people flooding out of Central in the AM peak, to catch a tram north into the CBD. It is expecting perhaps 10% of the nearly 6,000 passengers (according to the city centre access strategy) on 175 George St buses passing Rawson Place to change to a trams once these buses are diverted to Elizabeth St. These are heroic assumptions. During CSELR construction, half the George St buses will terminate at Eddy Ave while half will join with the 200 buses already on Elizabeth St for the crawl down to Circular Quay east. As demonstrated in this paper, the unconstrained AM peak demand at Rawson Place could easily be 11,000 passengers – 2.8 times the 3,900 passenger capacity – with 3,000 wishing to board at Central and 4,500 wishing to board at Rawson Place. It's not surprising that trams were phased out of Sydney in the 1950s when tram line capacity is well below street bus capacity. Sydney is one of the major cities with a very geographically constrained CBD. It thus needs the highest capacity modes of access if it wishes to remain Australia's most prominent city. We are presently on track to once again be the second city to Melbourne as noted in a recent ABS report.

Another CBD access strategy is required that increases CBD public transport capacity, rather than reduces it. By far the best strategy for south-east Sydney and the CBD would be to extend the Eastern Suburbs Rail Line from Bondi Junction to Bondi Beach, Bronte, Coogee, POWH, UNSW, Green Square, Alexandria and Sydenham with a turnaround loop south of Sydenham. The ESRL is at about one-third capacity in the peak-hour. The present total public transport demand for east and south-east Sydney is 20,500 passengers in the peak-hour. These can all be carried by the 24,000 capacity ESRL. A 16km extension of the ESRL would cost less than the Epping-Chatswood Line in inflation adjusted terms – perhaps \$3.0 billion in 2021. It would permit at least a 75% reduction in buses approaching Elizabeth St from the south and east, resulting in a major reduction in CBD public transport congestion. The 15 km trip from UNSW at Anzac Pde to Town Hall would take about 22 minutes – faster than the journey by tram or bus. UNSW and POWH are then intimately connected to the metropolitan public transport network. The outcome is vastly improved compared to the \$1.6 billion tram line.

In terms of surface transport, only two of the four length-of-the-CBD roads (Sussex, George, Pitt, Elizabeth) are used for public transport in a significant way. Extra public transport capacity could be achieved as follows:

- A) A single-track tram loop line could be re-established on Pitt and Castlereagh/Bligh/Young Sts – Pitt St mall should not be sacrosanct to trams. Likely, Pitt northbound, Castlereagh southbound;
- B) Southern, eastern and western bus routes modified to connect with each other rather than run north-south on George and Elizabeth Sts north of Eddy Avenue and thus spread the tram interchange loads;
- C) Connecting the South East tram line to the Inner West Line via the east side of Pitt St to operate as a single service – this would not clash with the Pitt/Castlereagh loop;
- D) Adding a new tram line from Bridge St at Macquarie Place via Oxford St to Bondi Junction and the south east tram line at Moore Park, using the never-used Bradfield Eastern Suburbs Rail Line tunnel from the Conservatorium of Music to the Hyde Park War Memorial – the line is underground from Macquarie Place to Oxford St;
- E) A branch of the Inner West Line via the Old Good Line tunnel under Railway Square to Regent St (Mortuary) Station – improves Darling Harbour access;

- F) A new separate double-track tram loop line along George, Alfred, Phillip and Elizabeth Sts and Eddy Ave with trams circulating at one minute intervals in the peak – requires ‘rack’ drive assistance on Phillip St;
- G) A reduction in on-street parking, a ban on personal use vehicles parking on-street in the CBD, and CBD peak-hour entry/exit restrictions for cars;
- H) A new station at Observatory Hill on the North Shore Line; and
- I) A raft of other measures.

The various figures quoted for capacity in this report, along with the very poor evidence of demand, indicate a poor understanding within TfNSW leadership of public transport capacity, and a continuing culture, at political and bureaucratic levels, of misrepresenting demand and capacity for personal and political gain.

Capacity

While tram and train manufacturers quote a capacity of four passengers per square metre for standing areas, this should be seen as a figure to ensure the vehicle will have adequate performance and safety in extreme circumstances. Sydney Trains regards 1.9 passengers per square metre in standing areas as the limit to ensure on-board circulation and board and alight operations within an acceptable dwell time (See the Douglas Economics 2012 report on train line capacity modelling for TfNSW leaked to the SMH). Passenger seating densities are a little over two seats per square metre. In practice, the operational capacity of metropolitan public transport vehicles is approximately two passengers per square metre irrespective of seating supplied. The EIS allows five passengers per square metre of standing area for special events (see CSELR EIS Technical paper 1, Transport Operations Report (TOR) Section 3.3 Special Events). Public order and safety, and personal space considerations, suggest the normal operational limit of two passengers per square metre should apply.

The Gold Coast trams correspond to the tram specification in the EIS. The tram is a seven segment Bombardier Flexity 2 – see Figure 1 and Appendix 2 to this paper. The diagram below is the five segment Flexity 2 for Blackpool, UK. Based on the Blackpool tram, the 43 metre Gold Coast trams have a 39 metre long passenger cabin and a capacity of 195 seated and standing passengers on the basis of two passengers-per-square-metre. This equates to five passengers-per-linear-metre of passenger cabin. Our buses and trains have an operational capacity of 5.5 passengers-per-linear-metre of passenger cabin as passengers will accept less personal space in buses as they are seen as lower quality form of public transport.



■ seated passenger, ○ standing passenger at operational capacity

The Sydney/Gold Coast trams have an additional two segments corresponding to those marked. A seven segment tram would have 88 fixed seats, 18 folding seats and space for 88 people to stand for a total of 195 passengers.

Figure 1- Bombardier Flexity 2 tram Blackpool marked up with passengers for a full load. .

195 passengers per tram should be regarded as the capacity required for the peak of the peak-hour to ensure people are rarely left behind by a tram. While the operational capacity of a 20 tram per hour service is 3,900 per hour, Figure 2 (Douglas Economics Figure 3.4 below) shows the peak of the peak-hour constrained demand is 15 percent above the peak-hour average. The operational capacity needs to be set at least 10% above the peak-hour average maximum demand ensure few passengers are left behind at the peak demand stop – Surry Hills according to TfNSW, but Rawson Place according to my analysis. The operational capacity should thus be set at 3,600 to ensure a reliable service. Of that 3,600 capacity, the government intends that only 1,600 should be seats.

Based on Appendix 2, total capacity of a seven segment tram is 88 fixed seats and 18 folding seats (total 106 seats) and 88 standing, for a total of 194 passengers. In practice, leaving out 8 fixed seats for a total fixed seat capacity of 80, only creates extra space for an operational capacity increase of 8 standing passengers. If folding seats are provided they will be used in peak-hour unless a locking mechanism is provided to secure them in the up position during peak-hour – an action that would infuriate passengers. The seating capacity in the morning peak will be fully occupied from the initial or second stop. Passengers will not stand for 30 minutes if seats are available.

It is notable that the 60 articulated bus express services from the south-east that enter the CBD via the Cahill Expressway have an operational capacity of 5,100 (85 per bus) and a crush-load capacity of 6,600 compared to 3,900 and 6,000 respectively for the tram line. The seat comparison is 3120 on the buses and 1,600 for the trams. The express buses provide a faster door-to-door service to the northern CBD than the proposed tram service.

Demand

Table 3-1 of the TOR forecasts long term 2% p.a. population growth in the City of Sydney and Randwick LGA and 1.5% p.a. employment growth in the LGAs. The UNSW student population grew at a rate of 4% p.a. in the last decade. Figure 6 (TOR Figure 2-19) shows the bulk of the CBD jobs are in the northern CBD. Projects like Barangaroo will ensure that remains the case.

This paper's Table 1 data is drawn from TOR, Figures 3-11, 3-12 and 3-13 and Section 7.3. Booz & Co/AECOM (TOR authors) advise the data is an estimate of passenger line loads in the 2021 AM peak based on the preliminary service specifications outlined by the Operations Adviser Interfleet's^A Initial Light Rail Operational Services Plan, 2013. The source data has been included in Appendix 1 along with commentary.

As noted in the notes to Table 1, demand is well in excess of capacity, with unconstrained line load at Rawson Place in the range of 9,000 to 11,000. With capacity at only, 3,900 per hour, the CBD access strategy in its present form is not viable.

(A. Kevin Chaloner, State Manager NSW, Interfleet Technology Pty Ltd – Level 17 55 Clarence Street Sydney NSW 2000 +61 (0) 29262 6011 <http://www.interfleet.com.au>)

Booz & Co/AECOM have not independently tested the data provided to them. They advise in Section 3.2 of the TOR:

To guide the transport planning process, Transport for NSW commissioned the development of a demand model specific to the requirements and intricacies of the CSELR project. This model – the Public Transport Project Model (PTPM) – extended the capabilities of existing models such as the Strategic Travel Model (STM) to deal with key aspects of anticipated future demand. The PTPM uses inputs including land-use patterns, rail operating plans, bus operating strategies, road network plans and parking availability and charging to understand the anticipated profile of demand under a range of future scenarios.

The PTPM provides transport planners with a tool to understand future travel requirements and demand patterns to ensure an appropriate level of service is provided to meet community expectations. Outputs from the PTPM were used in a number of stages to inform the development of the future traffic and transport network. Key elements of the profile of future demand are summarised below. More detail can be found in Transport for NSW's Demand Report.

☐ The Project is expected to attract about 18,000 AM peak hour boardings in both directions in 2021, growing to around 23,000 by 2036⁸¹;

☐ Line load on the CSELR peaks at more than 5,300 passengers per hour in the 2021 AM peak on the approach to Central Station⁸²;

☐ Driven primarily by student travel to UNSW, there is strong demand for contra-peak travel with line loads of approximately 4,100 passengers per hour in the 2021 AM peak hour and just over 3,300 alightings at the two UNSW stops⁸³; and

☐ In the 2021 AM peak hour, over 2,000 passengers are forecast to transfer from buses to light rail at the Kingsford terminus and over 1,600 passengers at the Belmore Road (Randwick) terminus⁸⁴.

☐ Total demand to the CBD on the CSELR is expected to total almost 40,000,000 trips by 2036⁸⁵;

While the effect is more pronounced at the key interchange stops of Central Station, Randwick and Kingsford, intermodal use will be a key feature of the CSELR at all stops. As shown in Figure 3-11, most stations anticipate transfers from other modes to varying degrees depending upon the nature of the catchment and style of stops.

The CSELR is also anticipated to take a significant proportion of the growth in future demand from the eastern suburbs to the CBD. As shown in Figure 3-12, peak line loads inbound (based on the preliminary service specifications outlined by the Operations Adviser⁸⁷) exceed 5,300 passengers per hour in the 2021 AM Peak Hour⁸⁸.

Unlocking Capacity

Buses currently cater for significant transport demand, and the need for capacity has caused significant growth in the number of buses accessing the CBD cordon which deteriorates the reliability of bus services and

negatively impacts the amenity of the CBD. George Street in particular carries up to 290 buses in the peak direction during the AM peak (7am – 9am) and this is expected to increase to over 310 by 2015. The congested bus network combined with the demands of other road users' impacts on customer service and delays essential business functions. The bus network cannot continue to grow to meet demand for capacity without increasing congestion levels.

