6. Development of Options

6.1 Heavy Rail

6.1.1 Infrastructure Requirements

Lateral Space Requirements

The minimum separation between obstructions and the track specified by NSW railway design standards needs to be maintained to avoid intrusion of any obstacles into the path of a moving train (kinematic envelope). Using current RIC transit space standards, minimum track centres of 4.0 metres should be provided for straight mainline track.

A maintenance access way should be provided within the fenced corridor and on at least one side of the tracks. On the maintenance access side of the tracks the rail boundary fence should be no closer than 6.2 metres from the nearest track centreline. The other fence should be at least 4.3 metres from the nearest track centreline. Using these lateral clearance standards, the minimum right-of-way width for straight mainline track with no structures or stations is 14.5 metres. Lateral clearance requirements may increase around curves due to centre/end throw effects and an increase in the kinematic envelope. These effects should be further assessed during detail design.

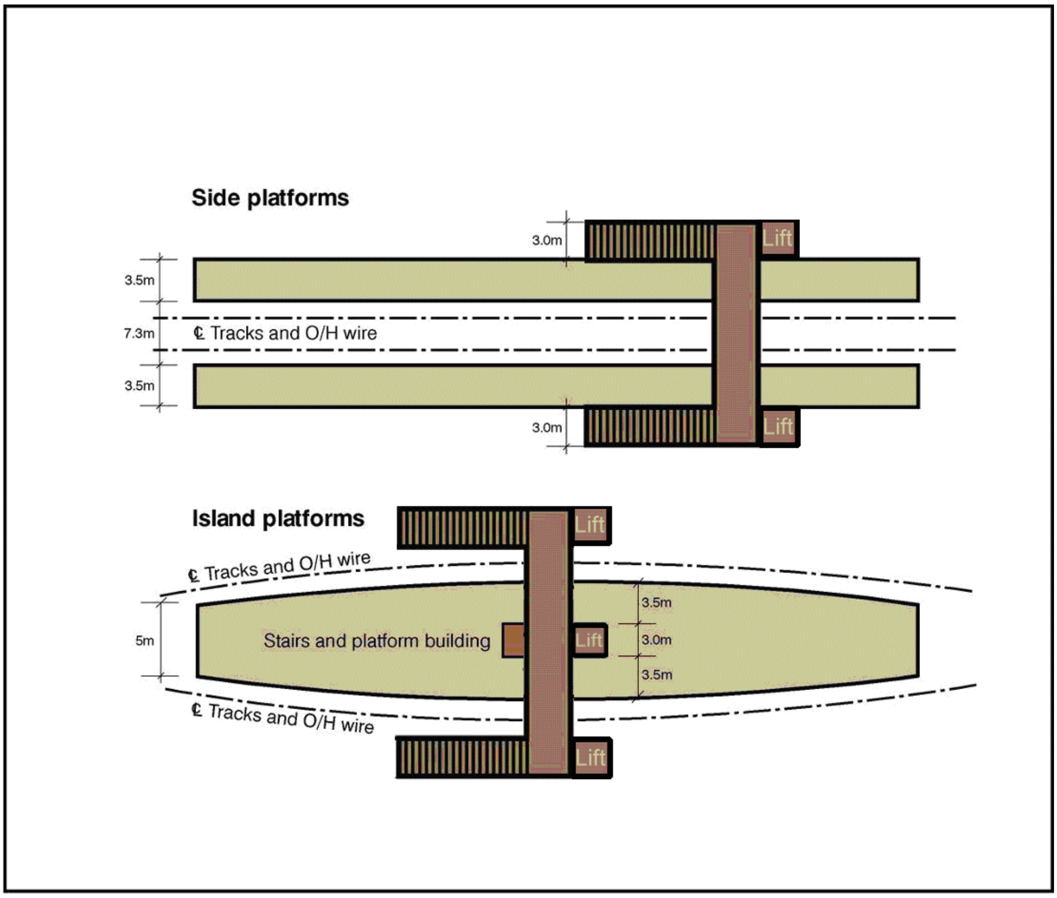
Stations

The maximum right-of-way width requirement occurs at potential station locations. StateRail's CityRail Station Design Guide (SRA, 1996) was used as reference to develop a typical station layout for the Western Sydney Orbital corridor. The station configuration is based on a single island platform, 170 metres long to accommodate an eight car passenger train set. The platform has a maximum width of 10 metres at the mid-point and tapers to a width of five metres at the platform ends. The 10 metre width provides a 3.5 metre clearance to the platform edge on both sides of a 3 metre wide access stairway located in the middle of the platform. The layout of a typical station with an island platform is shown in *Figure 6.1*.

