

CBD AND SOUTH EAST LIGHT RAIL PROJECT
ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1A

PART B: THE PROPOSAL AND ITS DEVELOPMENT





4. Definition design development

This chapter describes the approach to the refinement of the definition design for the Sydney CBD and South East Light Rail Project ('the CSELR proposal' or 'the CSELR'), including the development of design criteria and principles, the approach to the design principles and issues, design options considered and assessment against a range of criteria.

The definition design for the CSELR proposal would be refined during detailed design and may change following consideration of submissions from the community or stakeholders during exhibition of the definition design and final approval of the proposal.

4.1 Approach to design development

Following the public announcement of the CSELR preferred route by the NSW Government in December 2012, further design development was undertaken on the preferred route to take into account, and address where possible, the following key issues:

- stakeholder requirements and comments
- engineering constraints
- constructability risks
- functional and operational requirements
- environmental and social impacts and opportunities
- potential urban design and public realm benefits including minimising impacts to the corridor's streetscapes including loss of existing trees, green spaces and public spaces.

This process involved identifying and assessing a range of options for definition design elements such as:

- the alignment of discrete sections of the route
- stop locations and configurations
- interchange design and function
- special event running operations and stop design for special event stops
- stabling and maintenance facility locations and operational layouts
- design elements such as overhead wire pole placement and substation locations
- urban design elements such as extent of wire-free running and the George Street pedestrian zone
- likely impacts of the options and alignment on the public domain
- integration with the existing and diverse localities along the corridor, for example, Devonshire Street's strong inner city character.

4.1.1 Design and operational parameters and principles

CSELR alignment and stop design criteria

The design of the CSELR alignment and stop locations has involved several considerations including economic, engineering and environmental issues. The alignment design considered the following components:

- *general alignment* — The key criteria for the general alignment of the CSELR proposal track were to provide dual light rail tracks that are segregated from the impacts of traffic congestion, to minimise overall environmental and property and streetscape impacts, and to satisfy engineering design criteria. These parameters are defined by the rolling stock capabilities, speed, travel times, power consumption, passenger comfort and operational requirements.

- *stop locations* — The locations of the proposed stops are critical in ensuring the CSELR proposal provides a maximum benefit to the community and were, therefore, a key consideration in the alignment design process. Key criteria for establishing the preferred stop locations included providing conveniently located and accessible stops which were compliant with the *Disability Discrimination Act 1992* (DDA) as well as the national *Disability Standards for Accessible Public Transport* (DSAPT); minimise environmental impacts; and providing an amenity that enhances the customer experience, without incurring unnecessary cost.

In addition to the infrastructure design criteria identified above, a series of user criteria were also considered for the development of the stops and general alignment for the CSELR proposal. The key user requirements that were utilised during the development of the preferred route alignment included:

- optimising stop locations for user accessibility and surrounding populations
- creating effective interchanges with train stations and bus and ferry interchanges
- provision of special event services to large event attractor locations including Moore Park and Royal Randwick racecourse
- providing a 70 kilometre per hour maximum design speed, subject to alignment geometry and distance between stops, and allowing for a maximum of approximately 20 kilometres per hour within the pedestrianised zone
- providing straight tracks at stop locations (i.e. no curved or split-level stops)
- ensuring noise and vibration impacts are minimised to existing surrounding residents and businesses
- safeguarding future proposed/planned projects such as urban renewal sites or proposed infrastructure upgrades/extensions
- safeguarding future extension of the light rail alignment.

Road integration principles

As the CSELR would largely operate within existing roadways, it was also important to consider how best to integrate the light rail with other road functions, including:

- identifying light rail intersection priority opportunities and how the level of priority given to light rail would impact on the layout of road intersections
- maintaining or rationalising turn lanes for existing roadways, where possible
- minimising land acquisition and impact on property outside the existing road corridor
- considering emergency vehicle access along the route
- providing safe crossing access for pedestrians at platforms and midblock locations
- providing safe and efficient pedestrian access to platforms
- maintaining general property access and ability for both private and commercial property owners to access and service their properties wherever possible
- identifying differences in precincts within the light rail corridor along both urban, collector and arterial roads
- maintaining safety along the corridor and integrating light rail into the roadway with a mixture of segregated and non-segregated road environments.

4.1.2 Urban design context and principles

Whilst the engineering and light rail systems are important elements in the design of infrastructure components for the CSELR proposal, integration with the community and surrounds, meeting customer needs and providing a good public transport experience are also essential.

Integrated urban design process

Urban design, as a process, has assisted with focusing the development of options for the CSELR proposal. This has included a focus on achieving customer-based outcomes, as well as the proposal objectives set by Transport for NSW (refer section 3.3) and the design criteria discussed above.

At the time of announcing the preferred route for the CSELR proposal in December 2012, the core identity and context of the CSELR route was well understood and examined; however the urban design principles were flexible and could be adapted to suit the criteria as the definition



design was refined. It is considered important that the design includes a high degree of natural way-finding, where the corridors and connections are naturally obvious, the reliance on signage is reduced, and the areas around each stop become popular public spaces.

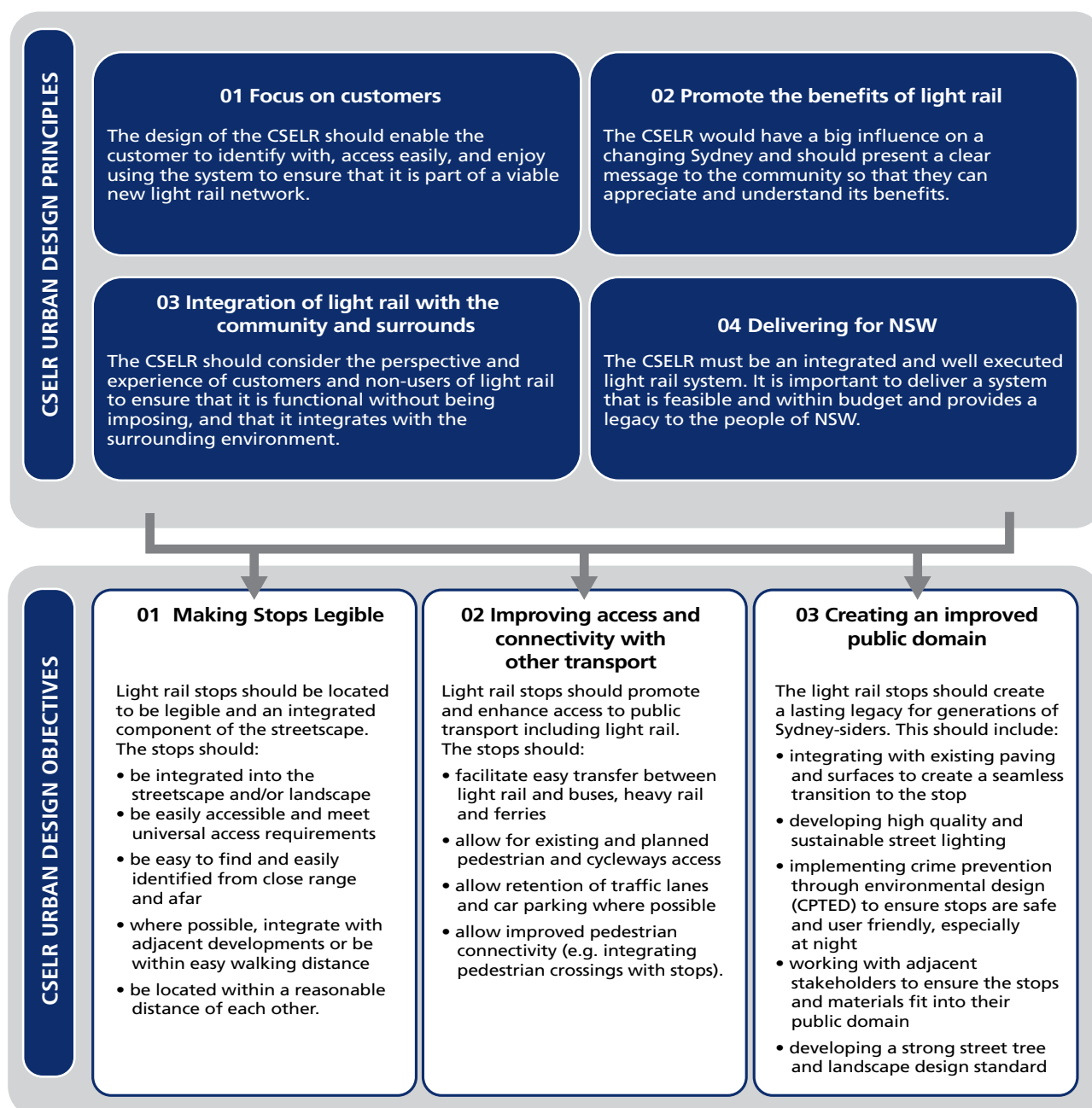
CSELR urban design principles and objectives

A series of urban design principles formed the urban design basis of the CSELR proposal from initial feasibility design through to the development of the definition design. These continue to provide a robust 'check and balance' mechanism for the ongoing development of the proposal's design.

Supporting the urban design principles is a set of three urban design objectives. These objectives were used to test, evaluate and focus the developed design throughout the refinement of the CSELR proposal. The urban design objectives have been used in conjunction with more detailed investigations and typically focused on the location of the proposed light rail stops. The three objectives are focused on legibility, access and the public domain.

A summary of the CSELR urban design principles and objectives is provided in Figure 4.1.

Figure 4.1 CSELR urban design principles and objectives



Light rail typologies

Based on the urban design objectives and principles identified above, a series of alternative light rail typologies were identified for the route of the CSELR. The identified typologies were developed for both the alignment of the CSELR and each of the proposed stops. The intent of these typologies was to allow options for the CSELR alignment and stop design to appropriately respond to the key characteristics of the existing urban setting, maximise their effectiveness as part of the proposal and minimise overall environmental, social and economic impacts.

Alignment typologies

For the alignment of the CSELR proposal, three main light rail typologies were identified. These alignment typologies closely correspond with each of the key urban design characteristics:

- *civic typology for the City Centre and Surry Hills precincts* — including pedestrianised, traffic, and village elements, represented by a highly developed built form and marked by iconic and identifiable buildings
- *park typology for the Moore Park and Randwick precincts* — characterised by a strong linkage to the open space of the surrounding land uses
- *boulevard typology for the Kensington/Kingsford Precinct* — characterised primarily by the built form, including medium-density low to mid rise apartments and shop-top housing, which includes a variety of small retail shops and restaurants.

Applying the typologies to the preferred alignment created three distinctive approaches to the design of the alignment, stops with interchange facilities and public domain of the corridors. Table 4.1 provides a summary of the functional requirements for the CSELR alignment through each of the identified alignment typologies and the response to these requirements.