Light rail offers a high-capacity transport option that:

Carries up to 300 commuters, the equivalent of around five regular buses on the road space of only three buses resulting in total capacity on the line for 9,000 passengers per hour;

Reduces the number of bus routes required to access the City Centre while providing an improved level of service;

Accommodates future growth by providing additional capacity that is able to scale to meet future challenges; and

Provides opportunities to connect to cross-regional destinations at major interchanges, growing the capacity of the broader transport system.

Unfortunately, as demonstrated above, only twenty trams per hour with a capacity of 3,900 passengers (not 9,000 as stated above) is being offered despite many statements in the EIS and by the government.

The TOR notes (as underlined above) that "intermodal use will be a key feature of the CSELR at all stops". That the CSELR is a tram line is like sending a boy on a man's errand – a train line is a better tool for the purpose.

While the PTPM model no doubt offers some useful insights, as the passenger demand for bus routes to be replaced by the tram service is known, the passenger demand for the tram service does not require the PTPM model for determination.

It is also unfortunate that the data in Figure 3-11 disagrees with that in figures 3-12 and 3-13 and Section 7.3. The data is analysed in Table 1 of this paper. The data provided allows maximum and minimum boundaries for boarding and alightings to be determined for each direction at each stop. In Table 1, it is apparent that the 18,000 AM peak hour boardings are divided into 10,000 in-bound and 8,000 out-bound. The small difference between in- and out-bound, and the lack of candour in the provision of demand data indicate that TfNSW is aware that likely demand exceeds capacity and no provision is being provided for future growth.

The EIS maximum line load of 5,366 inbound at Surry Hills is based on 2010 data for the buses to be replaced by the tram service – see Table 2-2 of the TOR (copied below). Based on the 1.65% p.a. demand increase to 2036, demand in 2021 will be 20% larger, at approximately 6,400, then in 2010. This is 1.65 times the available peak-hour capacity to Central. The demand is not balanced between the two branches – the Kingsford branch has 57% of demand compared to 43% for the Randwick branch. In the outbound direction, the AM peak ratios are reversed. Even for the outbound direction, demand exceeds operational capacity on both branch lines.

Crucially, TfNSW expects only a hundred or so of the 20,000 people flooding out of Central in the AM peak-hour to catch a tram north into the CBD. It is expecting perhaps 10% of the nearly 6,000 passengers (2011 data according to the city centre access strategy) on 175 George St buses passing Rawson Place to change to a trams once these buses are diverted to Elizabeth St. These are heroic assumptions. See Figure 5 for Broadway/George St bus data.

The CSELR construction plan calls for half Broadway buses to be terminated at Eddy Ave, while the rest proceed to the northern CBD via Elizabeth St. With nearly 300 buses, including the diverted Broadway buses, mostly northbound dropping passengers on Elizabeth St, the journey north to the job-rich northern CBD will be quite slow and tortuous. It is assumed a similar situation will apply post tram services commencing – i.e., no more than half Broadway buses will continue to the northern CBD via Elizabeth St once tram services commence. Trams will be a far faster method than buses to traverse the CBD in a north-south direction. See Figure 3 for revised CBD bus routes, Figure 4 to compare with the tram route, and Figure 7 for changes to bus numbers. Chalmers St and Rawson Place are the only opportunities for interchange.

3,000 bus passengers will be forced to change vehicle in the Rawson Place precinct and probably more than half the passengers on the continuing buses would like to do the same if a significantly quicker means of travel was available. 4,500 bus passengers could desire to change to a tram at Rawson Place in these circumstances. The line load demand at Rawson Place could easily be 11,000 in the AM peak hour while capacity is only 3,900 - 2.8 times demand. It's not surprising that trams were phased out of Sydney in the 1950s when tram line capacity is well below street bus capacity.

See Figure 6 (TOR figure 2-19) for the distribution of jobs in the CBD. It emphasises the importance of public transport services reaching the northern CBD.

Actual allowance made for transfers from heavy rail to light rail at Town Hall and Wynyard appear small. Barangaroo has likely not been factored-in for in- and outbound passengers.

Figure 7 from the draft Transport masterplan, shows 296 buses entering the CBD from the south and west are being reduced by 104 buses – 35%. The growth in buses entering the CBD westbound on Cahill Expressway, are articulated express buses from the South East which will remain when trams are introduced. These buses average 55 passengers

compared to 36 for the standard buses. The 60 articulated buses have greater capacity than the tram service. This another indicator of the inadequacy of the response to the growing congestion in the CBD.

Another CBD access strategy required

A better strategy for south-east Sydney would have been extending the Eastern Suburbs Rail Line from Bondi Junction to Bondi Beach, Bronte, Coogee, POWH, UNSW, Green Square, Alexandria and Sydenham with a turnaround loop south of Sydenham. The ESRL is at about one-third capacity peak-hour. The present total public transport demand for east and south-east Sydney is 20,500 passengers in the peak-hour. These can all be carried by the 24,000 capacity ESRL. This 16km extension of the ESRL would cost less than the Epping-Chatswood Line in inflation adjusted terms – perhaps \$3.3 billion in 2021. It would permit a 75% reduction in buses approaching Elizabeth St from the south and east, resulting in a major reduction in CBD public transport congestion. The 15 km trip to from UNSW at Anzac Pde to Martin Place would be about 22 minutes – faster than the journey by tram or bus. UNSW and POWH are then intimately connected to the metropolitan public transport network. The outcome is vastly improved compared to the \$1.6 billion tram line.

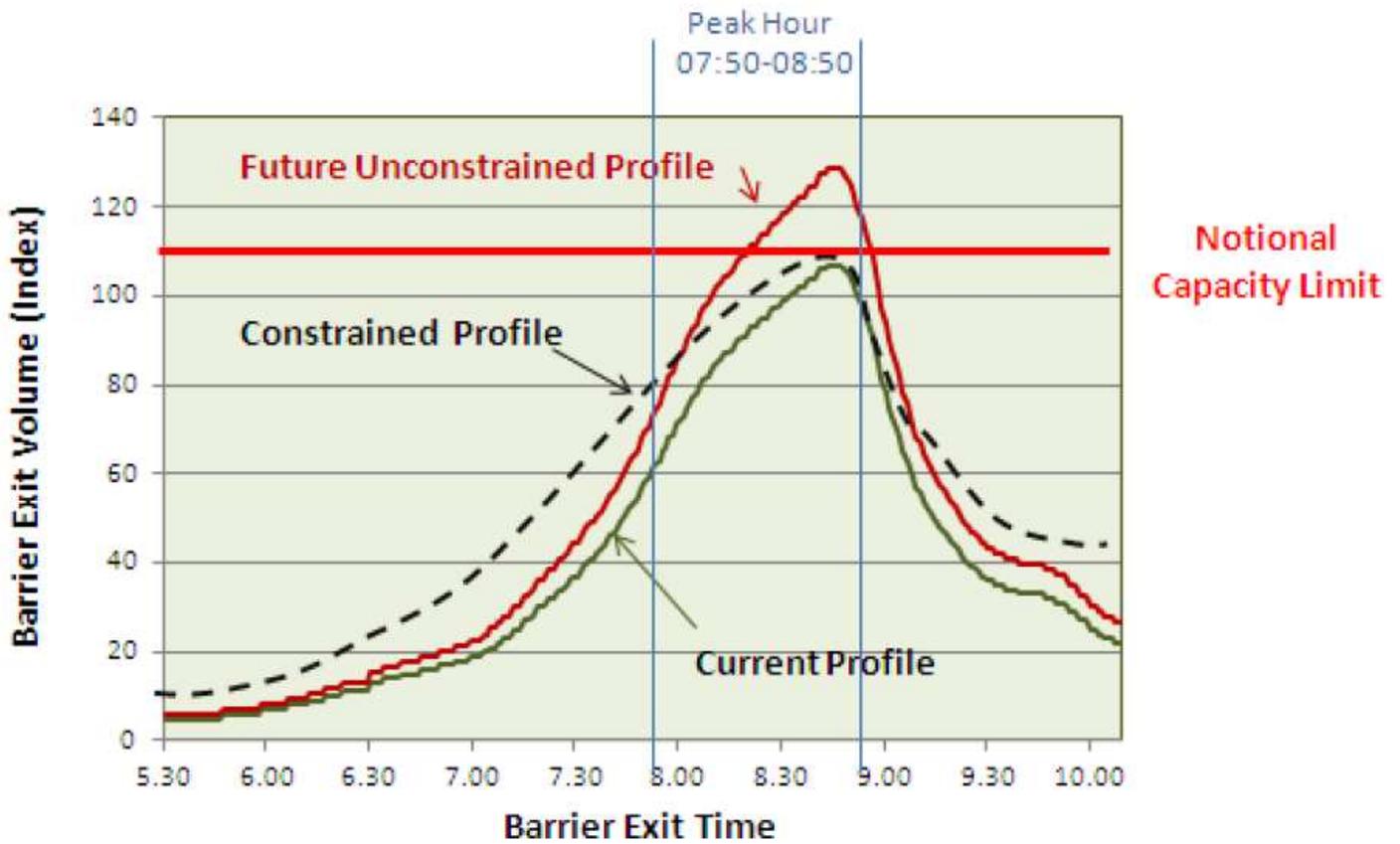
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Extra capacity could be achieved as follows:

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- F) Adding a branch of the Inner West Line via the old good line tunnel under Railway Square to Regent St (Mortuary) Station to improve Darling Harbour access;
- G) A reduction in on-street parking, a ban on personal use vehicles parking on-street in the CBD, and CBD peak-hour entry/exit restrictions for cars;
- H) A new station at Observatory Hill on the North Shore Line;
- I) Other measures such as wider footpaths, changes to bike paths, changes to bike helmet laws, encouragement of small electric vehicles and small plug-in hybrids now that BMW, with its i3 has produced an electric car that has public appeal.

A 66 metre, eleven-segment tram is required for a 300 passenger operational capacity. A tram of this length, with 6 bogies, may require two pantographs for power pickup, compared to the single pantograph for seven segment trams, if off-the-shelf equipment is preferred. While street blocks are of adequate length for a 66 metre tram, there will be train-like issues with ensuring passengers are clear of doorways as doors close.

Figure 3.4: Constrained and Unconstrained Temporal Patronage Profiles



Source Douglas Economics 2012 paper on computerised models for rail line capacity

Figure 2 - Sydney CBD – public transport demand profile – bus demand profile assumed similar to rail.

Figure 4-1: Key Bus Route Paths in the Sydney City Centre⁹⁸



When compared to Figure 4, the only overlap, and thus interchange opportunity is the Central precinct.