The platform width could be reduced to 7.0 metres by placing the stairway at one of the platform ends. However, this layout would result in end-loading of the platforms, a configuration StateRail generally does not support as it affects the station's operational efficiency. At the point where the platform is at its widest, construction of the station will therefore require a clear median width of 21.9 metres, as shown in *Figure 6.2* below.

Station locations are indicative, based on connecting existing activity nodes. The patronage assessment assumes that stations will be located at Miranda North, Taren Point, Sandringham, Bay Street and Cooks Cove. The station locations are also shown in *Figure 5.3* and in the previous section.

The development of a high capacity public transport option would be anticipated to have significant impacts on land use through the corridor. These impacts could lead to the development of new activity nodes, supported by increased public transport accessibility. The indicative reservation therefore has to allow sufficient width such that station locations may be moved subject to additional planning studies. Sufficient land requirements have been allowed in the engineering base model to adjust station locations.



Not to scale

Figure 6.1: Typical Station Layout

Over-bridges and Vertical Clearances

Where over-bridges are likely to be required over the railway, a 5.65 metre vertical clearance is required between the top of the rail and the underside of the over-bridge to allow for provision of the traction power overhead wire (OHW) installation.

Three typical cross sections were developed to assess the minimum space requirements of rail within the F6 Corridor and these typical cross sections are shown in *Figure 6.2*. Note that these cross-sections:

- are minimum requirements and do not show cycleways and/or footpaths. Cycleways and footpaths are provided outside the railway boundary as shown in *Figure 6.3*; and

- provide for a maintenance access road only in plain track areas as is normal practice. At stations or over-bridges the access road is stopped short either side of the station area or structure.