Table 4.1 Alignment strategies

ALIGNMENT TYPOLOGY	FUNCTIONAL AND URBAN FORM REQUIREMENTS	RESPONSE TO REQUIREMENTS
Civic (including pedestrianised; traffic; and village elements)	• Reflect Sydney's CBD civic character. • Foster visual transparency. • Provide for a large number of passengers. • Allow for uninterrupted pedestrian permeability that integrates with the existing paths of travel for pedestrians, in particular along George Street. • Provide opportunities for functional items that are characteristic of a civic domain, such as appropriate street furniture, lighting, etc. • Respects the distinctive local character of Surry Hills.	• Ensure accessibility from all sides by incorporating platforms within both pedestrianised and traffic zones, with the stops with interchange facilities designed according to functional and capacity requirements (at Circular Quay and Rawson Place). • Provide for a George Street pedestrian zone between Hunter Street and Bathurst Street. • Integrate the stops as much as possible with the surrounding pedestrian areas - maximising permeability, transparency, views, and access. • Define stops through infrastructure design including canopies such that each stop acts as a marker canopy. • Where existing topography allows, ensure an integrated 'step free condition' along the back face of the platform, such that the platform is at the same level as the surrounding pedestrian zone. • Utilise materials that strike a balance between the refined and elegant qualities required in the Civic zone, and the Park and Boulevard typologies along the CSELR route.
Park	• Reflect the character and landscape of Sydney's leisure precinct of Moore Park, Centennial Park, Royal Randwick racecourse and the Entertainment Quarter. • Sensitively balance the impact of the new infrastructure with the high quality public domain. • Manage and limit the physical and visual impact of the alignment as it crosses through valuable urban open space. • Preserve and maintain the significant Fig trees along Anzac Parade and Alison Road. • Preserve the permeability of the parklands across the light rail alignment, allowing people to maintain access and use of the parklands.	• Seamlessly integrate the light rail infrastructure into the high quality public domain that it is located within. • Minimise the impacts to existing significant trees, where possible, and integrate landscape and planting solutions along the corridor. • Maintain maximum pedestrian permeability and access across the light rail. • Provide stops that have a strong presence yet are simple and visually lightweight. • Materials should complement the natural palette of materials that currently characterise the area of Moore Park, Centennial Park, and the Royal Randwick racecourse. • Limit the amount of fencing along the tracks, and where pedestrian control is required, use other means such as planting and more visually sensitive approaches.
Boulevard	• Reflect the urban character of Anzac Parade through Kensington and Kingsford. • Reinforce formal streetscape patterns with a regular street grid and intersections. • Recognise the central median as the light rail corridor. • Provide further activation of the streetscape within the town centres of Kensington and Kingsford.	• Create a central alignment as the transit corridor. • Reinforce the importance of the link from Central Railway Station to the University of NSW (UNSW). • Utilise the central median for new landscape treatment as part of the urban design solution including selective tree/palm planting. • Allow for interchange facilities at the UNSW Anzac Parade stop. • Use a controlled palette of materials along the length. • Introduce new street tree plantings to the side footpaths of the corridor.

Stop typologies

In a similar way to the alignment typologies identified above, three main light rail stop typologies were identified for the CSELR proposal. These closely correspond with each of the key urban design characteristics and their associated alignment typologies. The light rail stop typologies identified were:

- *Civic stop typology* — Within the Civic stop typology, there are two zones, a pedestrianised zone and a traffic zone;
 - *George Street Pedestrian zone* — The design intent for these stops is to integrate with the streetscape, using materials that are complementary to the overall urban design of the pedestrian zone. These stops are to be highly accessible, with level access to the back of the platforms where possible.
 - *Traffic zone* — The design intent for these stops is to provide safe access for pedestrians when crossing vehicle lanes, while minimising the visual extent of barriers and bollards.
- *Park stop typology* — These stops would be located within or adjacent to expanses of open space. Therefore they would potentially become highly visible elements in the landscape that can be seen from a distance. The design intent for these stops is to minimise their visual impact whilst still maintaining clear access. They also need to be well lit at night for improved safety and wayfinding.
- *Boulevard stop typology* — The design intent for these stops is to provide a local suburban identity that responds to the scale and character of the streetscape they are located within.

A more detailed description of each of the stops and their layout and typologies is provided in Chapter 5.

4.2 Refinement of the preferred option

An iterative process of design development and evaluation has been undertaken to define the CSELR proposal within the preferred route identified in December 2012. The design of each element evolved as a consequence of the results of preliminary engineering, traffic, financial, economic and environmental consideration in response to issues raised during consultations with other NSW Government agencies, local government, the community and other stakeholders.

Development of the design of the CSELR proposal has involved an extensive program of consultation and a series of workshops involving study team members, stakeholders and various interdisciplinary groups. The main mechanism for the design development process was a series of weekly design coordination meetings, attended by the wider project team. Issues were allocated to the relevant discipline area, (e.g. engineering, traffic and transport, operations or environment) for investigation. A typical option assessment process adopted for the CSELR proposal is shown in Table 4.2.



Table 4.2 Design development process

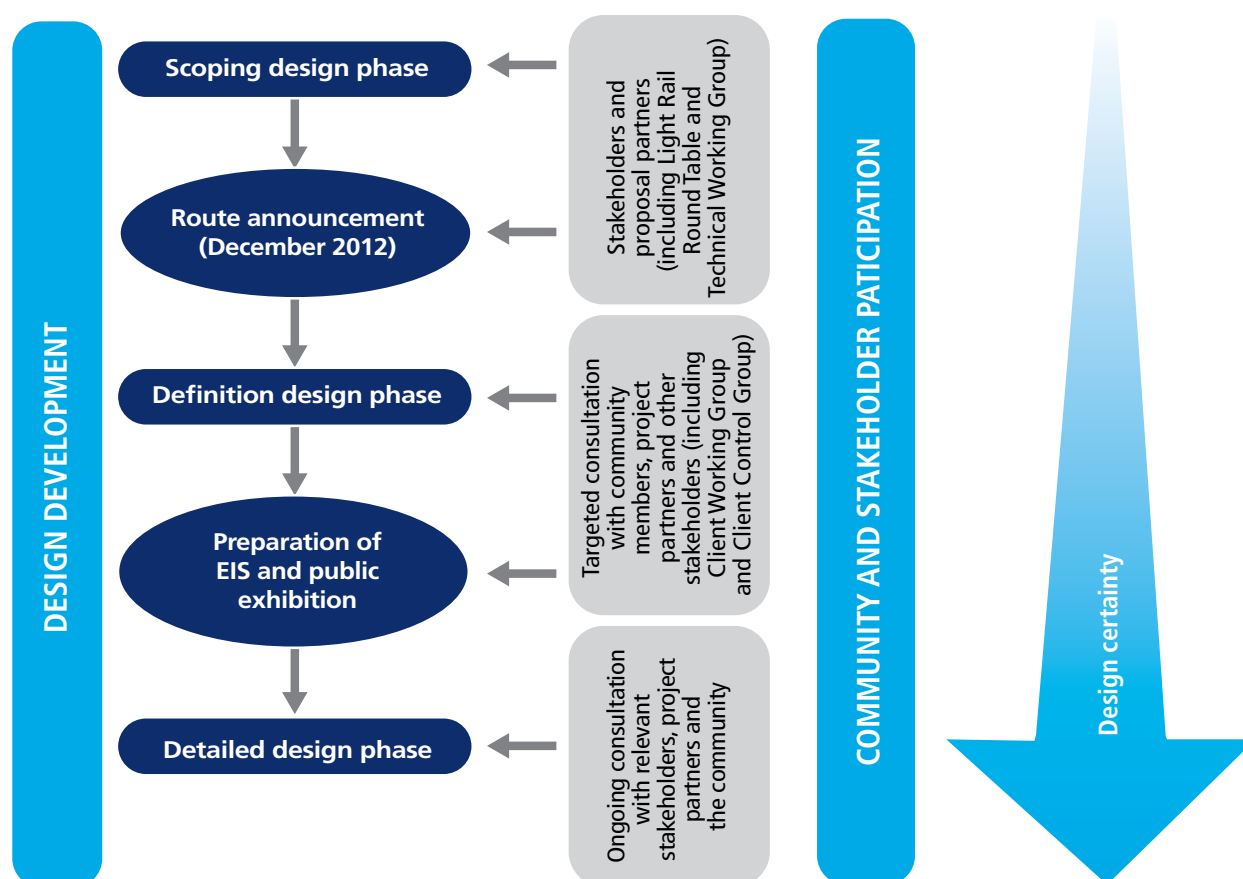
STEPS	ACTIVITIES/KEY QUESTIONS
Define the issue	Clearly identify the issue to be resolved through alternate option(s) (i.e. why do other options need to be considered?)
Confirm assessment criteria	List the criteria that the options will be assessed against to determine performance of the options.
Identify and describe options	- Develop a suite of potential options depending on the design issue or project element. - Validate options for feasibility and develop the options to a level of detail to allow an assessment of the impacts of each option against the assessment criteria. - Output to include concept drawings, operational descriptions and other data that would assist in the assessment phase.
Assess options and evaluate options	- What are the key benefits and disadvantages of each option? - How does the option(s) perform against the assessment criteria? - Would the alternate option(s) result in other adverse impacts? - Client Working Group paper prepared with a recommendation for the preferred option.
Decision making	- Does the alternate option(s) address the issue? - Does the option meet the proposal objectives?

Consultation with project partners and key stakeholders was undertaken to input into the design development process. Meetings focused on the requirements of key stakeholders or specific design elements, including:

- meetings with UNSW to discuss the location and layout of the UNSW Anzac Parade stop and UNSW High Street stop
- meetings with the Australian Turf Club to discuss the alignment and stop location for the Royal Randwick racecourse
- meetings with City of Sydney to discuss the extent of the George Street pedestrian zone and wire-free operations
- meetings with Randwick City Council to discuss the location and layout of the Randwick stop and the Wansey Road alignment
- meetings with the Centennial and Moore Park Trust to discuss potential impacts to land managed by the Trust.

Figure 4.2 shows a schematic representation of the integration between consultation and the development process through the previous and future design phases.

Figure 4.2 Design development process and stakeholder input



While numerous proposal elements were assessed and preferred outcomes were determined through the process described above, a number of key decisions were made that resulted in opportunities to further refine the design of the CSELR proposal. These are described further in the following sections and shown geographically in Figure 4.3.

4.2.1 Assessment criteria

The following assessment criteria were used to compare each of the design alternatives:

- *Light rail operations and functionality* — The operation and functional success of a proposal is guided by its ability to satisfy the strategic project needs (including travel times, patronage and capacity) and providing for major event transport needs. For the CSELR proposal, the assessment of design options considered these strategic needs (refer to section 3.3).
- *Light rail engineering design and constructability* — The engineering viability of a proposal is reflected in its ability to meet required engineering standards, while at the same time accommodating those constraints that influence the design. The design of the proposal was governed by both the relevant design standards and design parameters.
- *Environmental and social quality and impacts* — Environmental quality relates to the protection and enhancement of the local environment, integration of new and existing development, preserving heritage and achieving a sense of place with a high level of amenity, health and safety.
- *Accessibility* — Accessibility is generally defined in relation to the ease of access to opportunities (jobs, facilities, and activities) or the ease of being reached by customers, workers or clients. The criterion relates to the ability of the alternative to support and enhance both the regional and local traffic functions, access to public transport and conditions for pedestrians and cyclists.

Performance measures for each of the key assessment criteria described above are provided in Table 4.3.