Figure 3 – Revised CBD bus routes



Figure 4 - Tram route for comparison with the future bus routes

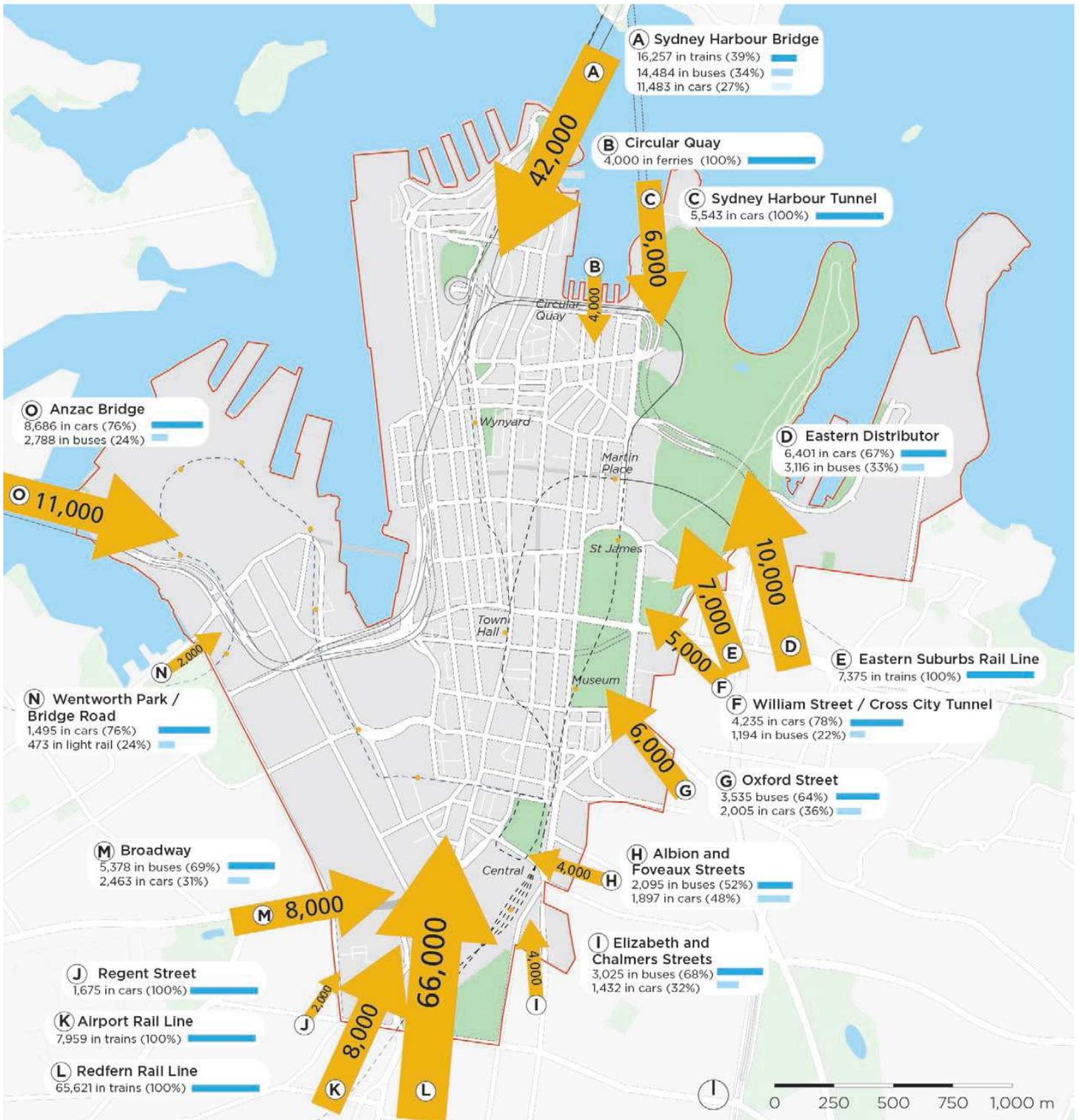
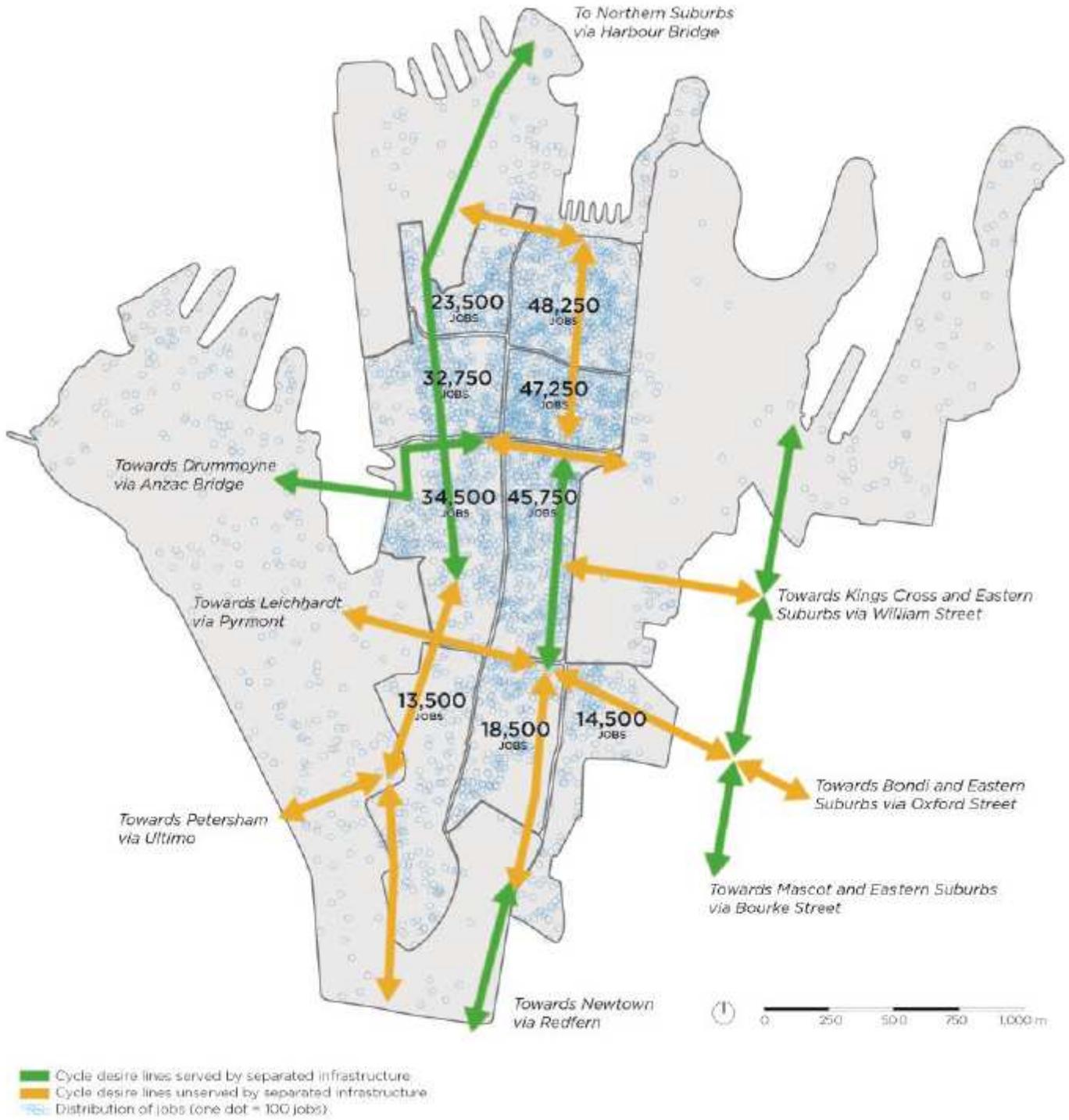


Figure 5 – CBD Access Strategy – AM peak hour data

Figure 2-19: Cycle Gateways Job Density

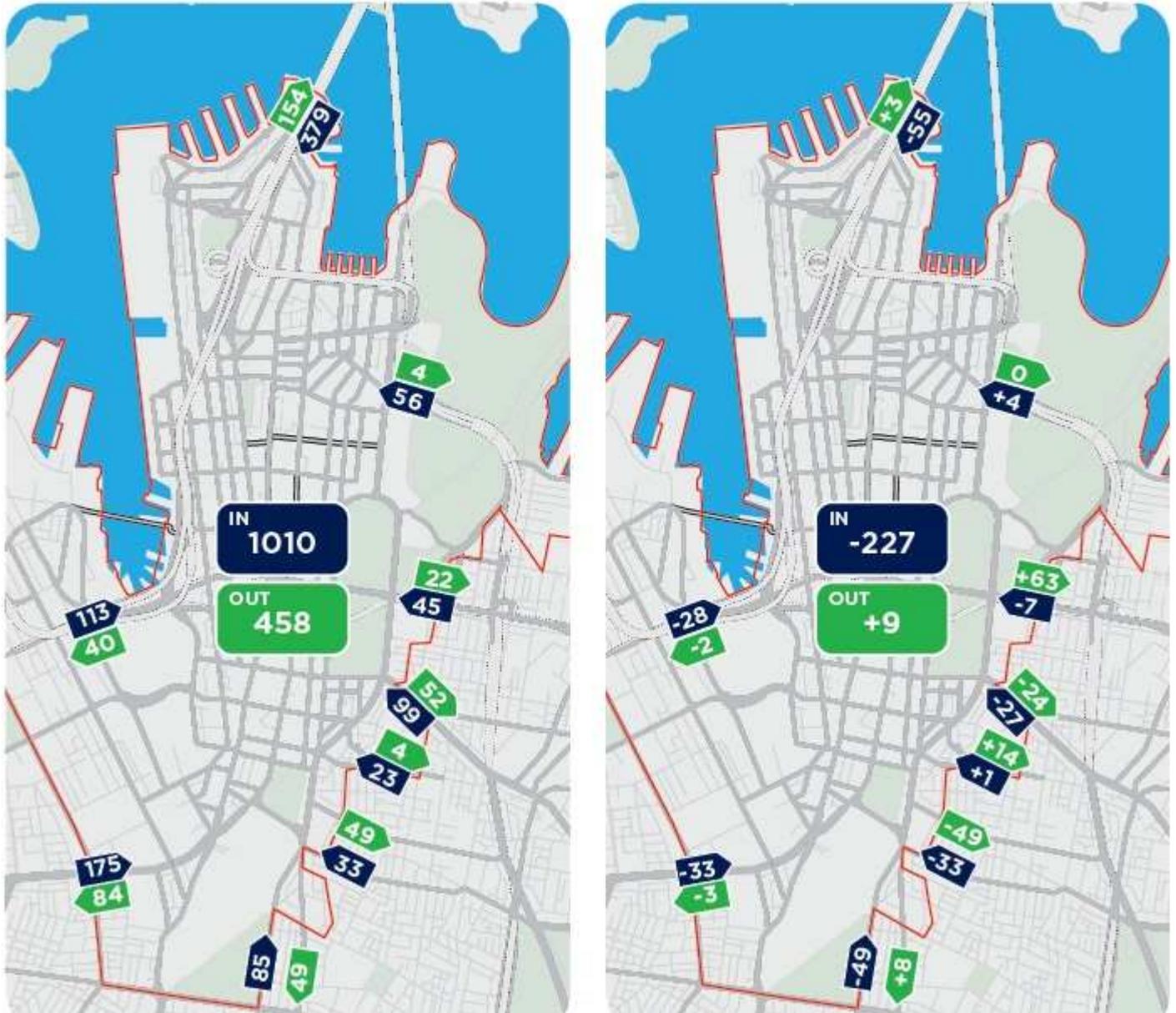


Source: Transport for NSW unpublished data

Figure 6 – CBD job locations by precinct

Existing bus network am peak hour (8:00 to 9:00am) bus volumes

Light rail and redesigned bus network am peak hour (8:00 to 9:00am) change in bus volumes



Source – Draft NSW Transport Masterplan 2012

PE – 296 buses entering the CBD from the south and east are being reduced by 104 buses – 35%. The growth in buses entering the CBD westbound on Cahill Expressway, are articulated express buses from the South East which will remain when trams are introduced – these buses average 55 passengers compared to 36 for the standard buses. The 60 articulated buses have greater capacity than the tram service.