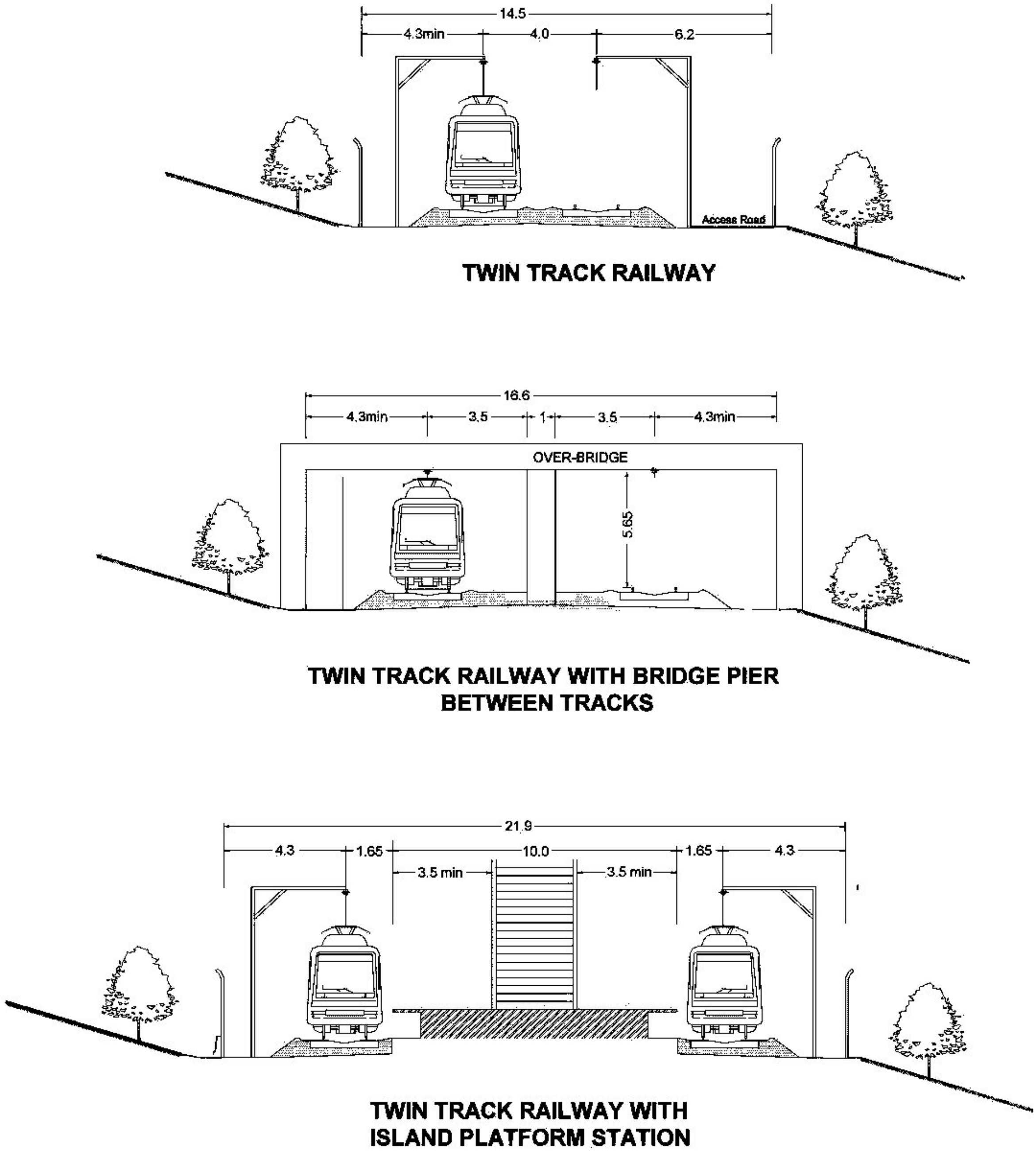


Figure 6.2: Typical Minimum Cross-sections for Heavy Rail

Alignment Standards

A proposed twin track passenger railway, designed to Class 1 standard, should have a minimum horizontal curve radius of 400 metres, a desirable mainline gradient of 1% (maximum gradient of 3%) and vertical crest and sag curve radii of 1,300 metres or more. At stations the gradient should not exceed half a percent (a zero gradient is preferred) and the minimum horizontal curve radius through stations is 800 metres.

6.1.2 Land Requirements

If the future development of a rail link in the F6 Corridor is to be retained as an option, it would be necessary to provide a corridor of sufficient width to accommodate:

- no less than two heavy rail tracks of appropriate standard (requires a corridor width of 14.5 metres);
- potential in some locations for a third "turnback" line (requires another 5.2 metres);
- overhead traction power supply mast structures, signal sticks and gantries;
- traction supply substations, sectioning huts and other lineside electrical equipment;
- a maintenance access road on at least one side of the corridor;
- potential stabling facilities that may be required in addition to those located at Cronulla and Waterfall; and
- stations at strategic locations.

A rail corridor should reserve a right-of-way sufficient to accommodate the twin tracks, stations and rail systems. Ancillary needs such as parking and interchange facilities can be provided outside the reservation boundaries and more appropriately situated in the future when land use changes are apparent. The absolute minimum fence-to-fence rail corridor width for rail is based on the typical cross-sections in *Figure 6.2*:

- for general main line twin tracks with an access road on the one side the minimum width would be 14.5 metres;
- for main line tracks through bridge structures, where a 1 metre wide bridge pier is located between the tracks but no access road is provided, the minimum width would be 16.6 metres; and
- at stations with island platforms the minimum width would be 21.9 metres.

It should be recognised that no vertical alignment design was carried out for this study. Consequently, it has not been possible to assess the space requirements of cut and fill batters or retaining structures. Allowance should also be made within or near the corridor for pedestrian and cycle access.

Given that final station locations would be very difficult to identify during the current study, it was acknowledged during the Reference Group workshop that a corridor of adequate width would be reserved to retain full flexibility in placing stations. It was also agreed that it would be prudent to retain sufficient land to accommodate a footpath and/or cycleway as well as some reserve for earthworks (batters).