Figure 4.3 Key design options considered

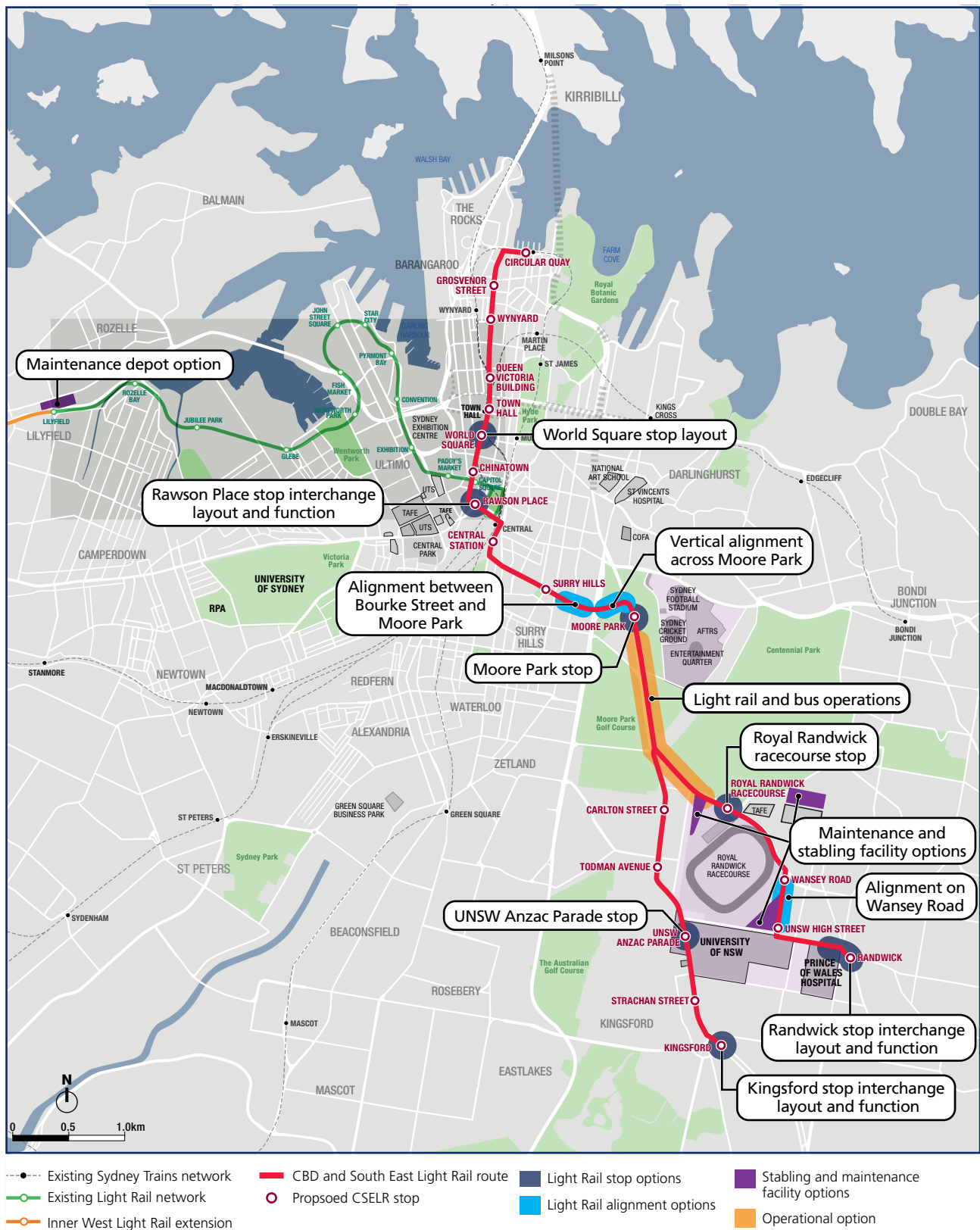


Table 4.3 Assessment criterion and performance measures

CRITERIA	PERFORMANCE MEASURES
Light rail operations and functionality	
Customer focus and benefits	• Change in travel time and reliability • Proximity to interchange with other public transport services • Change in the ease of access and use of stops • Impact on safety for light rail and other road users
Access to major facilities and developments	• Access to major trip attractors and urban growth areas • Ability to serve and stimulate areas of land use growth
Engineering design and constructability	
Engineering and construction risks	• Compliance with design parameters • Changes in engineering risks • Ability to incorporate safety in design elements • Risks to delivery program
Cost	• Capital cost • Extent and cost of property acquisition • Ability to compensate for property acquisition or impact
Environmental and social quality	
Changes to public and private amenity	• Change in the amenity and quantity of public spaces (usage, visual amenity, noise impacts, safety and security), including opportunities to improve or enhance the public domain • Change in amenity of private properties (usage, visual amenity, noise impacts, safety, privacy and security) • Change in the amenity of community facilities (usage, visual amenity, noise impacts, safety, privacy and security)
Environmental and cultural impacts	• Impact to biodiversity or loss of habitat • Impact to existing trees and landscape character elements • Impact on items of Indigenous and non-Indigenous heritage
Accessibility	
Local and regional traffic functionality	• Change to local connectivity • Change to capacity of regional roads
Accessibility and parking	• Change to direct property access on-street (including vehicle and by foot) • Change to parking and commercial zone

4.2.2 Ranking of alternatives

In order to provide an appropriate means of comparison, a qualitative assessment was undertaken, where relevant, using the following rankings:

- *Major positive effect* — A significant net gain or benefit is evident by comparison with the existing situation and/or would result in a very low cost.
- *Minor positive effect* — A net gain or benefit is evident by comparison with the existing situation and/or would result in a low cost.
- *Neutral effect* — No discernible change from the existing situation, or a balance between positive and negative effects, and/or would result in a moderate cost.
- *Minor negative effect* — A net adverse effect or disbenefit is evident by comparison with the existing situation and/or would result in a high cost.
- *Major negative effect* — A significant net adverse effect or disbenefit is evident by comparison with the existing situation and/or would result in a very high cost.

The comparison focused on the performance of each alternative in relation to the existing situation rather than relative to each alternative.



4.3 Light rail alignment options

4.3.1 Vertical alignment through Moore Park

Background

The CSELR proposal announced in December 2012 included an at-grade alignment through Surry Hills along Devonshire Street, passing through a residential area east of Bourke Street and across South Dowling Street at-grade before entering a tunnel under Moore Park west and Anzac Parade. As discussed in section 3.4.3, the at-grade alignment through Surry Hills was preferred over the Surry Hills tunnel option due to the cost and impact of building a long tunnel under Surry Hills and the Eastern Distributor, as well as the requirement for a stop in Surry Hills. A shorter tunnel option through Moore Park was preferred at this time as it provided the least impact on the Moore Park playing fields and did not cross Anzac Parade at-grade — a key requirement during the feasibility design to minimise traffic impacts on Anzac Parade.

During design development, an alternate vertical alignment was considered through this section of the route, whereby the alignment would be conveyed on a viaduct across Moore Park and Anzac Parade. This option was identified as potentially providing improved running times and reduced impact on the current traffic network relative to the tunnel option.

Description of feasible options

Two main options for the vertical alignment through Moore Park were considered for the alignment of the CSELR proposal. These options are briefly described below. Visualisations of each option are shown in Figure 4.4. Note: A surface option across Moore Park and Anzac Parade at-grade was not considered as it would adversely affect the Moore Park playing fields, creating severance and safety issues with sporting field users and would result in unacceptable traffic delays on Anzac Parade.

Tunnel

This option would comprise an at-grade crossing of South Dowling Street and a new bridge over the Eastern Distributor before the light rail would enter a shallow cut-and-cover tunnel at the western edge of the Moore Park playing fields. The tunnel would then extend under Moore Park and cross Anzac Parade, via a mined tunnelling technique, and then surface north of the Moore Park stop, located at-grade adjacent to the existing busway. During construction, the cut-and-cover tunnel would be disruptive to the Moore Park playing fields; however once complete the playing fields would be reinstated as one continuous open green space. This option would result in some delays on South Dowling Street as a result of the new signalised intersection, replacing the existing staged pedestrian crossing near Parkham Street (refer to section 9.2.2).

Viaduct

For this option, the CSELR would cross over Moore Park on an elevated structure, known as a viaduct. The viaduct would start to rise and cross over Parkham Place, South Dowling Street and the Eastern Distributor and Moore Park to the eastern side of Anzac Parade. To avoid steep grades on the eastern side of Anzac Parade prior to the Moore Park stop, this stop would also be elevated on the viaduct. A viaduct would avoid traffic impacts to local roads and South Dowling Street that would be caused by an at-grade crossing. The viaduct would be a significant change to the visual landscape in this area. However, a number of modern light rail networks around the world include viaducts, with striking modern designs that are integrated into the streetscape. A viaduct would also have safety benefits because it would elevate the vehicles and remove the light rail from other traffic interactions.

Figure 4.4 Visualisation of the vertical alignment options through Moore Park including a cut-and-cover tunnel (top) and viaduct (bottom)



Visualisation of cut-and-cover tunnel option



Visualisation of viaduct option



Assessment of feasible design options

An assessment of the Moore Park vertical alignment options against the identified assessment criteria is provided in Figure 4.5.

Figure 4.5 Assessment of vertical alignment design options through Moore Park

Assessment criterion	Options	
	Cut-and-cover tunnel	Viaduct
Light rail operations and functionality		
Customer focus and benefits		
Access to major facilities and developments		
Engineering design and constructability		
Engineering and construction risks		
Cost		
Environmental and Social quality		
Changes to public and private amenity		
Environmental and cultural impacts		
Accessibility		
Local and regional traffic functionality		
Accessibility and parking		

Major positive effect/Very low cost
 Minor positive effect/Very low cost
 Neutral effect/moderate cost
 Minor negative effect/High cost
 Major negative effect/Very high cost

Selection of preferred design option

The options exhibited similar performance against the access to major facilities and developments criterion, as both options provide improved access to the Moore Park sports and entertainment complex and other trip attractors and urban growth areas in the South East. Similarly, whilst both options present their own challenges with regard to their engineering and constructability risks, this was not considered to be a differentiating factor between the options.

However, the cut-and-cover tunnel would provide substantially better outcomes than the viaduct option with regard to the amenity and quality of public spaces. In particular, it would, on completion, allow the Moore Park playing fields to be maintained for their current use. Both options would allow for the provision of a new large open space that would benefit the local community on the site of the Olivia Gardens apartment complex. The tunnel option is also potentially less visually intrusive than the viaduct through Moore Park, as well as west of South Dowling Street where the viaduct would launch from within the new open space on the site of the Olivia Gardens apartment complex.

Whilst the viaduct is a lower-cost option, avoids an additional signalised intersection at South Dowling Street and would result in a marginal journey time benefit, this was not, on balance, considered to be sufficient to counter the potential visual impact and severance of the Moore Park playing fields associated with this option. Additionally, at the EIS preparation phase exhibition for the CSELR undertaken in September 2013 (refer Chapter 2), the cut-and-cover tunnel was generally the preferred option of the community for the vertical alignment design options through Moore Park. Based on this options assessment, the cut-and-cover tunnel was retained as the preferred alignment and is described as part of the proposal in Chapter 5.

4.3.2 Alignment between Bourke Street and Moore Park

Background

The CSELR route announced in December 2012 included an at-grade alignment through Surry Hills between Bourke Street in Surry Hills and Moore Park. The route travels along Devonshire Street to Bourke Street; however east of Bourke Street a number of options exist for the alignment through to South Dowling Street, before continuing across to Moore Park. Constraints within this area include narrow streets and lanes, Wimbo Park, residential houses and apartments (including the Olivia Gardens apartment complex, which comprises 69 residential apartments), the Langton Centre (a drug and alcohol rehabilitation centre) and Bourke Street Public School.

A suite of alignment options were identified between Bourke Street and Moore Park and were investigated to determine the preferred alignment.

Description of feasible options

A total of 10 at-grade alignment options were assessed, comprising:

- alignments that directly affect the Olivia Gardens apartment complex, including alignments passing through the north (Option 1a), centre (Option 1b) and south (Option 1c) of the Olivia Gardens site
- alignments immediately north or south of the Olivia Gardens apartment complex, including along Nobbs Lane (Option 3) and Parkham Lane (Option 4)
- alignments that avoid the Olivia Gardens precinct altogether, including along Nobbs Street (Option 2) and four alternatives that use Parkham Street (Options 5a–5d).

Each of the at-grade alignment options considered are shown in Figure 4.6 and described below.

Option 1a would cross Bourke Street from Devonshire Street and then travel due east passing through Wimbo Park, the northern part of the Olivia Gardens apartment complex and the Langton Centre car park. The alignment would cross South Dowling Street and the Eastern Distributor via a new rail and pedestrian overbridge, before entering the cut-and-cover tunnel across Moore Park.

Option 1b is similar to Option 1a, but would pass through the centre of Wimbo Park and the Olivia Gardens apartment complex, directly affecting all infrastructure in the complex, and the southern part of the Langton Centre car park.

Option 1c is similar to Option 1a, but would pass through the southern part of Wimbo Park and the Olivia Gardens apartment complex, directly affecting both apartment buildings, and a two-storey former warehouse fronting South Dowling Street that is currently undergoing residential conversion.

Option 2 would skew to the north-east at the Devonshire Street/Crown Street intersection and require the acquisition of five commercial and residential properties, before crossing Bourke Street (via a new signalised intersection) and continuing along Nobbs Street. Nobbs Street would be closed to vehicle traffic.