Figure 7 – CBD bus entry and exit and changes in conjunction with the CSELR

Table1.Estimate of passenger line loads 2021 AM peak based on the preliminary service specifications outlined by the Operations Adviser Interfleet's Initial Light Rail Operational Services Plan, 2013 (Figures 3-11, 3-12 and 3-13 and section 7.3 of EIS Tech paper 1 – Transport operations report)

Stop	Inbound Fig 3-12			Outbound Fig 3-13		Inbound and outbound ^^^						Inbound PE estimate ^^				Outbound PE estimate ^^			
	Line load ^^	Ave % full ^^^^	NET board-alight	Line load ^^	NET board-alight	Tot board Fig 3.11 Sc 7.3	Total Alight Sc 7.3	Qty Inbound board	Qty Outbnd Board	Qty Inbound Alight	Qty Outbnd Alight	Estimate based on min/max figures, Estimate seen as more likely by author							
												Board	alight	NET	Line load	Bord	alight	NET	Line load
Randwick 800 seats only	826	27.5	826	0	-361	1731** 826	361	1731** 826	0 0	905** 0	361 361	826 1050	0 0	826 850	826 1050	0 0	361 350	-361 -350	0 0
UNSW High St buses terminate at uni	1,426	47.5	600	361	-2,040	478 749	2,188	478 749 max 600 min	0 0 min 148 max	-122 ** 149 max 0 min	2040 min 2188 max	625 650	25 20	600 630	1426 1680	124 50	2164 2250	-2040 -2200	361 350
Wansey Road Residential only	1,871	62.4	445 Too low	2,401	160	505 921	316	345 max 445 min 761 max 445 min	160 min 60 max 160 min 476 max	316 max 0 min 316 max 0 min	0 min 316 max 0 min 316 max	740 650	295 20	445 630	1871 2310	321 110	161 10	160 100	2401 2550
Racecourse Residential and Randwick TAFE	2,330	77.7	459 Too high	2,241	45	473 691	187	428max 459 min 646 max 459 min	45 min 14 max 45 min 232 max	187 0 min 187 max 0 min	0 min 187 0 min 187 max	550 450	91 100	459 350	2330 2660	141 50	96 100	45 -50	2241 2450
Moore Park - Rwk Syd Boys/Girls	2,214 est	73.8 est	-116 est 44%	2,196	-49 est 50%	58 est 50%	210	58 max 0 min	0 min 58 max	161 116 min	49 min 94 max	44 20	160 160	-116 est -140	2214 est 2520	18 25	67 175	-49 est -150	2196 est 2500
Kingsford 800 seats only	1,454	48.5	1,454 **	0	-515	2,198 1,454	515	2,198 ** 1,454	0 0	744 ** 0	515	1454 1700	0 0	1454 1700	1454 1700	0 0	515 480	-515 -480	0 0
Strachan St Residential with a little retail	2,250	75.0	796 Too high	515	-79	322 802	84	322 max 796min 801 max 796 min	0 min -474** 0 min 6 max	5 max 0 min 5 max 0 min	79 min 84 max 79 min 84 max	800 600	4 20	796 580	2250 2280	2 10	81 80	-79 -70	515 480
UNSW Anzac Pde direct buses north to uni	2,539	84.6	289 Too low	594	-954	421 626	1,291	421 max 289 min 626 max 289 min	0 min 132 max 0 min 337 max	337 max 0 min 337 max 0 min	954 min 1086max 954 min 1291max	580 600	291* 20	289 580	2539 2860	46 50	1000 1150	-954 -1100	594 550
Todman Ave Residential with a little retail	2,813	93.8	274 Too low	1,548	-39	472 531	296	472 max 274 min 531 max 274 min	0 min 198 max 0 min 257 max	257 max 0 min 257 max 0 min	39 min 296 max 39 min 296 max	500 600	226* 20	274 580	2813 3440	31 25	70 75	-39 -50	1548 1650
Carlton St Small residential/shop area	2,968	98.9 ***	155	1,587	49	213 213	9	164 max 155 min	49 min 58 max	9 max 0 min	0 min 9 max	160 120	5 10	155 110	2968 3550	53 60	4 10	49 50	1587 1700
Moore Park - Kfd Syd Boys/Girls	2829 est	94.0 est	-148 est 56%	1,538	-49 est 50%	58 est 50%	267	58 max 0 min	0 min 58 max	218 max 148 min	49 min 119 max	44 20	192 190	-148 est -170	2829 est 3380	18 25	67 175	-49 est -150	1538 est 1650
Moore Park total Syd Boys/Girls	5,034	83.9	-264	3,734	-98	116 115	477	116 max 0 min 115 max 0 min	0 min 116 max 0 min 115 max	379 max 264 min 379 max 264 min	98 min 213 max 98 min 213 max	80 40	344 350	-264 -310	5034 5900	36 50	134 350	-98 -300	3734 4150

Stop	Inbound Fig 3-12			Outbound Fig 3-13		Inbound and outbound ^^^						Inbound PE estimate ^^				Outbound PE estimate ^^				
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Surry Hills Commercial/Resid ^See Table 2.2 below for 6400 figure – 5300x1.2	5,366 Max. load	89.4	332 Too low	3,832	-296 ???	3,276 889	852	3276 max 332 min 889 max 332 min	0 min 2944 0 min 558 max	556 max 0 min	296 min 3,276mx 296 min 889 max	600 700	268 200	332 500	5366 6400^	289 450	585 350	-296 100	3832 4450	
Central Stn # tnfer UNSW, CBD Too many pass off, way too few passengers on 15% of Cntral exit	3,488	58.1	-1,878 ~37% passng alight Ctrl too high	4,128	2669	477 2863	2,072	-2192 ** 0 min 194 max 0 min	2669 min 477 max 2669 min 2863 max	2072 max 1878 min 2072 max 1878 min	0 min 194 max 0 min 194 max	100 3000 15%	1978 1500 24%	-1878 1500	3488 7900	2763 3200 15%	94 400	2669 2800	4129 4350	
Rawson Place ## 5900 pass George @Goulburn – way too few transfer to bus	3,310	55.2	-178 Large positive expected	1,459	-417	1,331 1222	1,817	1331 max 0 min 1222 max 0 min	0 min 1331 max 0 min 1222 max	1400 max 178 min 1400max 178 min	417 min 1639max 417 min 1639max	10% bus 622 3000 50%	800 1500 20%	-178 1500	3310 9400	600 1000	1017 900	-417 100	1459 1550	
Chinatown Commercial Residential	4,070	67.8	760	1,876	-728	1040 1149	1,116	1040 max 760 min 1149 max 760 min	0 min 280 max 0 min 389 max	388 max 0 min 388 max 0 min	728 min 1116max 728 min 1116max	950 900	190 1900	760 -1000	4070 8400	199 400	927 600	-728 -200	1876 1450	
World Square ### Commercial Residential	4,351	72.5	281	2,604	222	1,124 838	335	281 min 902 max 281 min 616 max	843 max 222 min 557 222 min	0 min 335 max 0 min 335 max	335 max 0 min 335 max 0 min	450 400	169 1900	281 -1500	4351 6900	388 400	166 600	222 -200	2604 1650	
Town Hall ##### Bus/train William/Druitt 4000 bus pass	3,841	64.0	-510	2,382	465	541 827	872	0 min 76 max 0 min 362 max	541 max 465 min 827 465 min	510 min 872 max 510 min 872 max	362 max 0 min 362 max 0 min	300 300	810 1600	-510 -1300	3841 5600	527 500	62 600	465 -100	2382 1850	
QVB ##### Bus/ train Will/Druitt 4000 bus pass	2,975	49.6	-866	1,917	-151	691 691	1,708	691 max 0 min	0 min 691 max	1557 max 866 min	151 min 842 max	350 400	1216 1600	-866 -1200	2975 4400	341 500	492 600	-151 -100	1917 1950	
Wynyard ##### Train and bus interchange Barangaroo	1,388	23.1	-1587	2,068	720	1,014 1015	1,882	294 0 min 295 max 0 min	720 min 1014 max 720 min 1015 max	1882 max 1587 min 1882 max 1587 min	0 min 295 max 0 min 294 max	150 200	1737 2200	-1587 -2000	1388 2400	865 900	145 150	720 750	2068 2050	
Grosvenor St Lang Park bus and The Rocks	764	12.7	-624	1,348	787	884 884	722	97 max 0 min	787 min 884 max	722 max 624 min	0 min 98 max	50 100	674 1600	-624 -1500	764 900	834 600	47 100	787 500	1348 1300	
Circular Quay	0	0	-764	561	561	565** 561	764	0	561	764	0	0 0	764 900	-764 -900	0 0	561 800	0 0	561 800	561 800	
TOTAL ****	-	-	0		0	17,872 17,867	17,864					9887 15460	9887 15460			7981 9155	7981 9155		6747	
												Total board/ alight *****				17868 24615	Difference TfNSW & PE Primarily board @Central, Rawson PI			