Given the uncertainty with regard to vertical alignment design and the need for cut/fill batters, the location of stations and the appropriate location of turnback facilities and stabling yards a right-of-way width of 40 metres was selected for the assessment of residual land. This width would allow for:

- the minimum total width required at stations of 21.9 metres;
- an additional 5.2 metres for a third turnback/stabling road; and

- an allowance of 12.9 metres to accommodate fencing, cycleways and footpaths and cut/fill batters

A typical 40 metre corridor width is shown in *Figure 6.3.*

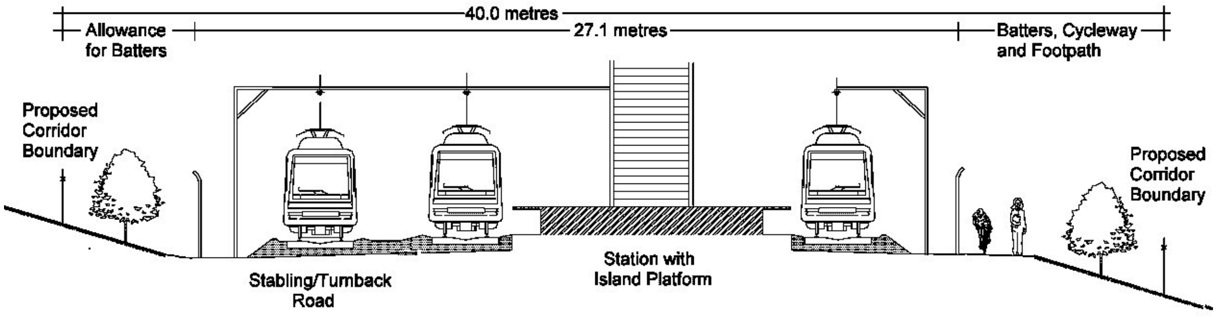


Figure 6.3: Recommended Corridor Requirement

Note that the rail maintenance access road is not required through the station area and is therefore not shown in *Figure 6.3*.

6.1.3 Rail Network Context

Both heavy rail options would connect to the Cronulla Branch Line at Miranda and head west, looping onto the F6 alignment, collecting trains from Cronulla. Option HA would connect to the Illawarra Line immediately south-west of Sydenham Station. Option HB would connect to the Airport Rail Link immediately south-west of International Terminal Station.

Both options would be able to divert demand from the capacity constrained sections of the Illawarra Line between Sutherland and Sydenham, provided trains would be able to continue to destinations in the CBD. However, the headways on a potential heavy rail link in the F6 Corridor would be constrained by the capacity of the line into which it connects:

- capacity on the Illawarra Line at Sydenham is likely to be a constraint on Option HA unless the infrastructure on the Illawarra Line is enhanced to increase line capacity between Sydenham and Erskineville Junction. This constraint is explained in more detail in *Section 4.1.2*; and
- Option HB may potentially be less capacity constrained than Option HA as there is some scope to run an independent shuttle service on the Airport Rail Line between Miranda and the unused platforms at St James Station in the City. Such a service would require less drastic infrastructure enhancements, mainly to junctions at Central and at St James Station. Retaining the current operational pattern and timetabling four Airport services onto the East Hills Line would realistically make four Airport trains divertible to Miranda via the East Hills corridor; and
- it may also be possible for rail in the F6 Corridor to connect to a future (proposed) metro line through the CBD.

Development of an integrated network strategy and timetable and resolution of network constraints was outside the scope of this study. For the purpose of patronage modelling, it was assumed that four services per direction per hour would be able to be provided within the F6 Corridor.

There is an alternative to be considered for the southern end of the alignment to collect services from the Illawarra. This could be achieved by creating a new link from the Illawarra line between Sutherland and Loftus to the Cronulla line and connecting to the F6 alignment prior to Miranda. A Y-link could also be provided at Miranda to provide connections from Sutherland to the CBD. This would require further analysis to determine its feasibility.

6.1.4 Engineering Considerations

The development of detailed alignments, vertical or horizontal, did not form part of this study. Parsons Brinckerhoff developed a typical cross-section for the rail system (shown in *Figure 6.3*), representing a practical corridor for a heavy rail system stations, shared footpath and cycleway and limited cut and fill batters.