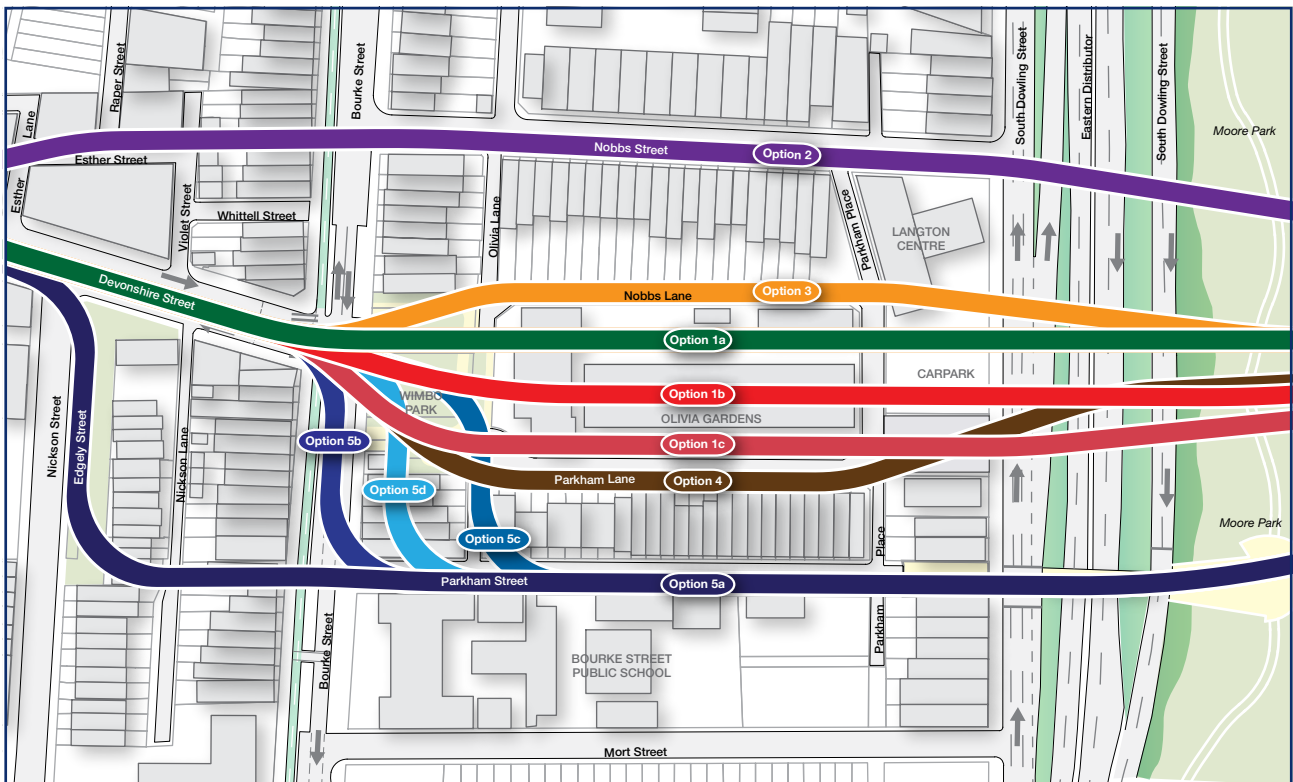
Option 3 is similar to Option 1a, with the exception that that it would run along Nobbs Lane and encroach on the rear of properties fronting Nobbs Street and would directly impact the Langton Centre building. This option would also require acquisition of a residential property on Bourke Street, adjacent to Wimbo Park.

Option 4 is similar to Option 1c; however, it would run along Parkham Lane and encroach on the rear of properties along Parkham Street, including a number of garages, and the two-storey former warehouse on South Dowling Street.

Option 5a includes a deviation from Devonshire Street at Nickson Street, where the light rail would run adjacent to Nickson Street through the Edgely Street Reserve, turn east, and pass through a children's playground and five residential properties between Edgely Street and Bourke Street. The alignment would then cross Bourke Street via a new signalised intersection and run along Parkham Street, which would be closed to vehicle traffic and would likely require either removal or the narrowing of one footpath.



Figure 4.6 At-grade alignment options between Bourke Street and Moore Park



Option 5b is similar to Option 6a; however, instead of turning into Nickson Street, it would turn at Bourke Street and run south before turning east into Parkham Street. One residential property, on the corner of Bourke Street and Parkham Street, would be demolished. From Parkham Street, this option would be identical in its impacts to Option 5a. This option would also result in potential delays for Bourke Street traffic due to the extended traffic light phasing for light rail vehicles.

Option 5c would be similar to Option 5b, but would pass through the middle of Wimbo Park and turn south into Olivia Lane, before turning east into Parkham Street. Two residential properties, on the corner of Parkham Street and Olivia Lane would be demolished. From Parkham Street this option would be identical in its impacts to Option 5a.

Option 5d would be similar to Option 5b and Option 5c, except that it would pass through an electrical substation in Wimbo Park and the five residential properties south of Wimbo Park, between Bourke Street and Olivia Lane, before turning east into Parkham Street. From Parkham Street this option would be identical in its impacts to Option 5a.

Operationally, all options that utilise Parkham Street would require the LRVs to travel at low speeds to avoid compromising safety around the Bourke Street Public School and as a result of the inadequate sightlines at Bourke Street (Option 5a), the South Dowling Street intersections and along Parkham Street. Lower speeds would also be required to mitigate potential noise impacts associated with wheel squeal on the tight curves. Lower design speeds through this section would have a marginal impact on overall journey time between Moore Park and Central Station.

Assessment of feasible design options

A comprehensive assessment of the alignment options undertaken against identified assessment criteria is provided in Figure 4.7.

Figure 4.7 Assessment of alignment design options between Bourke Street and Moore Park

Assessment criterion	Options									
	1a - Olivia Gardens	1b - Olivia Gardens central	1c - Olivia Gardens south	2 - Nobbs Street	3 - Nobbs Lane	4 - Parkham Lane	5a - Parkham via Nickson Street	5b - Parkham via Bourke Street	5c - Parkham via Olivia Lane	5d - Parkham via Wimbo Park
Light rail operations and functionality										
Customer focus and benefits	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Minor positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Neutral effect/moderate cost	Neutral effect/moderate cost	Neutral effect/moderate cost	Neutral effect/moderate cost
Access to major facilities and developments	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost
Engineering design and constructability										
Engineering and construction risks	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Minor negative effect/high cost	Minor negative effect/high cost	Neutral effect/moderate cost	Minor negative effect/high cost	Minor negative effect/high cost	Minor negative effect/high cost	Minor negative effect/high cost
Cost	Major negative effect/very high cost	Major negative effect/very high cost	Major negative effect/very high cost	Minor positive effect/very low cost	Neutral effect/moderate cost	Neutral effect/moderate cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost
Environmental and social quality										
Changes to public and private amenity	Major positive effect/very low cost	Major positive effect/very low cost	Major positive effect/very low cost	Minor negative effect/high cost	Minor negative effect/high cost	Minor negative effect/high cost	Major negative effect/very high cost	Major negative effect/very high cost	Major negative effect/very high cost	Major negative effect/very high cost
Environmental and cultural impacts	Neutral effect/moderate cost	Neutral effect/moderate cost	Neutral effect/moderate cost	Major positive effect/very low cost	Neutral effect/moderate cost	Neutral effect/moderate cost	Minor negative effect/high cost	Minor negative effect/high cost	Minor negative effect/high cost	Minor negative effect/high cost
Accessibility										
Local and regional traffic functionality	Neutral effect/moderate cost	Neutral effect/moderate cost	Neutral effect/moderate cost	Minor negative effect/high cost	Major negative effect/very high cost	Minor negative effect/high cost	Major negative effect/very high cost	Major negative effect/very high cost	Major negative effect/very high cost	Major negative effect/very high cost
Accessibility and parking	Minor negative effect/high cost	Major positive effect/very low cost	Major positive effect/very low cost	Major negative effect/very high cost	Minor negative effect/high cost	Minor negative effect/high cost	Major negative effect/very high cost	Major negative effect/very high cost	Major negative effect/very high cost	Major negative effect/very high cost

 Major positive effect/very low cost
  Minor positive effect/very low cost
  Neutral effect/moderate cost
  Minor negative effect/high cost
  Major negative effect/very high cost

Selection of preferred design option

Based on the assessment of the options against the criteria, all options located within the boundaries of the Olivia Gardens apartment complex were, collectively, preferred for the following reasons:

- These options have operational benefits compared to the other alignments as a result of a straighter alignment with improved sightlines for the driver, and better safety outcomes for the public.
- These options have better accessibility outcomes by avoiding closure of adjacent or nearby streets to traffic and removal of parking and access to properties on these streets.
- These options have significantly reduced environmental impacts during both construction and operation compared to the other alignments, which would pass in close proximity to residential properties along adjacent lanes and streets.
- The options through Olivia Gardens all allow for the provision of a new large open space, which would benefit the local community and is considered to compensate for any loss of open space elsewhere in Surry Hills as a result of the proposal.
- Notwithstanding the need to acquire a significant number of private properties, the acquisition process allows equitable monetary compensation of landowners.



Option 1b would result in a new park with the light rail as a central feature running through the middle. In comparison, the northern and southern options (Options 1a and 1c) would create a single contiguous space for development of new park. Despite this minor disbenefit when comparing these options, Option 1b was considered the best performing option as it would:

- avoid the need to acquire additional properties, specifically the two-storey former warehouse (currently being converted for a residential purpose) fronting South Dowling Street, reducing the overall cost of this option compared to Options 1a and 1c
- minimise the potential impacts to the Langton Centre (similarly to Option C)
- provide adequate opportunity for replacement parking for the Langton Centre within the former Olivia Gardens site
- provide a marginal additional benefit compared with Option 1a due to its location further south, away from the Eastern Distributor on-ramp.

As such, Option 1b was adopted as the preferred alignment and is described as part of the proposal in Chapter 5.

4.3.3 Alignment on Wansey Road

Background

Wansey Road is a local two-way road running atop an embankment adjacent to the eastern boundary of the Royal Randwick racecourse. The eastern side of Wansey Road is fronted by residential properties, all of which have access to off-street parking. On-street parking is available along both kerbsides.

Through discussions with Randwick City Council and consideration of traffic, engineering and environmental constraints, the following key elements were considered in development of the design through this section:

- the amount of kerbside parking displacement
- impacts to local traffic flow
- the potential impact on trees in Royal Randwick racecourse directly adjacent to the Wansey Road footpath
- requirement for re-engineering of the retaining wall currently supporting Wansey Road on its western side adjoining the Royal Randwick racecourse
- vertical geometry issues at the crest of Wansey Road
- the need to maintain stop locations at both the Alison Road and High Street ends of Wansey Road to serve these catchments.

Description of design options

Four alignment options were developed for consideration. These included:

- Option 1, which comprised a light rail alignment located on the western edge of the Wansey Road, removing existing parking spaces on both sides of Wansey Road but allowing for the retention of two lanes of traffic to continue to operate along Wansey Road. The High Street stop would be placed parallel to Wansey Road near the corner of High Street.
- Option 2, which comprised a light rail alignment along Wansey Road similar to Option 1, but retaining parking on one side of Wansey Road and allowing for one-way traffic operation only, in a westbound direction.
- Option 3, which comprised a shared traffic and light rail alignment along the centre of Wansey Road, with no parking impacts. The High Street stop would be as per Option 1.
- Option 4, which comprised an alignment that would deviate into the eastern portion of the privately-owned land operated by the Royal Randwick racecourse to the west of Wansey Road. The High Street stop would be located within the racecourse land.

The options considered are shown in Figure 4.8.

Figure 4.8 Wansey Road alignment options



Assessment of feasible design options

A comprehensive assessment of the alignment options undertaken against the identified assessment criteria is provided in Figure 4.9. Each of the options was assessed as part of the grouped options identified above.