Table notes – see over page

Table notes

1. ^ maximum line load at Surry Hills – 5366 based on 2010 bus data, will reach 6,400 by 2021 based TOR growth rate of 1.65% p.a. for period 2021-2036
2. ^^ **Number in red indicates demand in excess of operational capacity. Numbers in Blue are from Section 7.3. Numbers in Green are the author's estimate of demand.** Figure 3-13 labelled 2036 on figure but referred to as 2021 in text. 2021 assumed. 10. UNSW total outbound alighting is 3,300 in TOR text, and has been adopted by the author in his estimate.
3. ^^^ maximums and minimums generated for each row based on the underlined NET board/alight minimum figure.
4. ^^^^ Average per cent full based on crush-load capacity of 300 per tram – 3,000 crush-load capacity for each branch line. Author estimate of operational capacity – 195 per tram (39 metre long passenger cabin, 5 pass/M, or 2 pass/M² – 1,950 per branch, 3,900 combined).
5. There is a significant data mismatch between figures 3-11 and 3-12 of TOR. However, the board and alight figures of Section 7.3 of TOR agree with Figure 3-12.
6. ** Incompatible data at start or finish of line. Negative number indicates data mismatch as a negative number of people boarding or alighting is not possible.
7. *** Surely an indicator of 'massaged' in that it is just under the crush-load capacity. However, as it is 98.9% of the crush-load of 3,000 for the full hour, it is well above the operational capacity (about 1,900%). But demand varies considerably across the peak hour as noted in "Modelling Train & Passenger Capacity Report to Transport for NSW By DOUGLAS Economics July 2012 for distribution" leaked to the SMH. Operational capacity is thus not 1,950 but more like 1,800 (60% of theoretical capacity), if regular significant instances of trams leaving passengers behind is to be avoided. Thus the number of trams provided should be based on 180 passengers per tram (more than twice their seated capacity of 80). Even with this capacity figure (180), a majority of peak-hour passengers will rarely get a seat on a tram – negatively influencing passenger perception of the service.
- 8 **** Figure quoted in report for total of in- and out-bound boarding is the rounded number of 18,000 passengers. Amounts in Figure 3.11 and section 7.3 add to 17,870+/-3. But when split into inbound and outbound, are approximately 10,000 (55%) and 8,000 (45%) respectively. This is a most unlikely scenario without pick-up restrictions at Central and Rawson Place, and are more evidenced of 'massaged' data. Considering that these figures are used to structure transport networks to get people to work, 'massaging' has appalling economic consequences. As the relevant boarding/exit data for buses is not readily available, the author has estimated likely numbers from the Interfleet graphs, other data in the EIS (including the newly released figure of employment data for CBD precincts), the Sydney CBD access strategy, and the author's knowledge of the CBD and south east Sydney.
9. ***** The authors estimate of unconstrained total boardings is 24,600 and possibly 26,000 considering the likely interchange demand at Rawson Place. The unconstrained inbound-outbound ratio in the AM peak is likely 65%-35%. The author's estimate of 6750 higher patronage is essentially composed growth adjusted south east patronage plus expected boardings inbound at Central and Rawson Place. In practice 7,000, or more, commuters will need to find alternate transport.
10. # In 2021 over 110,000 pass will arrive by train in CBD. Over 20,000 pour out of Central each day based on BTS 6.30 to 9.30 AM figures. Assume 15% catch tram northbound to the city while another 15% (TOR data), catch tram east to UNSW/POWH. Central 38,450, Town Hall 42,307, Wynyard 37,930. – <http://www.bts.nsw.gov.au/Statistics/Train>
11. ### Rawson Place – transfers bus to tram. Broadway buses 5,378 passengers 2011 according to the CBD Access Strategy. South West transfers allow access to UTS, USyd, RPAH.
12. #### World Square - 5,900 bus passengers at Goulburn St from Broadway – Source 2011 Access Strategy.
13. ##### Town Hall 4,500 passengers on east-west buses on Druiitt/Park Sts in AM peak hour – assume one 1/12th get tram north, and 1/12th get tram south, plus transfers from Town Hall trains and local residents.
14. ##### QVB is similar distance as Town Hall to east-west buses on Druiitt/Park Sts in AM peak hour – assume one 1/12th get tram north, and 1/12th get tram south, plus transfers from Town Hall trains and local residents.
15. ##### Wynyard will have transfers from buses and trains – 16,000 on buses stopping at Wynyard and about 20,000 getting off trains – assume just 3% get trams – 200 northbound, 900 southbound.
16. Peak hour boarding are expected to grow from 18,000 to 23,000 between 2012 and 2036 – 27.8% growth – 1.65% p.a. Appears rather low for an 'improved' journey and future demand expectations. Tram numbers will only rise 20% - From 20 to 24.
17. Douglas Economics 2012 Figure 3.4 above, shows peak hour demand variation for rail. The peak of the peak-hour is 15% above average constrained demand for the peak-hour. Capacity should be targeted at 10% above average peak-hour demand to ensure few people are left behind at the peak line load stop. The peak-hour average demand should be no more than 3,600, or 160 per tram. TfNSW intends peak loads of 85% of crush-load capacity - 255 passengers per tram.
18. Rawson Place will take on much of the role of Railway Square as bus-rail interchange for George St.
19. Author's estimate corrects for anomalies in table such as relative boardings/alightings between stops. It also assumes the modal interchange penalty will be removed for CBD transfers. The government is introducing a new mode (trams) for many passengers – the Opal interchange penalty is inequitable. The free 555 bus service currently allows interchange without penalty – as it runs on George St, it will be abolished?

Appendix 1 - Transport operations report (TOR) demand data and commentary

Transport operations report Section 7.3 precinct analysis data for each stop

Circular quay 561 boardings and 764 alightings forecast for 2021. 874 boardings and 979 alightings forecast for 2036.
 Grosvenor St 884 boardings and 722 alightings forecast for 2021. 1,180 boardings and 958 alightings forecast for 2036.
 Wynyard 1,015 boardings and 1,882 alightings forecast for 2021. 1,267 boardings and 2,491 alightings forecast for 2036.
 QVB 691 boardings and 1,708 alightings forecast for 2021. 811 boardings and 2,171 alightings forecast for 2036.
 Town Hall 827 boardings and 872 alightings forecast for 2021. 1,149 boardings and 1,129 alightings forecast for 2036.
 World Square 838 boardings and 335 alightings forecast for 2021. 942 boardings and 400 alightings forecast for 2036.
 Chinatown 1,149 boardings and 1,116 alightings forecast for 2021. 1,461 boardings and 1,309 alightings forecast for 2036.
 Rawson Place 1,222 boardings and 1,817 alightings forecast for 2021. 1,450 boardings and 2,063 alightings forecast for 2036.
 Central 2,863 boardings and 2,072 alightings forecast for 2021. 3,830 boardings and 2,835 alightings forecast for 2036.
 Surry Hills 889 boardings and 852 alightings forecast for 2021. 1,292 boardings and 1,035 alightings forecast for 2036.
 Moore Park 115 boardings and 477 alightings forecast for 2021. 134 boardings and 571 alightings forecast for 2036.
 Carlton St 213 boardings and 9 alightings forecast for 2021. 241 boardings and 10 alightings forecast for 2036.
 Todman Ave 531 boardings and 296 alightings forecast for 2021. 637 boardings and 421 alightings forecast for 2036.
 UNSW Anzac Pde 626 boardings and 1,291 alightings forecast for 2021. 708 boardings and 1,673 alightings forecast for 2036.
 Strachan St 802 boardings and 84 alightings forecast for 2021. 1,024 boardings and 99 alightings forecast for 2036.
 Kingsford 1,454 boardings and 515 alightings forecast for 2021. 1,851 boardings and 615 alightings forecast for 2036.
 Racecourse 691 boardings and 187 alightings forecast for 2021. 802 boardings and 213 alightings forecast for 2036.
 Wansey Rd 921 boardings and 316 alightings forecast for 2021. 1,029 boardings and 358 alightings forecast for 2036.
 UNSW High St 749 boardings and 2,188 alightings forecast for 2021. 842 boardings and 2,803 alightings forecast for 2036.
 Randwick 826 boardings and 361 alightings forecast for 2021. 1,008 boardings and 401 alightings forecast for 2036.

Table 2-2: Existing Bus Service Types

Bus Service Type	Service Characteristics	Existing Bus Trips (2010 AM Peak Hour)		
		Average Loading (per Bus during 2010 AM Peak Hour)		
1. CBD Allstop Services				
☑ Stop frequently from their suburban origin to the CBD				
☑ Operate All Day in both directions				
☑ Primarily use Oxford, Cleveland or Foveaux Street to access the CBD from the South East				
		135	36	4,860 passengers
2. CBD Express Services				
☑ Stop frequently on suburban routes before reaching a key node and running direct to the CBD without stopping				
☑ Typically operate during the peak periods only in the peak direction				
☑ The bulk of these services (54/62) utilise the eastern distributor to access the CBD and operate contra peak south along Elizabeth Street				
		62	55	3,410 passengers
				<u>8,270 total</u>
3. Cross-Regional Services				
☑ Do not enter the CBD but rather provide links between key centres, such as Bondi Junction				
		47	-	

PE - 135x36 (4,860) standard bus and + 8x55 (440) = 5,300 enter CBD via Central and will be replaced by trams. Based on forecast growth of 18,000 to 23,000 (both directions) from 2021 to 2036 (1.65% p.a.). 5,300 will grow 20% to 6,360 by 2021.

The bulk of existing bus services within the south east CSELR corridor are CBD All Stop services (135 trips per hour) which operate to the CBD throughout the entire day. This includes the existing Metro Bus Routes M10 and M50. These services are supplemented when demand increases during the peak period by express bus services (62 trips per hour) which generally pick up until Randwick or Kingsford and then run express into the northern end of the CBD via the Eastern Distributor (Note the X39 is the only express service in the study area not operating via the ED).

Existing bus services within the CSELR corridor operating to the CBD carry approximately 8,300 customers during the AM peak hour. The bulk of CBD bus customers (59%) in the CSELR corridor use the All-Stop services although the loadings per bus trip are significantly lower when compared to express services.

The express CBD express services are currently experiencing the strongest growth in patronage, a trend anticipated to continue.

Cross regional services are also provided to create connections to other key centres as well as linking the numerous education, shopping and health precincts.

In addition to regular route services, express university buses are provided to the UNSW, school special services to Sydney Boys and Girls High School, and Special Event services are provided to the Moore Park precinct and Royal Randwick Racecourse during events. These are also discussed within this report.

Table 7-1: Light Rail Stop Precinct Forecast Mode Share

Year	AM peak light rail trips by access mode				Access mode share		
	Bus /ferry	Walk	Rail / light rail	Total	Bus /ferry	Walk	Rail
2021	9,497	5,589	2,782	17,867	53%	31%	16%

Source: NSW Bureau of Transport Statistics, 2013.

Table 7-1 shows that the anticipated primary mode for access to light rail will be bus – accounting for approximately 53% of all passengers during the AM peak. The second highest forecast mode share for light rail access is walking, with nearly 31% of all passenger access forecast by pedestrians. Heavy rail interchange is expected to provide the next highest at approximately 16%.

There will however be significant variance within the anticipated levels of modal demand for access to light rail across the system, dependent on the stop location and availability of complementary public transport stations, stops and services.

Notable exceptions will be locations such as Town Hall and Central Station stops, both of which will experience a significant heavy rail to light rail interchange due to the proximity of the major, established CBD rail stations.

PE - 2,782 rail/light rail is primarily UNSW/POWH bound passengers getting on outbound trams at Central.

2.3. Bus Services

Approximately 1,600 bus services enter the Sydney CBD during the two-hour morning peak, through the primary CBD cordon points at the Sydney Harbour Bridge, Anzac Bridge, Broadway, Oxford Street, William Street and Elizabeth Street. **PE – 1,000 in the one-hour peak**

In the **South East CSELR Corridor**, the bus network can be segmented into three broad service types:

- ☐ **CBD All-Stop Services:** stop frequently from their suburban origin to the CBD, operating all day in both directions and **primarily using Oxford, Cleveland or Foveaux Streets to access the CBD.** These services carry over 9,000 passengers in-bound during the AM Peak (PE - more than 5,500 during the intense peak 1 hour);
- ☐ **Cross-Regional Services:** these services generally **do not enter the CBD**, but rather provide links between key centres, such as Bondi Junction and the Airport and operate all-day;
- ☐ **CBD Express Services:** stop frequently on suburban routes before reaching a key node (Kingsford town centre at Gardeners Road, and Randwick town centre at Belmore Road) and running direct to the CBD without stopping. These services operate during the peak periods only in the peak direction. **The bulk of these services use the Eastern Distributor to access the CBD and operate contra-peak south along Elizabeth Street.**

2.3.1. CBD bus issues

George Street in particular carries up to **290 buses in the peak direction** during the AM peak (7am – 9am) and this is expected to increase to over 310 by 2015. The congested bus network - combined with the demands of other road users - impacts on customer service and delays essential business functions.