A concept centreline was developed within the F6 Corridor using the design criteria described in *Section 6.1.1* and a corridor width of 40 metres was applied to this centreline. A preliminary assessment of the potential geotechnical constraints that could be encountered along the alignment was also undertaken, based on a limited desktop study. From this conceptual development of the horizontal alignment it has been concluded that:

- the southern connection to the Cronulla Branch Line at Miranda would require a tight radius curve to turn a rail line in the F6 corridor to connect to the Cronulla Line;
- the topography between the Cronulla line and the Georges River is such that deep cuttings or even a cut and cover tunnel may be required in this area;
- a new crossing of the Georges River is likely to be required. It is assumed that this crossing of the Georges River is likely to be a tunnel;
- from the Georges River to just south of the M5 motorway at Cooks Cove, the topography is reasonably favourable but adverse geotechnical conditions may be encountered. These include existing landfill materials, watercourse and wetlands as well as alluvial sediments comprising peat, sandy peat and mud. Significant differential settlements are likely due to the loose and variable nature of the landfill materials and the low bearing capacity of the alluvial sediments;

In addition to the challenges listed above, two significant issues will require careful study if concepts for heavy rail in the corridor are to be developed further. Firstly, the alignment is likely to be in tunnel from immediately south of the M5-East motorway at Cooks Cove. This area is likely to present a technical challenge as tunnelling beneath the M5 East within the alluvial sediments is likely to induce significant settlements that the M5 East structures are probably not designed to withstand. A future railway in corridor is also expected to pass beneath the Airport Rail Line with similar difficulties expected as for the traversing of the M5 East. Secondly, a junction between a future possible F6 railway and the Airport Rail Line should ideally be located south-west of the

International Terminal Station. This may result in tight radius curves and expensive and complex tunnels if a grade separated junction were considered.

6.1.5 Cost Estimate

An order of cost for the development of rail in the F6 corridor was calculated using experience on other similar projects. Rates for the following major elements were extracted from Parsons Brinckerhoff's current projects such as the Parramatta Rail Link and the extension of the Gold Coast Rail Line:

- track system;
- signalling, traction power and communications systems;
- bridges and tunnels; and
- other civil works

Estimates were prepared for each of the two options and are subject to the following assumptions:

- an immersed tube tunnel will be required under the Georges River;
- most other tunnelling will occur in soft ground;
- road overbridges may be required at up to twelve locations and these may require property acquisition; and
- most of the permanent way construction will take place on existing landfill materials, or alluvial sediments comprising peat, sandy peat and mud.

Based on these assumptions, our initial assessment indicates a unit cost of approximately $48.6 to $62.5 million per kilometre for twin track heavy rail in the corridor. The cost of a heavy rail link between Miranda and Sydenham or International Airport Stations is in the range of $670 million to $1.0 billion.

Table 6.1 Estimated Range of Costs for Heavy Rail in the F6 Corridor

Description	Miranda to Sydenham	Miranda to International Airport
Length	16.0 km	13.8 km
Track and systems	$270 to $320 million	$240 to $270 million
Stations (5)	$50 to $80 million	$50 to $80 million
Civil works, including tunnels and bridges	$480 to $620 million	$390 to $500 million
Total	**$790 to $1000 million**	**$670 to $850 million**
Cost per kilometre	$49.4 to $62.5 million	$48.6 to $61.6 million

A conservative approach for the development of costs has been adopted given the conceptual nature of the investigations to date. Consequently the range of costs in *Table 6.1* is indicative only and is subject to further project development. The estimated costs appear reasonable in the context of other similar projects. The current estimated

Parramatta Rail Link cost is approximately $70 million per kilometre for a tunnelled railway in favourable tunnelling conditions[4].