Figure 4.9 Assessment of alignment design options along Wansey Road

Assessment criterion	Options			
	Option 1 - Wansey Road including removal of all parking	Option 2 - Wansey Road one-way traffic and retention of one lane of parking	Option 3 - Shared traffic and light rail along Wansey Road and retention of all parking	Option 4 - Royal Randwick racecourse deviation
Light rail operations and functionality				
Customer focus and benefits				
Access to major facilities and developments				
Engineering design and constructability				
Engineering and construction risks				
Cost				
Environmental and social quality				
Changes to public and private amenity				
Environmental and cultural impacts				
Accessibility				
Local and regional traffic functionality				
Accessibility and parking				

Major positive effect/ Very low cost
 Minor positive effect/ Very low cost
 Neutral effect/ moderate cost
 Minor negative effect/ High cost
 Major negative effect/ Very high cost

Selection of preferred design option

The assessment demonstrates that the alternative alignment through Royal Randwick racecourse land (Option 4) performed well against the criteria. However, due to the additional acquisition costs and potential construction program risk, as well as the potential need to relocate the existing horse stables in the south-east corner of the racecourse, this option was not preferred.

In comparing the three remaining options that utilise Wansey Road the following observations were made:

- *light rail operations and safety* — Option 3 was considered to be the worst performing option due to the safety and operational issues, in particular the potential conflict between cars and light rail vehicles and anticipated delays to the light rail services while waiting for cars to park or access driveways.
- *local traffic accessibility and parking* — Discussions and feedback with the community and Randwick City Council indicated that retaining two-way traffic was preferred over parking as there were concerns that restricting traffic to one-way southbound only would result in traffic flow impacts, impacting functionality and accessibility.

All Wansey Road options were considered to have similar impacts with regard to the environment and general amenity, and engineering and design risk and, therefore, these criteria were not used to differentiate between options. The existing pedestrian and cycleway along Wansey Road would also be maintained as part of each of the options considered.

Based on the above observations, the preferred option for the CSELR proposal was identified as Option 1 — along the western side of Wansey Road, which would retain two-way traffic but remove all parking from the western side of Wansey Road.

4.4 Light rail stop options

4.4.1 Assessment of stop location options

Using the assessment approach described in Section 4.1 above, a long list of potential stop locations for the CSELR proposal was initially identified. Each of these locations was assessed against a broad set of criteria, which included the following:

- potential role and function of the stop (origin, destination)
- potential walk-up catchment of the stop
- access to modal interchange/transfers (such as to/from bus, heavy rail or ferry services)
- compatibility and potential for integration with the proposed George Street pedestrian zone (for proposed CBD stops within this area)
- environmental constraints
- constructability (time to construct, potential cost, requirements for earthworks)
- potential for local urban renewal opportunities and land use changes
- the overall and average distance between potential stop locations
- site constraints such as existing topography and access arrangements for compliance with the DDA and DSAPT
- stakeholder input
- potential patronage in relation to existing and projected population and employment localities (such as the existing urban renewal developments within the CBD, including Barangaroo, and the current investigations as part of the Randwick Urban Activation Precinct).

After applying these criteria, a short list of preferred stops was determined. The short list of CSELR proposal stops included 20 preferred stop locations selected through the assessment process described above to provide maximum benefit to the community.

The design and layout of the 20 proposed light rail stops was dependent on a number of functional and urban design requirements, including interchange function, safety requirements (particularly around major trip generator stops), accessibility, integration with the existing public domain and minimising traffic impacts.

Some examples of where stop designs responded to these requirements include the design of:

- island platforms at Grosvenor Street, World Square, Surry Hills, Carlton Street, Todman Avenue and Strachan Street stops to minimise impacts on traffic flow
- side platforms at Circular Quay, Wynyard, Queen Victoria Building and Town Hall stops to integrate with the Alfred Street public domain and the George Street pedestrian zone
- side platforms at key interchange stops and major trip generator stops to allow easy transfer to light rail and reduce platform crowding, for example at the Wynyard, Town Hall, Chinatown, Rawson Place, Central Station, UNSW-High Street and UNSW-Anzac Parade stops
- larger canopies at the Rawson Place, Randwick and Kingsford stops to provide for better interchange between buses and light rail, with weather protection for all customers
- a grade-separated access to Moore Park stop to enhance safety and operational reliability during major event services, by avoiding the need for passengers to directly cross the light rail to access platforms
- minimisation of the impact to vertical alignment and cross-section to ensure DDA compliance at the World Square and Rawson Place stops
- locating the UNSW-Anzac Parade stop, near the main entrance to the University Mall, to link directly with the main pedestrian mall on campus
- minimising the footprint at the Royal Randwick racecourse the stop, while still retaining stop function, to minimise impacts to heritage
- optimising the layout of the Kingsford and Randwick stops to maximise interchange function, provide a safe environment for passengers and maintain bus service reliability.



A number of potential alternative stop locations and layouts were considered during the CSELR proposal development for a number of these stops. A summary of the proposed CSELR stop options at World Square, Rawson Place, Moore Park, Royal Randwick racecourse and UNSW Anzac Parade is provided in Table 4.4. Due to their importance as key interchanges for the light rail system, a number of alternate layouts were considered for the Randwick and Kingsford stops. Section 4.4.2 and section 4.4.3 provide a summary of the key stop options considered for the Randwick and Kingsford stops respectively. As part of the ongoing design development process, further evaluation of stop locations and alternative options is likely to occur in consultation with key stakeholders and the community.

Locations of the stops where alternative design options were considered are shown in Figure 4.3.

Table 4.4 Short-listed alternative stop locations considered for the CSELR proposal

OPTION	DESCRIPTION OF OPTIONS	RATIONAL FOR PREFERRED STOP LOCATION, LAYOUT AND FUNCTION
World Square stop configuration	Three main options were considered for the World Square stop: - two side platforms to the north of Liverpool Street - a split stop option with separate side platforms to the north and south of Liverpool Street for inbound and outbound travel respectively - an island stop to the north of Liverpool Street.	The option for two side platforms north of Liverpool Street would not allow for the provision of a southbound traffic lane, whilst the split stop option and the island stop would both allow for a northbound and southbound traffic lane on either side of Liverpool Street. However, the split stop option would also present two additional design challenges including: - the reduction of the existing footpath along George Street (which is already considered to be constrained for the number of pedestrians that currently use the area) - the need to substantially regrade the section of George Street to the north and south of the proposed stop to ensure a DDA compliant stop, which would have considerable impact on traffic in this area during construction and operation. The island stop to the north of Liverpool Street is the preferred option and would provide a number of advantages including: - minor regrading of George Street to achieve compliance with DDA requirements - retention of the northbound traffic lane along George Street, minimising the impact to traffic flows.
Rawson Place stop and interchange function	Two main options were considered for the location and functional layout of the Rawson Place stop: - a stop location on the northern side of Rawson Place with buses interchanging with light rail on the southern side in a west to east direction - locating the Rawson Place stop on the southern side of Rawson Place with buses interchanging with light rail on the northern side in an east to west movement.	The northern option presented a series of disadvantages which included: - incompatibility with the proposed redesign of the city centre bus network - potential impact to the external levels of the McKell building southern façade - precluding light rail and bus access to Rawson Place interchange from operating within the same traffic phase. The southern stop is the preferred option with the provision of the busway to the north of the stop. This option would provide a number of advantages including: - compatibility with the proposed redesign of the city centre bus network - opportunity for further activation of the existing properties on the southern side of Rawson Place with supportive uses (e.g. retail and food outlets) - allowing light rail vehicles and buses to access the Rawson Place interchange within a single traffic phase at the Pitt Street and Eddy Avenue intersection.

Table 4.4 cont.

OPTION	DESCRIPTION OF OPTIONS	RATIONAL FOR PREFERRED STOP LOCATION, LAYOUT AND FUNCTION
Moore Park stop and event running	Three stop designs were investigated for the proposed Moore Park Stop: • at-grade (surface level) • below ground, considered in conjunction with the option for a cut-and-cover tunnel alignment through Moore Park (refer to section 4.3.1) • elevated stop considered in conjunction with the option for a viaduct alignment through Moore Park (refer to section 4.3.1). The three stop location options were all generally within the same location.	As discussed in section 4.3.1, the viaduct was not selected as the preferred light rail alignment through the Moore Park playing fields and for the crossing of Anzac Parade. The elevated option for the Moore Park stop was therefore not considered further as a viable option for this stop. A comparison of the remaining two options, showed that: • The at-grade option was significantly cheaper than the below ground option, which would require extensive earthworks and ground stabilisation, including additional features such as safe egress and fire and safety and drainage requirements. • The below ground option would require additional space, including clearing of trees and impacts to facilities such as the existing AFL training field, in order to be constructed. • The below ground stop provides for a grade separated access to the platforms, removing the potential safety and operational issues associated with large numbers of people accessing the stop during event running services. The preferred option is to proceed with a stop at-grade, but to provide a grade-separated access to the stop via a ramp and stairs to minimise safety and operational impacts.
Royal Randwick racecourse stop	Two main design options were considered for the Royal Randwick racecourse stop: • a stop located to the north of Alison Road, to the west of the intersection of Darley Road and Alison Road • a stop located within the Royal Randwick racecourse site, on the southern side of Alison Road. As part of this option, the light rail alignment would cross Alison Road at the intersection of Doncaster Avenue and Alison Road.	The northern stop location would require large numbers of pedestrians to cross Darley Road and Alison Road. Provision of this crossing and additional associated signal phase to permit light rail to cross Alison Road would reduce the efficiency of the intersections' operation. When combined with the loss of traffic lanes on the city bound approach to Alison Road to accommodate the proposed light rail alignment, this would result in a significant loss in traffic carrying capacity for the intersection. The preferred option for the CSELR proposal is a light rail stop to the south of Alison Road within the Royal Randwick racecourse site. This option would provide the most effective location for the proposed stop and would include a number of advantages including: • improved safe access for special event customers accessing Royal Randwick racecourse via light rail without needing to cross Darley Road or Alison Road • large forecourt available within the Royal Randwick racecourse site to safely and effectively marshal customers post event(s) • good inbound bus and light rail interchange opportunities immediately adjacent to the proposed Royal Randwick racecourse stop • improved performance of the Darley Road/Alison Road intersection which would not need to cater for large amounts of pedestrians crossing this intersection during event periods • no impact to trees on northern side of Alison Road • the taxi pickup and queuing zone along Alison Road would only operate on special event days. This would therefore result in the existing northbound operations (i.e. three traffic lanes with kerbside bus stop) being retained during normal operations.



Table 4.4 cont.

OPTION	DESCRIPTION OF OPTIONS	RATIONAL FOR PREFERRED STOP LOCATION, LAYOUT AND FUNCTION
UNSW Anzac Parade stop	Four main alternatives for the UNSW Anzac Parade stop were considered: - a series of options that would provide for a stop within the lower campus of the UNSW campus, characterised into two main alternatives: - offset adjacent to Anzac Parade - offset within the lower campus of UNSW - an island platform within Anzac Parade - platforms along the eastern kerb side of Anzac Parade - parallel side platforms on either side of Anzac Parade.	The preferred option for the CSELR proposal was one of the offset platform options located adjacent to the UNSW campus to the eastern side of Anzac Parade. The offset would be located adjacent to the existing alignment of Anzac Parade. This option would provide the most effective location for the proposed stop and would include a number of advantages including: - Pedestrian movements between the light rail platforms and the lower campus of UNSW would not require crossing of Anzac Parade, resulting in improved safety for students. - In general a widened footpath is proposed to the southern end of the platform to create a plaza for customers waiting and alighting to/from light rail vehicles (LRVs). - The option would maintain two lanes of traffic in each direction along Anzac Parade. The stop location would not substantially impact on any adjacent buildings within the UNSW campus. The existing outdoor stairway from the UNSW Squarehouse is immediately adjacent to the proposed platform and may impact the proposed footpath width. This would be resolved during the detailed design stage.

4.4.2 Randwick stop location

Background

The Randwick stop would serve as the terminus for the Randwick branch of the CSELR and would provide a critical interchange function serving interconnecting bus services from the South East suburbs extending to Coogee, La Perouse and Maroubra. It is important that this stop enables an efficient modal change between bus and light rail for public transport passengers to meet the expected high patronage in peak periods and across the day. The stop would also provide access to the major trip generator of the Prince of Wales Hospital (and associated medical facilities), as well as the local Randwick shopping centre and retail uses along Avoca Street and Belmore Road.