As illustrated in Figure 2-3 below, the bus reliability issues for the combined inbound and outbound bus movements along the key corridors are most prominent during the AM peak.

However, travel time reliability continues to be impacted throughout other times of the day. The lower activity lunch hour still demonstrates 2-3 minutes delays and the busier afternoon peak 3-4 minutes. (Barely a delay – trains have difficulty matching this.

Finally, the University of NSW is a major trip generator in the CSE Corridor, and requires a significant volume of buses to transport students and staff – primarily between Central Station and the Kensington campus. Currently, over 340 bus trips per day operate this route in both directions; but even with this volume of buses congestion is regularly experienced at the Eddy Avenue bus stand. The UNSW student population is expected to grow from 37,000 to about 50,000 – an increase of 43 per cent²⁰.

PE - 270 buses in peak two hours from South East – same as Broadway. But 60 express buses averaging 55 passengers each (in the second hour) enter CBD via Eastern distributor to run south down Elizabeth St. 52 of these buses will continue once trams are operating. The X39 services do not use the ED and will be replaced by trams.

As an example, at Railway Square there are 250 inbound buses in the two-hour peak period, which means a bus has to stop, unload/load, and depart almost every 30 seconds. The situation at Wynyard is similar: there are almost 600 inbound buses over the two-hour peak meaning approximately 12 seconds turnaround time per bus,

while entering the CBD from the Oxford/Flinders Street corridor there are approximately 270 inbound buses over the two-hour peak.

Figure 2-4 illustrates average bus variability during the AM peak hour along key access routes through the CBD which are on average between 5 – 733 minutes behind schedule. Key findings from the analysis by corridor are summarized as follows:

- ☒ Elizabeth Street – a large number of buses approaching the CBD from the east merge with general traffic on Elizabeth Street, causing high levels of congestion which results in bus services experiencing average delays of 7.0 minutes in the AM peak.
- ☒ York Street - many inbound buses from northern Sydney travel on the Harbour Bridge and through the CBD via York Street. Buses travelling along York Street experience average delays of 5.9 minutes in the AM peak.
- ☒ George Street - is a main corridor for western and southern region buses travelling through the CBD, along with the free shuttle bus (555). Buses travelling along George Street experience average delays of around 5.6 minutes in the AM peak.
- ☒ Anzac Parade - is a key corridor providing access in to the CBD for a large number of South Eastern Region buses. Buses travelling along the Anzac Parade corridor experience average delays of around 5.2 minutes in the AM peak.

PE - the average variance to timetable would suggest that a few minutes need to be added to the timetable.

3.3. Special Events

It is intended that light rail will replace the current special event bus operations between Moore Park and Central station. Regular light rail services will also replace the operation of dedicated park-and-ride shuttle to the University of NSW and Randwick Racecourse that operate for some events. With a combination of event shuttles and regular services, a maximum headway of 2.5 minutes (**PE -24 services per hour rate**) can be achieved in the peak direction during the post-match period.

With passenger capacity of 5 passengers per square metre, a total hourly capacity is possible of:

☒☒45 metre LRV – 9,836 passengers/hour (both directions combined)

PE – equals 205 passengers per tram – barely 2 standing passengers per square metre

☒☒90 metre LRV – 14,175 passengers/hour (both directions combined)

PE – equals 295 passengers per tram – about 4 standing passengers per square metre

Based upon maintaining a 36% mode share to light rail for all crowd sizes, the likely duration of event specials will range from 20-55 minutes following an event depending on capacity required and operational strategy employed.

PE - A tram fitted with 80 fixed seats and no other, has 46 m² to 50 m² of standing space. The capacity at various standing densities as noted in Appendix 1 of this paper is as follows:

2/M2 gives 80+92-100=172-180; 3/M2 gives 80+138-150=218-230; 4/M2 gives 80+184-200=264-280; 5/M2 gives 80+230-250=310-330 passengers.

The various figures quoted for capacity in this report indicate a poor understanding within TfNSW leadership of public transport capacity.

4.2.2. South East bus network

This section provides an overview of the bus service changes that will deliver an integrated bus and light rail public transport network in the South East CSELR corridor.

The key elements of the South East Bus Network are described below with the route changes illustrated in Figure 4-2 and summarized in Table 4-1. Those bus routes not mentioned should be assumed to continue operating on their existing routes. At this stage the proposed bus service changes in the South East are draft and will be subject to further refinement through community consultation.

In general the changes propose the establishment of an all 'day network' of light rail trunk services to the city with feeder and cross regional bus services. The strategy proposes to retain selected express buses during the peak periods to the northern end of the Sydney CBD to complement the 'all day' network.

The key features include:

- ☒ The majority of existing All-stop CBD bus services which operate along Alison Road and Anzac Parade in duplication of the CSELR are proposed to no longer operate to the CBD but change to become feeder routes for the light rail. These provide all day connections to light rail stops in the eastern suburbs. Examples include:
 - Some Anzac Parade services (Routes 391, 392, 394, and 399) feed the CSELR at Kingsford but continue on to Todman Avenue, Kensington providing direct connections from the south to the UNSW;

– Randwick bus services feed the CSELR at Randwick but instead of terminating they generally extend to Bondi Junction or other new cross regional links, or terminate on Belmore Road at Alison Road.

☒ Additional cross-regional routes would be introduced to satisfy growing demand between key trip generators such as the Airport, Green Square, the University of Sydney, Edgecliff and Paddington as well as provide improved connections to the CSELR;

☒ UNSW will be served by cross-regional routes via High Street including routes 348, 370, 375, 400 and 410;

☒ CBD express bus services which operate via the eastern distributor are proposed to be retained to provide a direct journey for customers travelling to destinations in the northern CBD during the peak periods only;

PE – 52 current express bus services with 2011 average load of 55 passengers retained operating in contra-peak direction on Elizabeth St.

☒ In the PM peak, CBD Express services are proposed to operate via Elizabeth Street and Oxford Street rather than through the Eastern Distributor (as existing); (PE -Operating in Peak direction)

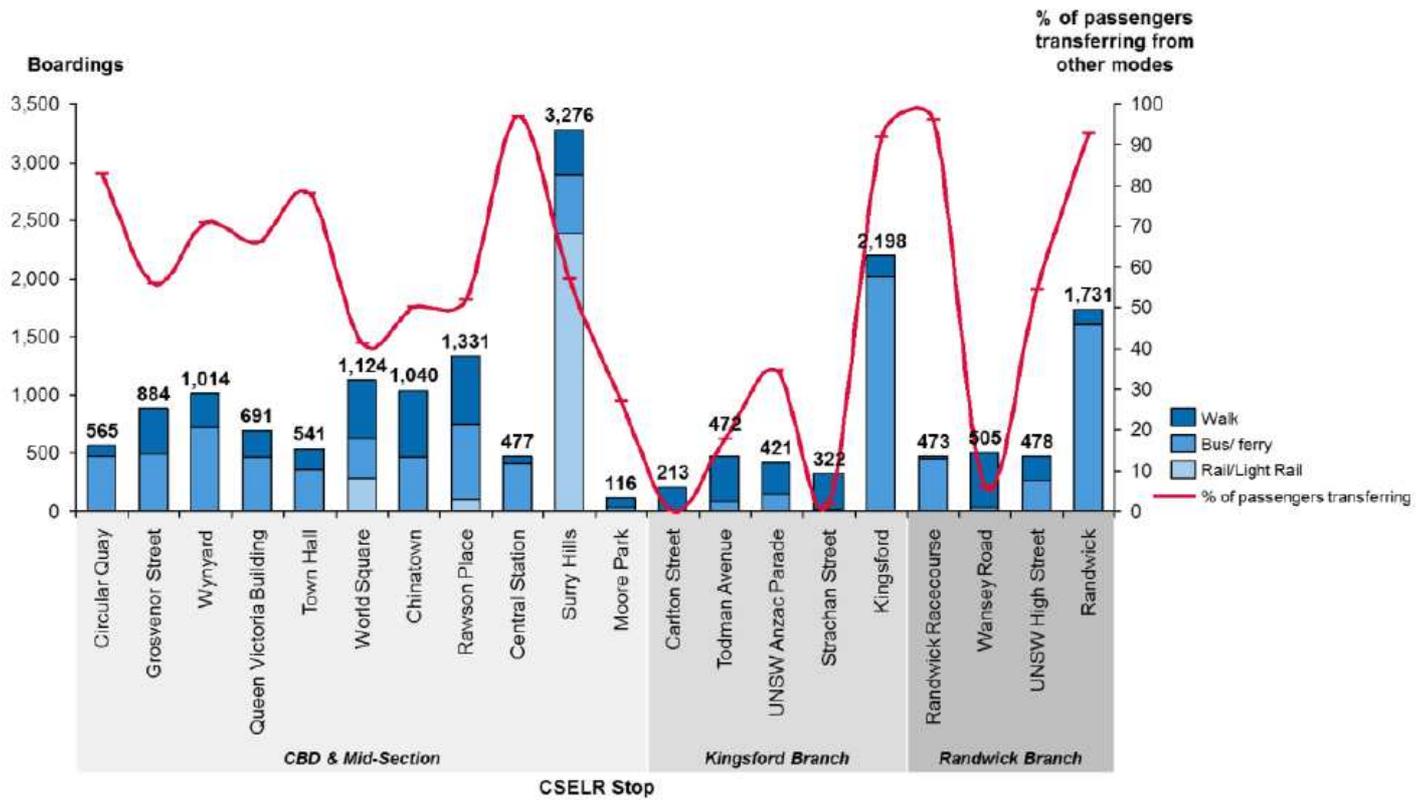
☒ University Express Bus Services provided between Central Station and the UNSW would be replaced by the CSELR;

☒ School Special Bus Services provided between Central Station and Sydney Boys High School and Sydney Girls High School would be replaced by the CSELR;

☒ Special Event bus services provided between Central Station and Moore Park precinct and Royal Randwick Racecourse are expected to be redesigned to provide new links during events to supplement the CSELR and increase public transport mode share for special events as discussed in Section 3;

☒ Metrobus routes M10 and M50 are not proposed to operate in the Eastern Suburbs as their function is largely undertaken by the CSELR.