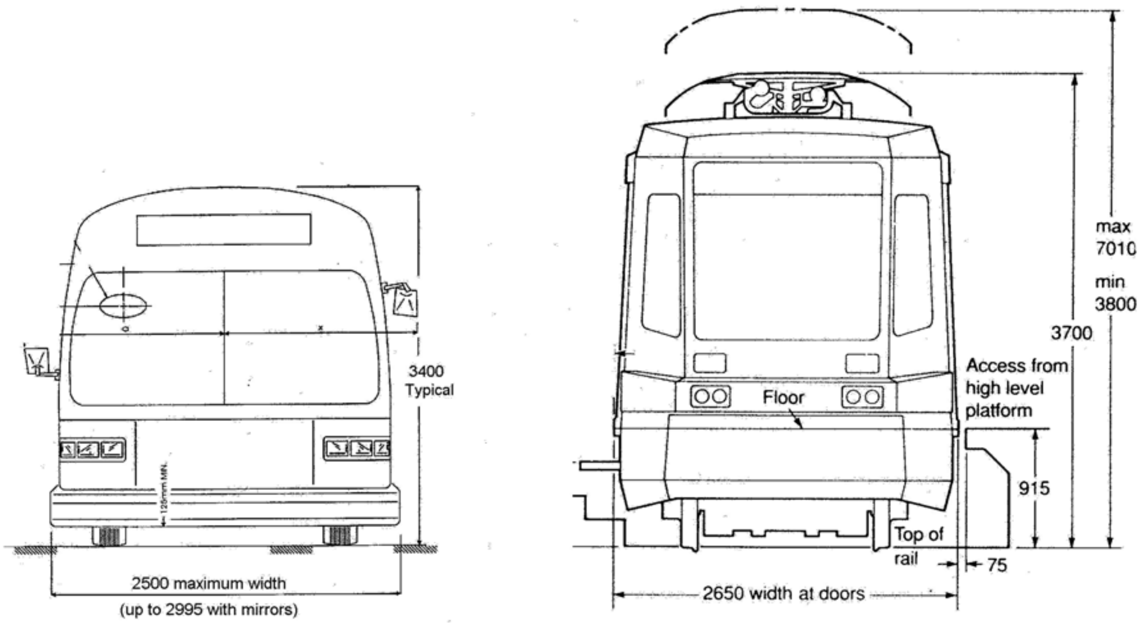
6.2 Medium Capacity Modes: Light Rail or Bus Rapid Transit in Exclusive Corridor

6.2.1 Infrastructure Requirements

Bus and Light Rail Compatibility

Over the long term, land uses adjacent to public transport links can be expected to change with any consequent patronage increases, warranting consideration of a change in operating technology. In this respect, as much flexibility as is reasonable should be incorporated in the design of the busway to allow possible future conversion to light rail operation. The busway should therefore be designed to current light rail standards in respect of transit space and geometry.

Infrastructure for light rail and busways can be designed to be compatible as the transit space requirements are very similar. *Figure 6.4* shows the frontal dimensions of typical bus and light rail vehicles for comparison.



Note: Additional width for mirrors on light rail vehicles can vary by around 50-400mm on either side, depending on whether CCTV or mirrors are used.

Figure 6.4: Typical Bus and Light Rail Vehicle Dimensions

In general, busway alignments are suitable for light rail, except for minimum turning radii at intersections. Intersection treatment and priority arrangements would be subject to complete redesign should a busway alignment be converted to light rail operation. As

[4] *Source - Parsons Brinckerhoff PRL design team*

long as design criteria for light rail are applied in defining the right-of-way, compatibility with busway requirements will be assured.

Due to its application in the urban environment modern light rail vehicles run with 750 Volt DC. Dual voltage light rail vehicles would be required if these vehicles should be extended to Cronulla using the existing railway line concurrently with CityRail suburban trains. This option was not investigated fully as part of this study. However, it is noted that some restrictions may apply in running light rail and heavy rail vehicles on the same track due to the differences in crash resistance.

Lateral Space Requirements

Busways would typically have two lanes, each 3.5 metres wide, one in each direction, with shoulders 0.6 metres wide, for a total roadway width of 8.2 metres. *Figures 6.5* and *6.6* shows a typical cross-section for the provision of a busway and light rail in an exclusive alignment.