There are two main locations for a stop in Randwick that would potentially meet the functional and accessibility requirements of this stop. Whilst a stop in High Cross Park would provide benefits from an interchange function perspective, ongoing consultation with key stakeholders, including Randwick City Council and Health Infrastructure, has indicated a preference for a light rail stop on High Street to directly serve the primary entrance to the Prince of Wales Hospital. Randwick City Council has also expressed concerns regarding a High Cross Park stop, due to impacts on the park, which has heritage and social significance and is a highly utilised area of public open space.

To assess the relative benefits of the potential stop locations in Randwick, and in response to stakeholder issues, stop layouts were developed at High Street and High Cross Park for further consideration.

Description of design options

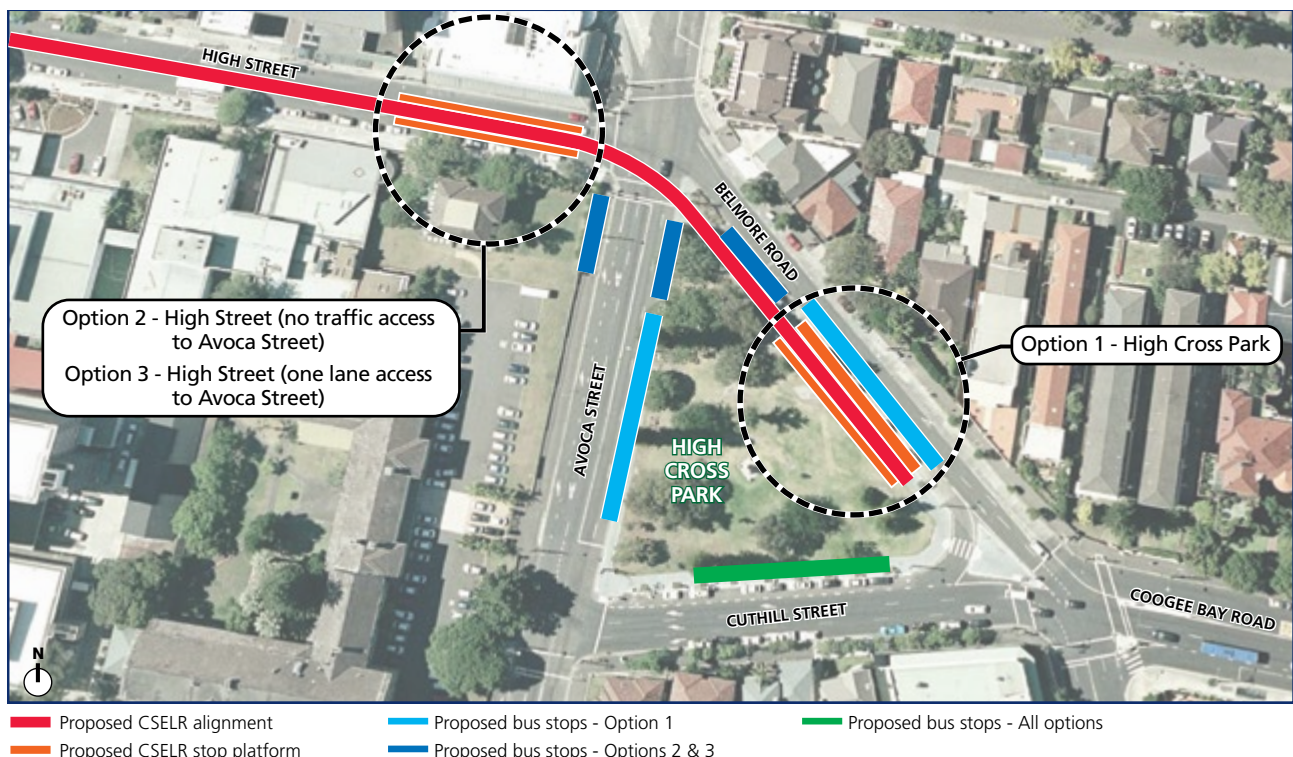
Three stop layouts, over two distinct locations, were considered:

- *Option 1* – This comprised a stop located in the eastern portion of High Cross Park (Option 1), requiring some tree removal and loss of public open space, but retaining the Anzac Memorial. A stop in this location would require a light rail crossing of Avoca Street, at High Street, with an additional traffic phase for light rail vehicles. Buses would stop on all three sides of the triangular High Cross Park, with full accessibility and permeability to the light rail stop across the park. Access to the Prince of Wales Hospital would be along High Street, via a pedestrian crossing of Avoca Road, a distance of approximately 150-200 metres.
- *Option 2* – This comprised a stop located on High Street, west of the intersection with Avoca Street, with two side platforms and a complete closure of High Street at Avoca Road. Whilst this stop location would provide good access to the Prince of Wales Hospital, it presents more challenges for transferring between buses and light rail than Option 1, particularly in the PM peak, where bus stops would be located on the southern and western sides of High Cross Park.
- *Option 3* – This comprised a stop located on High Street, west of the intersection with Avoca Street, with an island platform to reduce the width of the terminus, allowing for one road traffic lane, which could operate one-way (eastbound). Access to the hospital and bus stops would be the same as for Option 2.

Options further west were not considered as they would be limited by the vertical profile of High Street, which falls more steeply to the west, and the need to avoid impacting the car and emergency vehicle access near Clara Street and Hospital Road.

The stop options for the Randwick stop are shown in Figure 4.10.

Figure 4.10 Randwick stop options





Assessment of the preferred design option

A comprehensive assessment of the Randwick stop against the identified assessment criteria is provided in Figure 4.11.

Figure 4.11 Assessment of Randwick stop locations

Assessment criterion	Options		
	Option 1 - High Cross Park	Option 2 - High Street (no traffic access to Avoca Street)	Option 3 - High Street (one lane access to Avoca Street)
Light rail operations and functionality			
Customer focus and benefits			
Access to major facilities and developments			
Engineering design and constructability			
Engineering and construction risks			
Cost			
Environmental and social quality			
Changes to public and private amenity			
Environmental and cultural impacts			
Accessibility			
Local and regional traffic functionality			
Accessibility and parking			

Major positive effect/Very low cost
 Minor positive effect/Very low cost
 Neutral effect/moderate cost
 Minor negative effect/High cost
 Major negative effect/Very high cost

Selection of preferred design option

Since approximately 85 per cent of light rail passenger boardings are expected to transfer from buses, the need for simple, fast and legible interchange for customers is a key differentiator in comparing these options. The High Street stop options (Options 2 and 3) offer a sub-optimal outcome from a public transport integration perspective.

The stop in High Cross Park (Option 4) provides significant benefits in interchange function over the two High Street options, including avoiding the need for customers to cross Avoca Street and/or Belmore Road to interchange between bus and light rail from existing bus stops. As a large majority of users of the Randwick stop are expected to be transferring to or from bus services, overall the High Cross Park location offers an improved interchange for light rail customers.

Options 2 and 3 offer a number of advantages from a customer perspective. Notably, they offer a stop closer to the Prince of Wales Hospital, and without crossing Avoca Street to the Prince of Wales Hospital — particularly for less mobile customers.

Local and regional accessibility performance is reduced with Options 2 and 3 as High Street would be either completely closed or limited to one-way traffic only. Maintaining through-traffic along High Street, an important east-west link, and access to the hospital from the east and west would not be possible for the High Street stop options. Additionally cross-regional bus services which currently use High Street would need to be re-routed through surrounding streets. There would be a small benefit to the performance of the Avoca Road/High Street/Belmore Road interchange with Options 2 and 3 as light rail would not need to cross this intersection. However, this would likely be negated by traffic being diverted onto the surrounding streets, which are already congested.

With regard to the environmental and social quality criteria, Option 1 was considered to perform poorly due to the adverse impacts to High Cross Park, in particular the reduction of open space, removal of trees and potential heritage impacts to the park.

Whilst acknowledging the environmental and social impacts of a stop in High Cross Park, Option 1 is considered to be the preferred stop location and layout due to the benefits that it provides in terms of overall transport interchange between the CSELR proposal and buses. Ongoing development of the High Cross Park option would be undertaken during detailed design, in consultation with the Randwick City Council and other relevant stakeholders to consider ways of reducing the potential land take and impact to the park.

4.4.3 Kingsford stop and interchange layout and function

Background

The light rail terminus and bus interchange at Kingsford would provide a critical transport link that caters for integrated modal change between bus and light rail passengers. Whilst serving the immediate catchment of Kingsford, the interchange is also designed to service a wider catchment, including La Perouse, Maroubra and suburbs to the south. It is therefore expected that the light rail service would significantly reduce the need for existing bus services to connect to the CBD.

It is therefore desirable that the Kingsford stop provides a convenient interchange for passengers between the existing bus network and proposed light rail. In order to maximise the convenience for passengers, maintain a high level of efficiency for the bus network, and provide a high level of safety for users, a series of options was considered for the functional layout of the Kingsford stop that addressed each of these criteria. All of the options were located within the existing Anzac Parade median between the Nine Ways intersection and Sturt Street.

Description of design options

Four main design options were considered for the Kingsford stop. These options are summarised as follows:

- *Option 1* — This would incorporate a cross platform interchange and would provide separation of bus and light rail movements between the platforms and the Nine Ways intersection. Two turnback tracks would be provided to allow light rail vehicles to operate via dedicated inbound and outbound platforms, which would be co-located with inbound and outbound bus services respectively. Option 1 would include shared running of light rail and buses between the Nine Ways intersection and Meeks Street.
- *Option 2* — This would provide a variant of Option 1, by maintaining a degree of cross platform interchange, as well as shared bus and light rail operation between the Nine Ways intersection and Meeks Street. However it would provide a light rail cross-over north of the light rail interchange, as opposed to the turnback track provided in Option 1. Option 2 would also provide separate bus and light rail lanes north of the interchange; however the crossing of light rail and buses would remain.
- *Option 3* — This would provide an alternative arrangement which separates the bus and light rail platforms. The bus stop platforms would be located further south within the central median between Wallace Street and Sturt Street. A central island platform would provide for easy access to both inbound and outbound light rail movements.

The options for the layout of the Kingsford stop and function of the interchange are shown in Figure 4.12 to Figure 4.14.