Figure 3-11: 2021 AM Peak CSELR Boardings and Mode of Access by Light Rail Stop⁸⁶



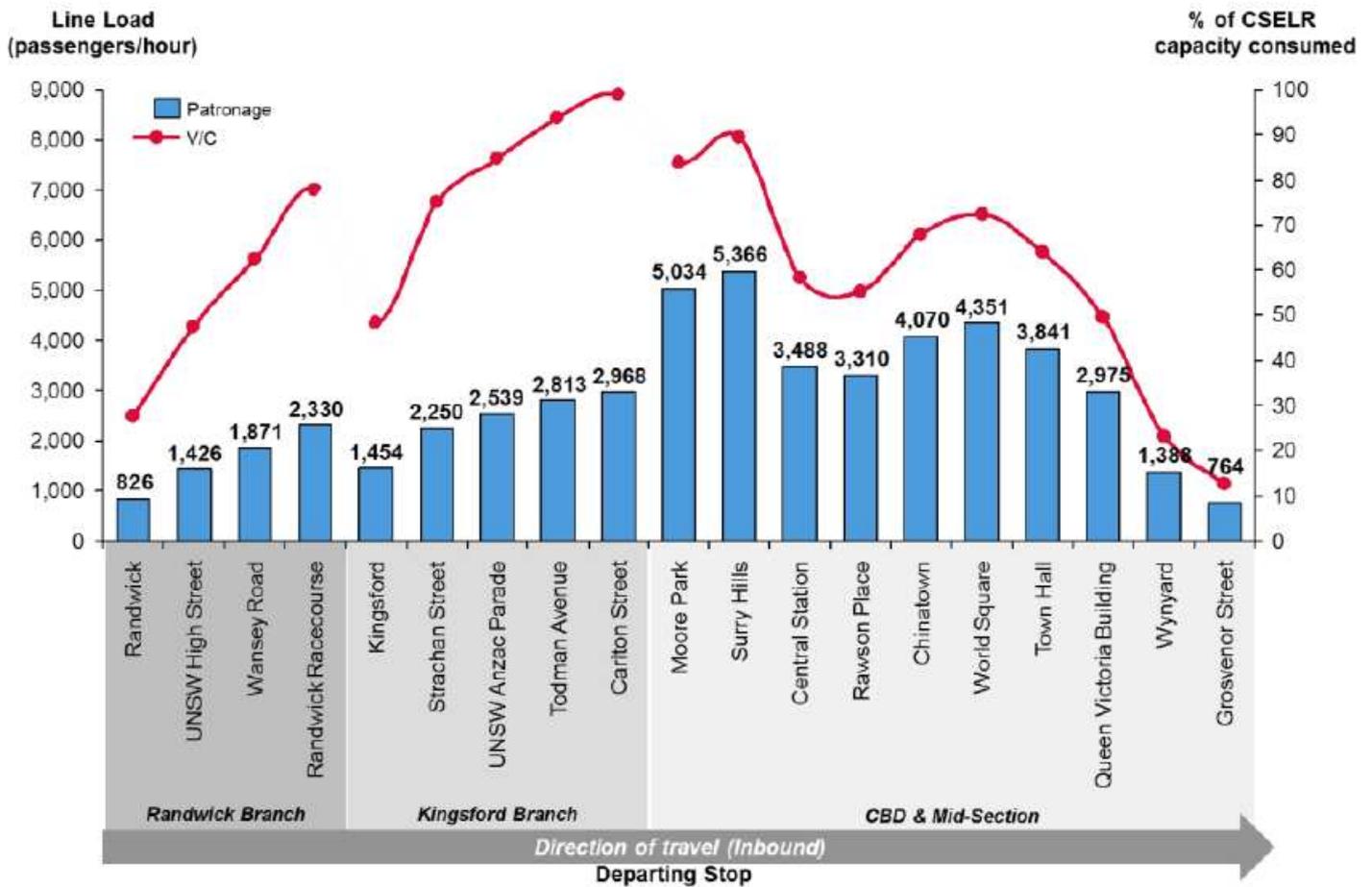
The CSELR is also anticipated to take a significant proportion of the growth in future demand from the eastern suburbs to the CBD.

As shown in Figure 3-12, peak line loads inbound (based on the preliminary service specifications outlined by the Operations Adviser 87) **exceed 5,300 passengers per hour in the 2021 AM Peak Hour⁸⁸**.

PE - Table 2-2 shows that 5,300 passengers were carried into the CBD in 2010 by the buses that are to be replaced by trams. Based on the expected growth in boarding from 18,000 to 23,000 between 2021 and 2036, boarding should grow 20% between 2010 and 2021 to 6,360.

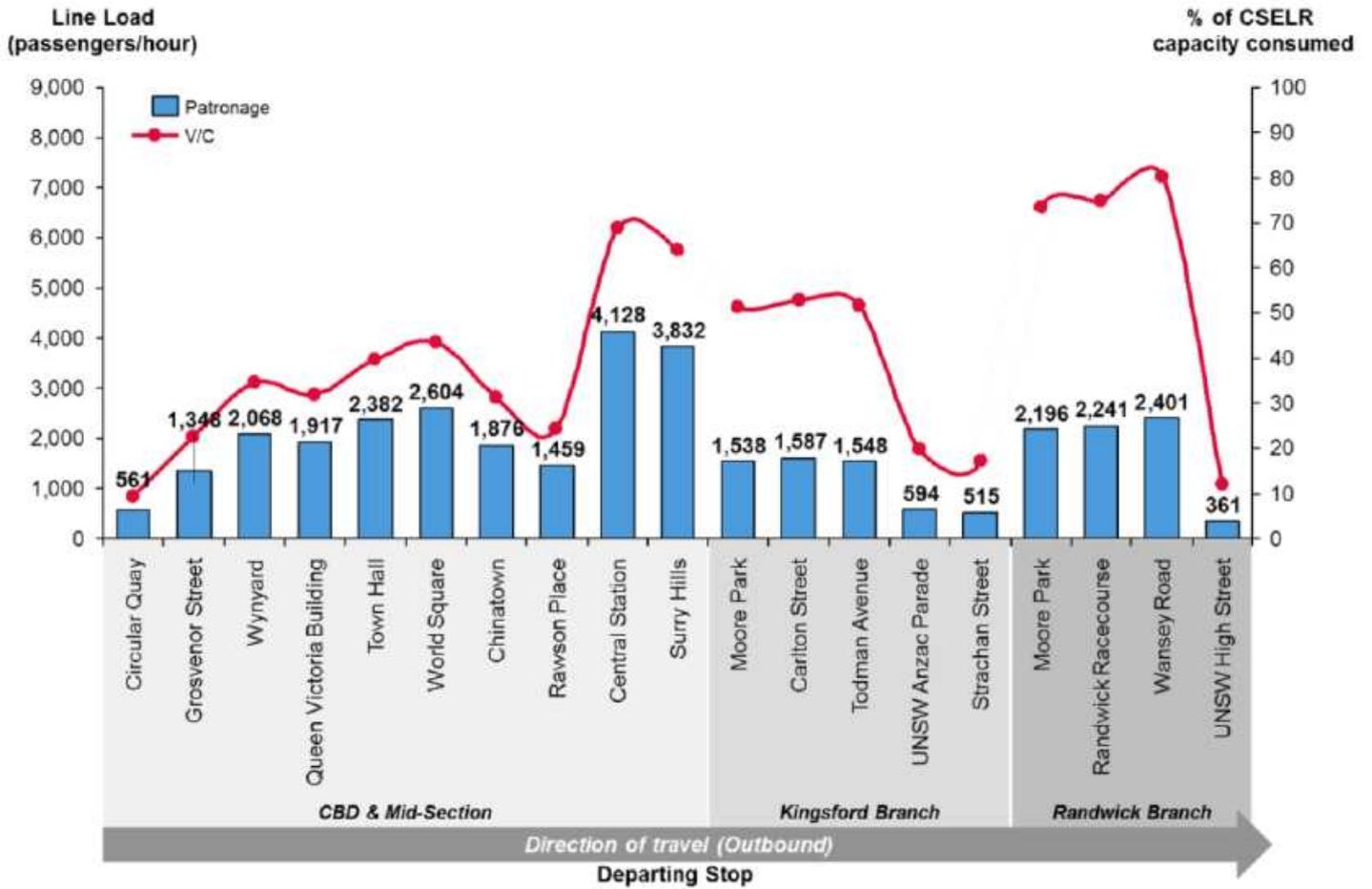
This table does not agree with Figures 3-12 and 3-13 and Section 7.3 (which gives total boardings and alightings for each stop) as demonstrated in the above table.

Figure 3-12: 2021 Inbound AM Peak CSELR Line Load and Capacity Consumed⁸⁹



PE - Capacity consumed is based on 300 passengers per tram – well above operational capacity of 195 passengers

Figure 3-13: 2036 Outbound AM Peak CSELR Line Load and Capacity Consumed⁹²



PE - Capacity consumed is based on 300 passengers per tram – well above operational capacity of 195 passengers

Figure 2-4: CBD Buses - AM Peak Timetable Variance for Both Directions in Minutes by Street³⁴



PE - The variability is an indicator that timetable journey times need to be extended. The variability appears less than by private vehicle. Growing journey times are an indicator of a need to a higher capacity public transport mode – that is rail not light rail.

5.4.1.2. Rawson Place

Functional changes

With the implementation of light rail on George Street and the city centre bus network redesign, Rawson Place will become a major interchange for bus and light rail passengers (Figure 5-4 -over page).

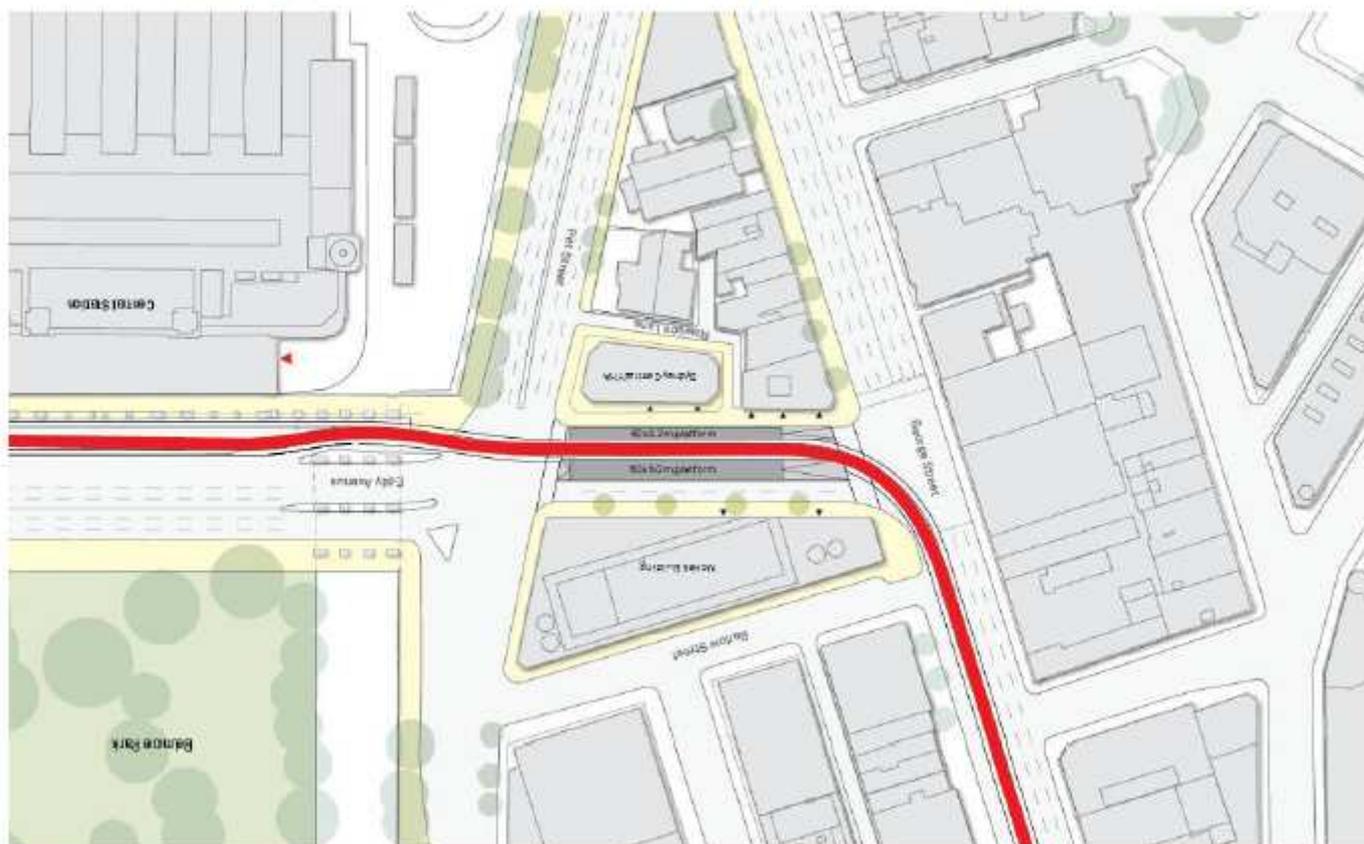
To facilitate efficient bus and light rail movements Rawson Place will only accommodate bus (westbound only) and light rail. As such, the functional changes to Rawson Place have been designed to complement the city centre bus network redesign and to provide the required bus stopping and turn around capacity required to operate reliable bus services to the CBD. Existing local traffic that uses Rawson Place will be diverted via Pitt and Barlow Streets, whilst through traffic is likely to divert via alternative corridors such as Elizabeth and Goulburn Streets.

Buses will be provided with a bus stopping lane adjacent to the light rail platform (i.e. provides cross platform interchange) and an additional passing lane to the north. Traffic signals at the eastern end of Rawson Place will provide controlled access for turning buses into Rawson Place from Pitt Street and Eddy Avenue. At the western end of Rawson Place traffic signals will permit buses to turn left into George Street and across the light rail alignment. Both sets of traffic signals will provide convenient pedestrian access to Rawson Place and across George and Pitt Streets.

Due to the volume of bus services in this precinct, additional stops for city bound bus services will be provided on the western side of Pitt Street just north and south of Rawson Place. These stop locations enable bus passengers to transfer to light rail without crossing any traffic movements.

Eddy Avenue cannot be used by the bus routes that are stopping adjacent to, or at, Rawson Place as it is not possible to turn right from Pitt St into Eddy Ave from the kerbside lane or north of Rawson Place. This is consistent with the city centre bus network redesign.

Figure 5-4: Light rail alignment along Rawson Place corridor



Appendix 2 - Technically similar trams to EIS specification

The Sydney specification tram is virtually identical to the Gold Coast tram – a seven segment tram. Blackpool, United Kingdom and Ghent and Antwerp, Belgium, have ordered 5 and seven segment version of the Gold Coast tram. Their specifications from the Bombardier website and are applicable to the Sydney trams.

Operational standing capacity is 2 passengers per square metre. 4/sq. metre and 6/sq metre are shown because it is physical possible to pack human beings that tightly. Such crowding is occasionally seen in developing countries. For normal peak hour services and sporting and special events, it is not desirable for public safety and public order reasons for people to stand at greater density than 2 passengers per square metre. Seating density is approximately 2/sq.metre.

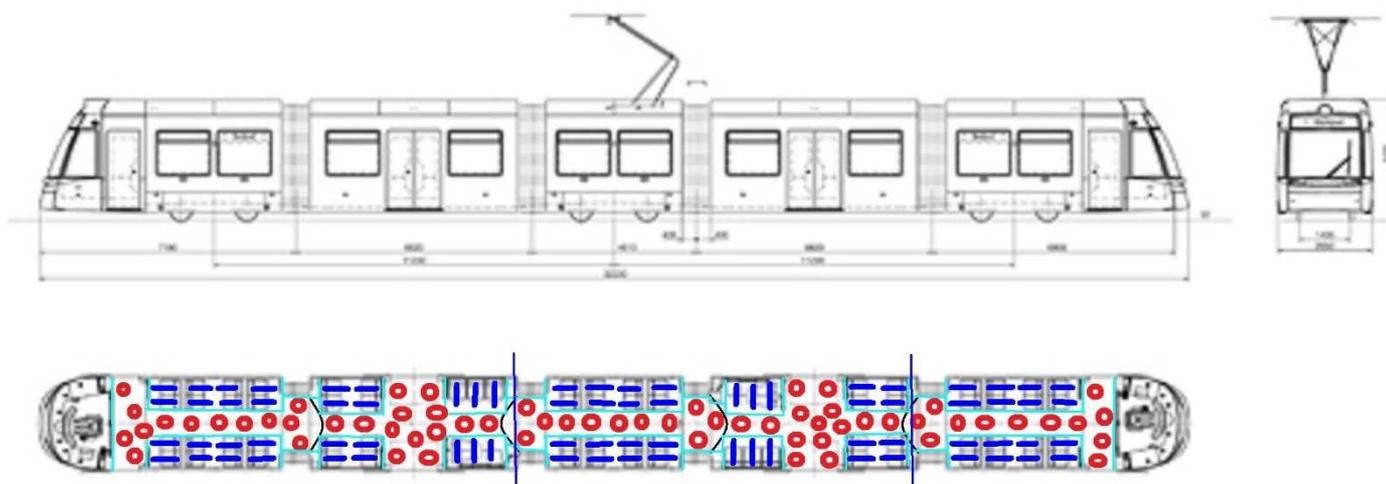
Based on the Blackpool drawing, the driver's cabins are 2 metres long each. The passenger cabin of the 43 metre Gold Coast tram is 39 metres long. Another way to look at public transport capacity, is passengers per linear metre of the passenger cabin. Our 3 metre wide trains and 2.65 metre wide buses have an operational capacity of 5.5 passengers per linear metre of the passenger cabin based on RailCorp and Sydney Buses figures. Trams are the width of a bus, but have the personal space expectations of a train. 5 passengers per metre is a realistic estimate for the capacity of a tram. $5 \times 39 = 195$ passenger operational capacity.

In Figure 1 below, the Blackpool tram has 76 seated (64 in fixed seats and 12 folding seats in segment with wheel chair/pram space – when occupied, the seated capacity is reduced) with standing capacity of 63 to 64, for a total of 140 operational capacity. At this capacity, on-board circulation is restricted, slowing down alighting and boarding.

For Gold Coast and Sydney, an extra motor segment and intermediate segment is added – an extra 24 fixed seats and 6 folding seats with space for 25 standing. Total capacity is 88 fixed seats and 18 folding seats (total 106 seats) and 88 standing = 194. In practice, leaving out 8 fixed seats for a total fixed seat capacity of 80, only creates space for another 8 standing passengers.

A tram fitted with 80 fixed seats and no other, has 46 m^2 to 50 m^2 of standing space. The capacity at various standing densities is as follows:

$2/\text{M}^2$ gives $80+92-100=172-180$; $3/\text{M}^2$ gives $80+138-150=218-230$; $4/\text{M}^2$ gives $80+184-200=264-280$; $5/\text{M}^2$ gives $80+230-250=310-330$ passengers



— seated passenger, ○ standing passenger at operational capacity

The Sydney/Gold Coast trams have an additional two segments corresponding to those marked.

Figure 1 - Flexity 2 Blackpool with passengers added for full operational capacity.

FLEXITY 2 - Gold Coast, Australia

Following on from the 16 five-module *BOMBARDIER FLEXITY 2* trams ordered by the launch customer Blackpool, UK, the Gold Coast Rapid Transit system is Bombardier's first order for the longer, 7-module *FLEXITY 2* tram version. The order placed in June 2011 is for 14 distinctive, modern 45 m long *FLEXITY 2* trams.

In another first for Bombardier Transportation, the luggage racks for the new trams have been designed to accommodate surf boards to support the Gold Coast's most popular sport in this city which is known by many as the ultimate surfers' paradise.

Operator	Gold Coast Council
Length	43 m
Width	2.65 m
Max. Speed	70 km/h
% low floor	100 %
Seated Passengers	80 + 4 tip-up seats
Standees	229 (4 pass/m ²)

FLEXITY 2 - Ghent and Antwerp, Belgium

The Flemish transport operator has placed the biggest single tram order in its history for the supply of 48 *BOMBARDIER FLEXITY 2* trams for the cities of Ghent and Antwerp with Bombardier Transportation. The contract includes an option for additional 40 trams. This tram order will provide a full facelift for the networks in the two largest Flemish cities in Belgium.

Not only will the *FLEXITY 2* trams replace the ageing fleet of PCC trams, they will also increase capacity. Thanks to the increased length of 20 of the new vehicles, the new vehicles can carry more passengers than the current trams. Passengers will benefit from the easy access and comfort onboard the low-floor vehicles that are equipped with multi-purpose areas for wheelchair users and storage space for bicycles and prams.

The vehicles come in different lengths and configurations. Ghent will receive 10 bi-directional seven-module vehicles with a length of approximately 43 m, able to accommodate 378 passengers. Antwerp will receive 38 uni-directional trams: 10 seven-module vehicles with a length of approximately 43 m and a capacity for 380 passengers and 28 five-module vehicles with a length of approximately 31 m, able to accommodate 266 passengers in total. The trams are 2.3 m wide and equipped with meter gauge bogies with conventional axles offering a smooth ride as well as low wear and tear of both wheels and tracks. The motorized bogies feature fully suspended motors and gearboxes to keep ground vibrations to a minimum. All vehicles are equipped with heating, ventilation and air conditioning (HVAC) systems for drivers and passengers. The passenger HVAC system features efficiency improvements such as variable CO₂ controlled fresh air flow to ensure an optimized climate for the passengers.

Operator	De Lijn
Length	31,430 mm / 42,660 mm
Width	2,300 mm
Max. Speed	70 km/h
Minimum horizontal curve radius	16 m
Maximum gradient	62 ‰
% low floor	100 %
Seated Passengers	72 - 108
Standees	212 - 330

PE - 212 standees = 4 pass/sq.metre, 330 = 6/sq.metre. In practice, 2 pass/sq.metre is operational capacity.

FLEXITY 2 - Blackpool, United Kingdom

The City of Blackpool is the launch customer of the *BOMBARDIER FLEXITY 2* tram. In delivering these 16 trams, Bombardier Transportation is contributing to the revitalization of Britain's most traditional tram system, enhancing the city's attractiveness while reducing energy consumption.

Based on the highly successful *FLEXITY* platform with a strong reputation for performance and reliability, the *FLEXITY 2* tram combines proven features and innovation in a single vehicle. It sets the highest standards in the areas of comfort, safety and environmental protection.

Blackpool's FLEXITY 2 trams are 32.2 m long and 2.65 m wide, with five sections and three bogies. The vehicle is capable of carrying about 74 seated passengers, with additional wheelchair and pushchair space plus standing room.

Their technical advantages include an improved carbody concept, with better corrosion protection and an enhanced bogie design, the FLEXX Urban 3000. The overall vehicle mass is reduced and the MITRAC propulsion technology will result in significantly lower energy consumption

The Blackpool & Fleetwood Tramway today carries nearly three million passengers a year, about 75% of them tourists.

Operator	Blackpool Transport Services Ltd
Length	32,230 mm
Width	2,650 mm
Max. Speed	70 km/h
Minimum horizontal curve radius (track/depot)	25 m/20 m
Maximum gradient	60‰
% low floor	100%
Seated Passengers	74
Standees	148 (4 pass/m ²)



Figure A2- Gold Coast Flexity 2 tram