Figure 4.12 Kingsford stop layout – Option 1

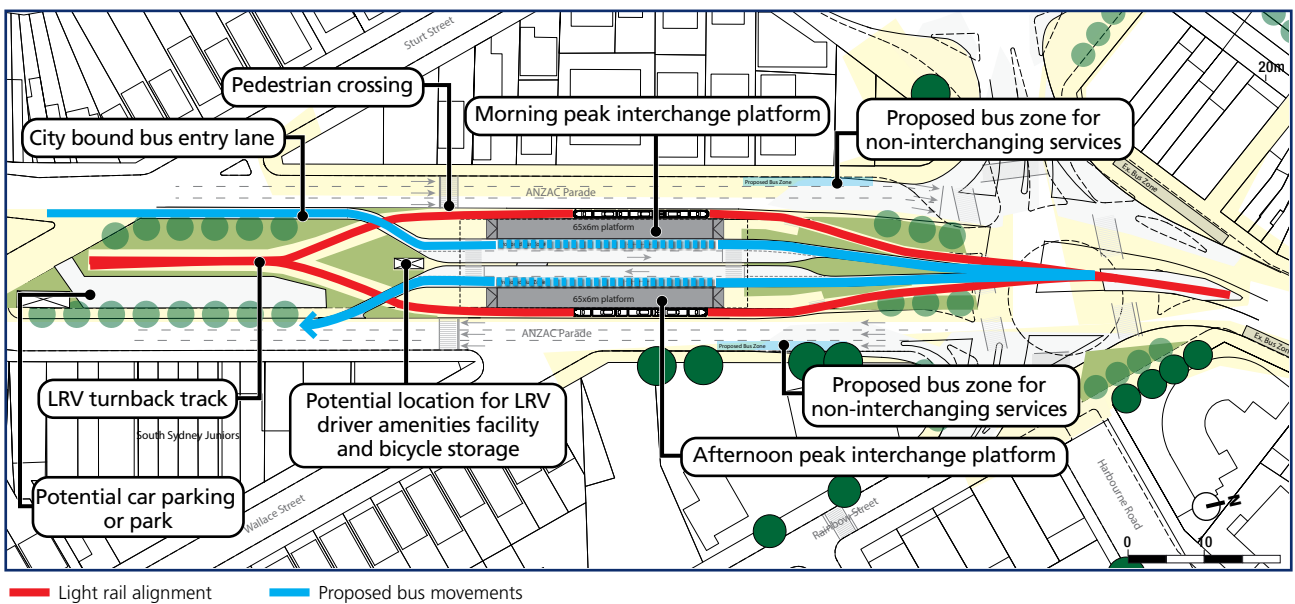


Figure 4.13 Kingsford stop layout – Option 2

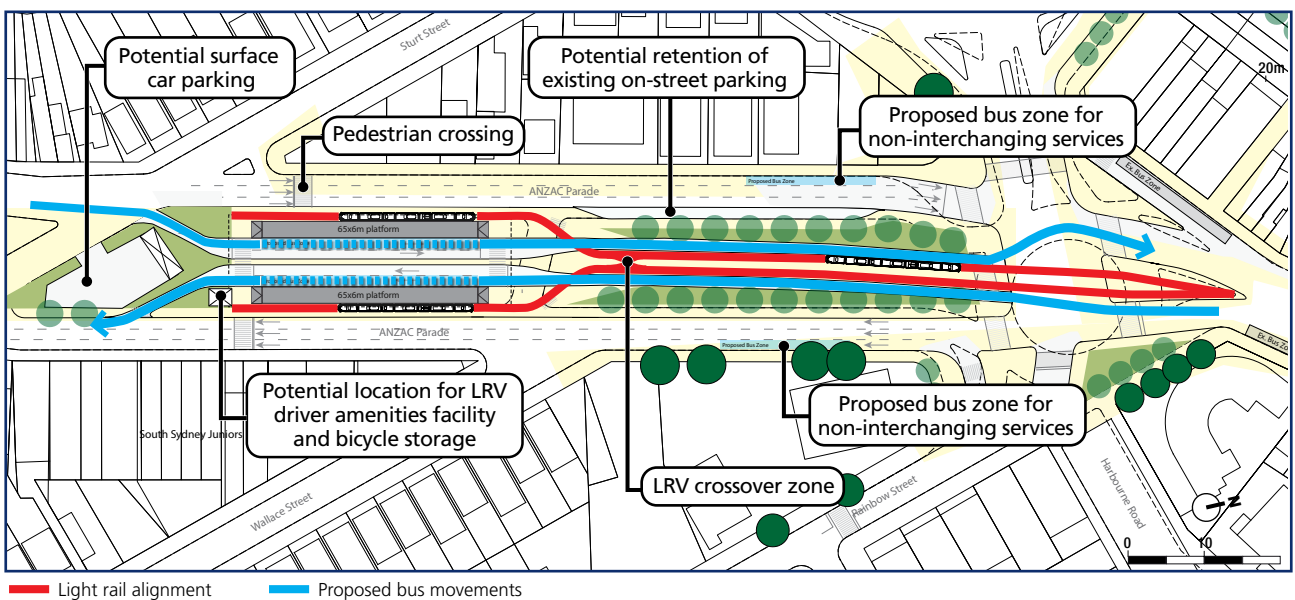
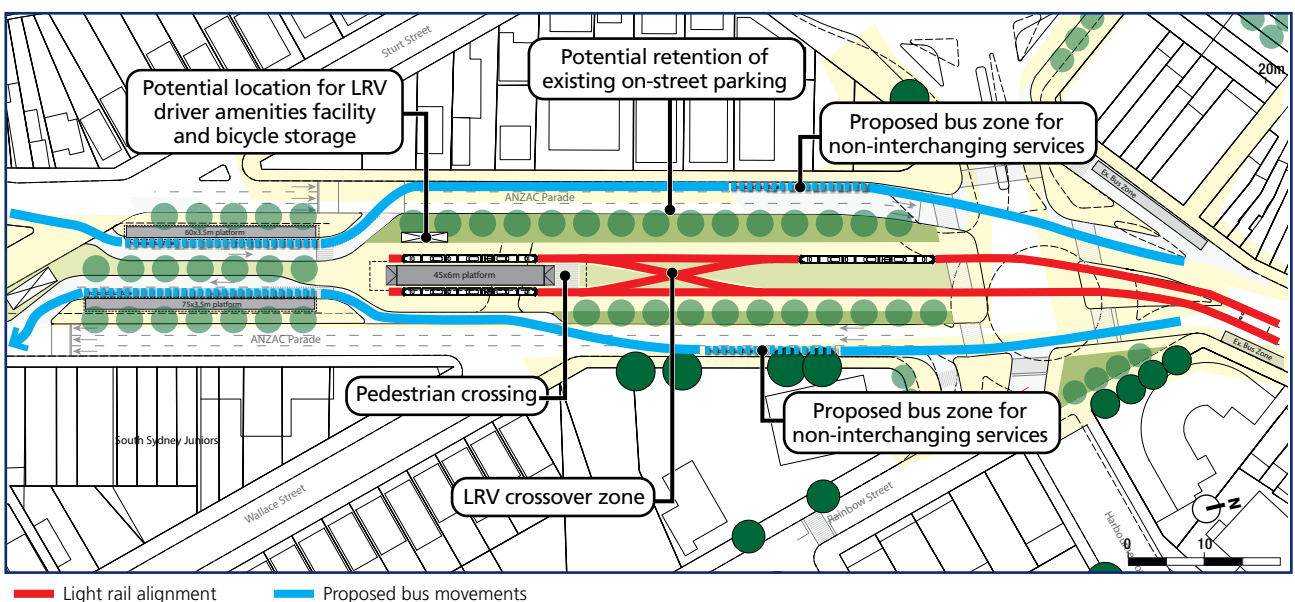


Figure 4.14 Kingsford stop layout – Option 3



Assessment of preferred design option

A comprehensive assessment of the Kingsford stop options against the identified assessment criteria is provided in Figure 4.15.

Figure 4.15 Assessment of Kingsford stop locations

Assessment criterion	Options		
	Kingsford stop - Option 1	Kingsford stop - Option 2	Kingsford stop - Option 3
Light rail operations and functionality			
Customer focus and benefits			
Access to major facilities and developments			
Engineering design and constructability			
Engineering and construction risks			
Cost			
Environmental and social quality			
Changes to public and private amenity			
Environmental and cultural impacts			
Accessibility			
Local and regional traffic functionality			
Accessibility and parking			

 Major positive effect/Very low cost
  Minor positive effect/Very low cost
  Neutral effect/moderate cost
  Minor negative effect/High cost
  Major negative effect/Very high cost

Selection of preferred design option

Whilst all of the options would provide a range of benefits for public transport users, Option 1 would provide an improved opportunity for passengers, in particular through the provision of a consistent citybound platform arrangement, thereby improving service legibility and customer safety, particularly for less mobile passengers. Options 3 and 4 would not provide an efficient cross platform interchange, and would require passengers to walk up to an additional 20 metres to transfer between transport modes.

Operationally, Option 1 would provide for a light rail track layover within the median beyond the stop, providing a benefit for light rail operations and LRV turnback arrangements at the terminating stop. Options 2 and 3 would also provide an operational benefit through the provision of the proposed light rail track crossover within the median area of the stop, rather than within the reconfigured intersection of Anzac Parade and Rainbow Street (as proposed in Option 1). Additionally, Option 3 was considered to be the worst performing with respect to any potential future expansion of the light rail network, as this option would require the demolition of the bus interchange to allow for any extension.

With regard to constructability and engineering risks associated with the options, all options would require some form of retaining wall structure to allow for the proposed integration of bus lanes and light rail tracks, due to the cross fall of the site. Each of the options would result in a similar impact to land and property; however Option 1 and Option 2 would allow for some potential car parking to be reinstated to the south of the stop.

With regard to environmental and social quality, each of the options would result in a similar cultural and environmental impact. However, Option 1 would provide a slightly better social outcome than the other options, as the platforms and interchange locations for Option 1 are more closely located to the adjoining shopping areas to the west and north of the proposed stop.



As with the Randwick stop, almost 90 per cent of light rail passenger boardings would transfer from buses. As such, the need for simple, fast and legible interchange for customers was a key differentiator in comparing these options. Therefore, whilst acknowledging the engineering risks and parking impacts associated with the proposed stop location, Option 1 was considered to be the preferred stop location and layout as, on balance, it would provide the best outcome for bus interchange, improved customer experience, operational flexibility and traffic integration over other options. This stop is described in greater detail in Chapter 5.

4.5 Options for other CSELR proposal elements

4.5.1 Stabling and maintenance facility options

Background

Design options were developed for integration of the CSELR proposal with the operations of the existing Inner West Light Rail system. This included consideration of maintenance and stabling facilities that would accommodate the overall light rail network.

A range of options were considered to provide both independent and combined stabling and maintenance facilities for the overall light rail network.

Description of design options

Five main design options were considered for potential stabling and/or maintenance facilities associated with the CSELR proposal and the overall light rail network. These options included:

- a stabling-only facility utilising a portion of land adjoining the Royal Randwick racecourse site, off Doncaster Avenue
- a stabling-only facility utilising a portion of Royal Randwick racecourse land to the west of Wansey Road, at the intersection of High Street and Wansey Road
- a maintenance-only facility utilising the former Randwick tram shed located at King Street, Randwick
- a maintenance-only facility utilising the former Rozelle Rail Yards (in the suburb of Lilyfield)
- a specialised maintenance operation combined with the Inner West Light Rail requirements at the Rozelle Rail Yards site.

The location of the proposed maintenance and stabling facility option sites is shown on Figure 4.3.

Assessment and selection of the preferred design option

A series of principal requirements were developed to guide the development and assessment of the maintenance and stabling facilities to cater for the estimated size of the light rail fleet, including the CSELR proposal and the existing Inner West Light Rail fleet. The key requirements for each of the facilities are summarised in Table 4.5.

Table 4.5 Principal requirements for the proposed maintenance and stabling facilities

	STABLING FACILITY	MAINTENANCE DEPOT
Requirements	• Stabling tracks for 30 x 45 metre LRVs • Sufficient land to accommodate stabling tracks for at least 42 x 45 metre LRVs (allowing for future fleet growth) • Wash and sand plants • A light maintenance shed to cater for minor out of course repairs • Office accommodation for the operator's management team • An operational control centre • Cleaning facilities and stores • Staff facilities and car parking	• A maintenance shed providing six berths capable of undertaking full inspection of vehicles • An underfloor wheel lathe • Workshops and stores • Paint booth • Office and staff facilities including a car park • A site footprint requirement of approximately 4,000 square metres including office, workshop and stores taking up 800 square metres

An assessment of all of the options identified that the proposed use of the existing King Street tram shed site would not accommodate the functional requirements of the proposed light rail network, including the required number of LRVs for the operation of the CSELR proposal. Additionally, the King Street tram shed site is located in a predominantly residential area and would potentially result in substantial noise and light spill impacts on these residents from heavy maintenance activities undertaken at the facility. As such, these two options were not considered any further as viable options for the CSELR proposal.

The assessment of the stabling-only facility at the Royal Randwick racecourse identified that this site met all the functional requirements and remains the preferred option for the stabling facility. The location is close to the junction of the Kingsford and Randwick branches allowing good access to both the terminating stops along the Randwick and Kingsford lines.

Similar to the Randwick stabling site, the consideration of the Rozelle Rail Yards as a potential maintenance facility identified that the site would meet all of the established criteria required for this facility. Additionally, the site is of sufficient size to meet any functional requirements for the site to be expanded to assist future light rail network growth. Whilst the provision of the maintenance facility at the Rozelle site would result in some minor operational impact due to the need for CSELR vehicles to travel further for maintenance, these movements would not be frequent, as minor LRV maintenance would still be able to be undertaken in the stabling facility. This option would also be able to accommodate some of the requirements of the Inner West Light Rail maintenance facilities, creating a more efficient use of this site within an existing industrial area.

A benefit of a co-located site is that a combined stabling and maintenance facility would not require the transfer of vehicles between facilities for heavy maintenance. However, heavy maintenance activities may generate additional noise and lighting impacts on adjacent residential properties above that of the stabling-only facility.

The stabling-only facility within racecourse land adjacent to Wansey Road would provide a key benefit over the Doncaster Avenue site as this site is generally situated below the surface of Wansey Road residences, providing some screening for noise and visual impacts of stabling facilities. However, this site is slightly less optimal than the site at Doncaster Avenue site as it is located further from both the Circular Quay and Kingsford stops, resulting in additional time to reach these termini for the commencement of daily light rail services.

The key differentiator between the two stabling only sites in the western and south-eastern portions of the Royal Randwick racecourse is that, whilst both sites would require significant land acquisition, the site adjacent to Wansey Road is currently occupied by a number of horse stables, which would require relocation prior to accessing this site. This would likely entail additional cost and property acquisition, which reduces the cost effectiveness of this option.

In considering the analysis of the options, the separated Randwick stabling facility and Rozelle maintenance depot were identified to meet all of the functional requirements and, as such, were considered to be the preferred options for each of these facilities.

4.5.2 Light rail and bus operations within Moore Park and Centennial Park

Description of design options

The section of the proposed route between the Moore Park stop and Doncaster Avenue, where the alignment runs within Moore Park and Centennial Park, is unique in that the light rail would be segregated from the public road network (with the exception of where it crosses Lang Road). This provides the opportunity for high speed running, subject to design and safety considerations. Throughout this section there is an existing busway which conveys buses from the South East suburbs to the CBD.

The three options considered were:

- shared running of light rail and buses in the existing busway
- a designated light rail alignment adjacent to the existing busway
- designated light rail running in the existing busway, with buses displaced onto public roads.



These options were considered for the light rail route adjacent to Anzac Parade (between Moore Park stop and Robertson Road) and between Robertson Road and Doncaster Avenue adjacent to Alison Road (refer to Figure 4.16).

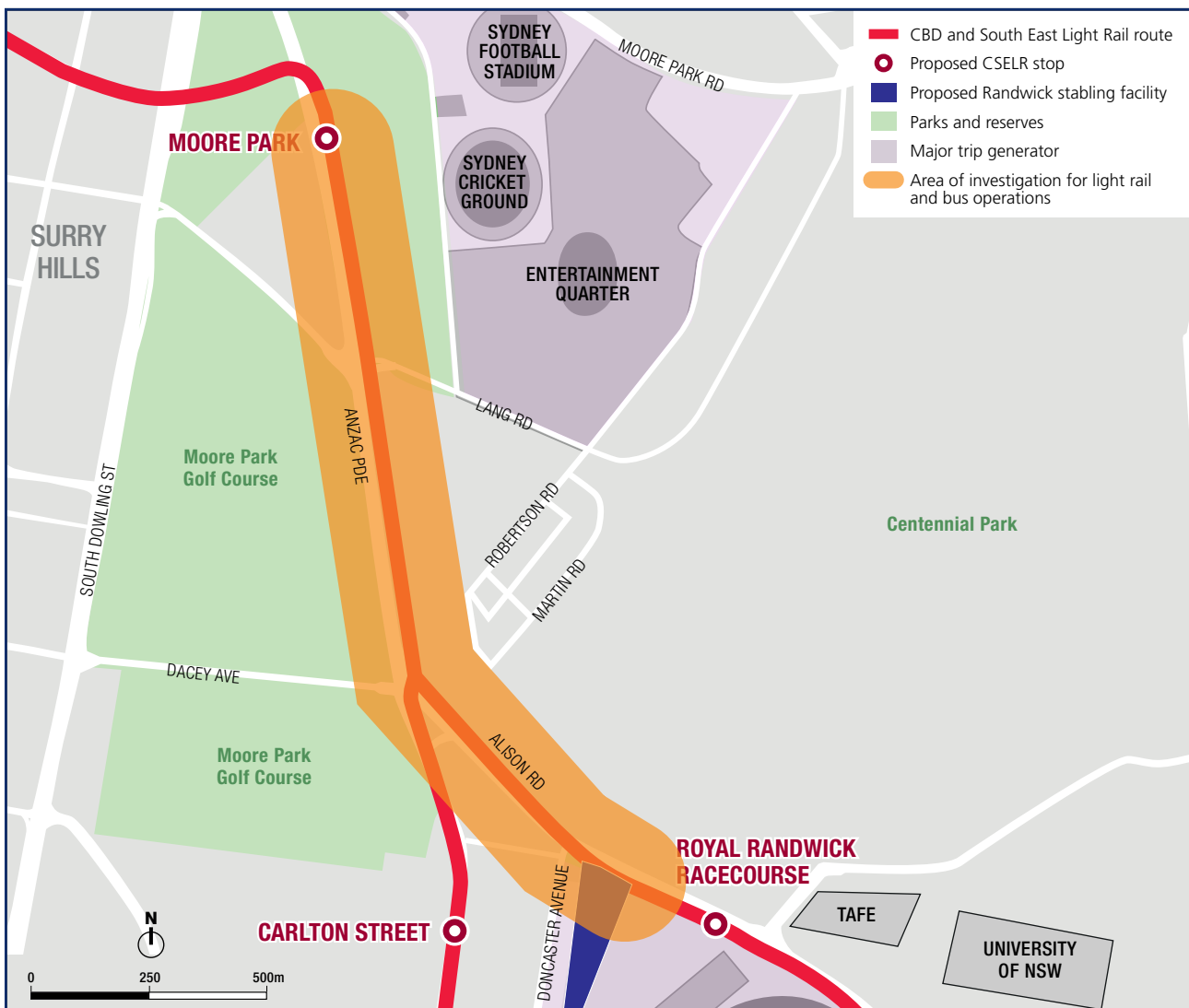
Assessment and selection of the preferred option

Key design and operational elements considered in this assessment included:

- public transport efficiency and reliability
- safety
- environmental and amenity impacts
- impacts to the regional and local traffic network.

In general terms, a dedicated light rail alignment is preferred as it provides a more reliable and efficient public transport service, which would avoid delays to light rail due to bus operations and maintain priority for bus services that do not originate from/serve the light rail catchment.

Figure 4.16 Area of investigation – Light rail and bus operations along Anzac Parade and Doncaster Avenue



For the section north of Robertson Road, where space is available, provision of segregated light rail and bus services would also maintain the ability to service special events at Moore Park with both buses and light rail.

Additionally for this section, running light rail vehicles in the existing busway, whether co-located with buses or with buses displaced onto Anzac Parade, would likely require significant pruning or removal of the large figs adjacent to the busway to accommodate the overhead wiring system. Wire-free running is not an option through this section due to the high speeds and distance between stops (refer to section 4.5.3).

Therefore, the preferred option between Moore Park stop and Robertson Road is for a dedicated light rail track running adjacent to the busway on the eastern side.

In the section between the Anzac Parade/Dacey Avenue/Alison Road intersection and Doncaster Avenue there is limited space for a designated light rail alignment adjacent to the existing busway without impacting the Kensington Ponds to the north, the row of trees between Alison Road and the busway, or the existing cycleway between the busway and Kensington Ponds.

Displacement of bus services onto Alison Road, which currently experiences significant congestion during the peak periods, would result in worsening of traffic congestion and journey time reliability for the remaining buses and is therefore not preferred.

There would be a reduction in frequency of light rail vehicles and buses coming from Randwick and its environs when compared to the section to the north, which also accommodates light rail vehicles and buses coming from or going to Kensington and beyond. Therefore, shared running south of Robertson Road has less impact on the efficiency and reliability of the light rail system.

Co-location of light rail and bus services along the section between Anzac Parade and Doncaster Avenue is preferred because:

- The shared running section would only be 600 metres long and impacts to reliability and journey time would not be significant, although there may be some impact if inbound express buses are retained in the peak. This is subject to ongoing investigation.
- It would result in a better environmental outcome, by avoiding impacts to the Kensington Ponds and adjacent trees.
- It would avoid of increased traffic congestion on Alison Road resulting from displaced buses.

4.5.3 Light rail power supply and design options

A number of alternatives for power supply and design of power infrastructure were considered in the design development phase. This included:

- light rail power supply options:
 - overhead wiring
 - wire-free running
- overhead wiring pole configuration — centre or side poles
- substation numbers and required locations.

Input into the considerations included:

- consultation with stakeholders, particularly around urban design of the above elements
- operational requirements
- review of best practice from other light rail systems around the world
- design and engineering constraints, for example space-proofing requirements for pole configurations
- environmental considerations.



Light rail power supply

Whilst wire-free running is less visually intrusive than overhead wiring, there are a number of constraints to wire-free running including steep grades and high speed running. These factors require additional traction power to meet LRV power demand, which may not be possible through current wire-free technology. The distance between stops also provides a constraint to wire-free running, with greater distances providing less than optimal operations.

Through consultation with City of Sydney and in response to the *George Street Concept Design* (City of Sydney 2013), the proposal includes wire-free running along the length of the George Street pedestrian zone. The proposed extent of wire-free operations could be increased during detailed design should design innovation or technology improvements permit. Wire-free running is discussed further in section 5.2.11.

Side versus centre poles

The overhead wire system and associated poles would be the most visible aspect of the CSELR network to most people, as these would be fixed in the visual landscape. Whilst the wires themselves would be visually 'light-weight' and not overly bulky or excessive, where they are attached to poles, the poles themselves would be more noticeable and therefore, required consideration regarding how best to minimise their impact. Other considerations include:

- safety, specifically around potential for collision with poles
- space-proofing to ensure the servicing of light rail infrastructure is limited to within the rail corridor
- stakeholder inputs.

Side-mounted poles, if designed and located geometrically, provide the opportunity to be combined with other existing services, for example power poles and street lighting. During construction of footings in the footpath for side poles there may be an issue with existing below ground services; however this can be somewhat mitigated through detailed survey of utilities and consultation with service providers.

Centre poles would create a strong visual element within the centre of a street which could be viewed negatively, especially if street lights and other side-mounted poles exist. Centre poles would also require a greater corridor width. Whilst centre poles would have less impact on utilities and services and trees along footpaths, as a new physical element they would create a potential collision point, especially in sections where buses and light rail are co-located.

A combination of both side and centre poles is proposed throughout the different precincts of the CSELR alignment, based on which overhead wiring option provides the greatest opportunity to minimise clutter in the landscape and enhance visual amenity. Overhead wiring is discussed further in section 5.2.11 and the final design of the proposed overhead wiring system would be determined during detailed design.

Substations

Substations are required to provide power supply for the LRVs, at the required voltage, to the light rail system. The substations would provide 750-volt DC electricity supply and would require approximately 80 square metres for the building footprint and 250 square metres for the overall substation land take (to allow for maintenance access, crane access for equipment replacement, parking and security fencing).

The number of substations required for the light rail system is determined by the power demand of the system, which is influenced by the number and frequency of light rail vehicles on the system. To meet power demand for the system, 12 substations are proposed along the alignment.

The location of the 12 substations was based on the substations being:

- in close proximity to the alignment
- appropriately spaced to provide adequate coverage for the system (typically spaced within two kilometres of each other)
- within easy access of Ausgrid zone substations
- easily accessible for maintenance purposes
- located in open spaces or in other areas generally agreed with property owners.

Environmental and social impacts and mitigation were also considered. Examples of where these influenced substation siting and design include:

- avoidance of areas of high archaeological or built heritage significance
- development of substations typologies for urban and park environments to minimise visual impacts
- consideration of below ground substations where space allows to minimise impacts on visual amenity and open space
- acoustic cladding or below ground substations to minimise noise impacts of substations.

Substations are discussed further in section 5.2.11.

4.6 The CSELR proposal

The design for the preferred CSELR route has been developing since December 2012. This design development will continue to refine elements of the proposal, including constructability and design issues for operational components of the proposal.

A detailed description of the design and operational features of the CSELR proposal is provided in Chapter 5.