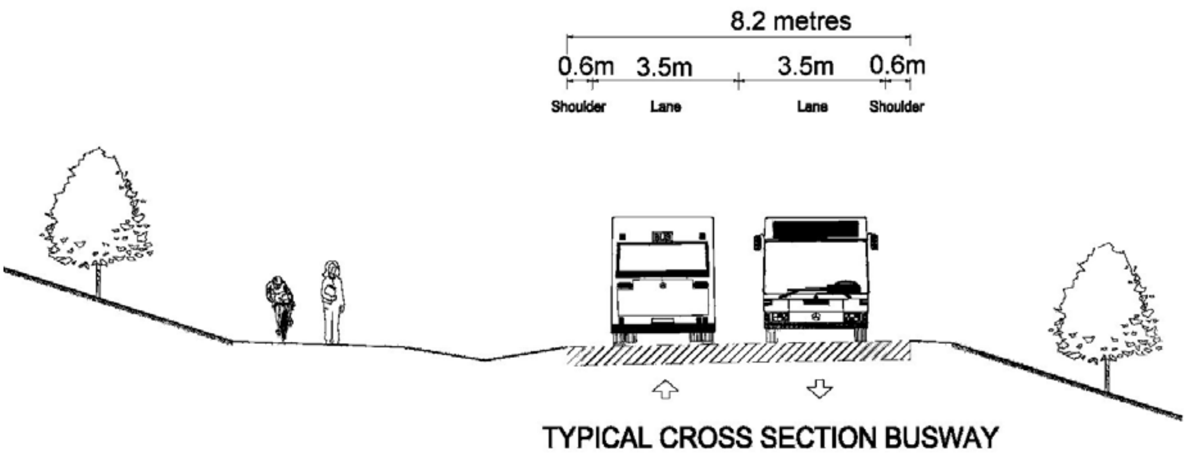


Figure 6.5: Typical Cross-section of Busway in Exclusive Alignment

A light rail system would be characterised by a double track alignment. Transit space requirements for typical (2.65 metre wide) light rail vehicles are similar to those for buses and a corridor width of between 6.65 metres and 7.55 metres is required depending on design speed and on whether the mast for the overhead wire is placed between the tracks or not. Consequently, the 8.2 metre roadway width provided for a busway would be adequate for retrofitting of a light rail system.

It is noted that cross-sectional requirements for light rail systems must provide for the “developed kinematic envelope”. This is the maximum width under any circumstances, of a light rail vehicle in motion at a particular point. The developed kinematic envelope takes into account all the possible effects of curvature, including track super elevation, and end and centre throw of the vehicle. This would be developed and confirmed during a detailed design process.

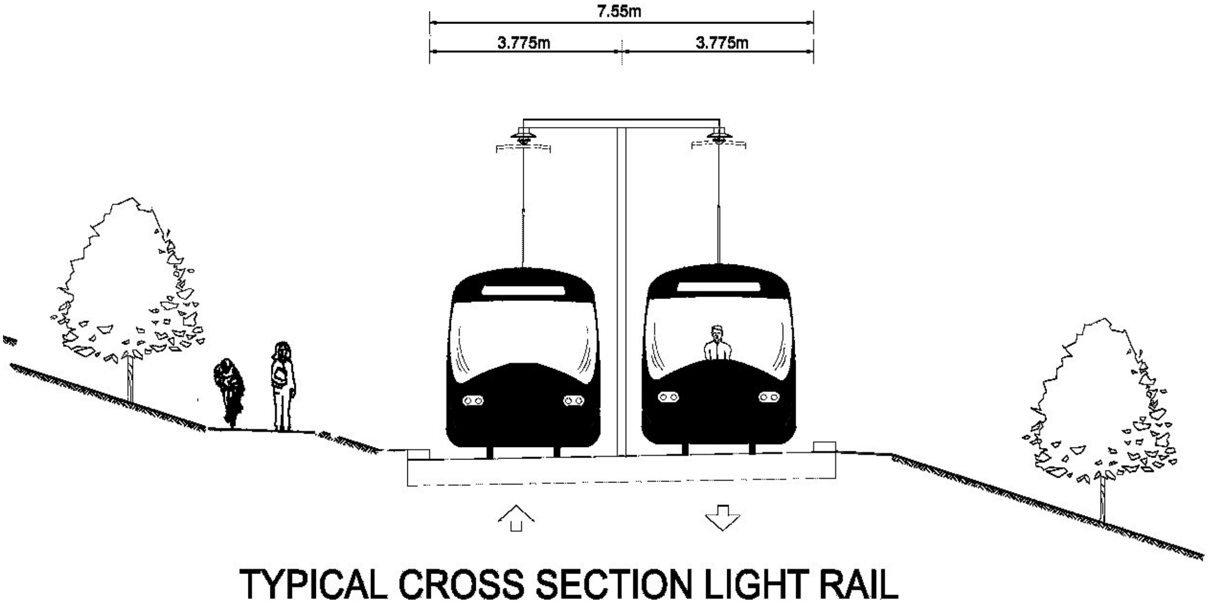


Figure 6.6: Typical Cross-section of Light Rail in Exclusive Alignment

Over-bridges and Vertical Clearances

In terms of vertical clearances, light rail vehicles are typically 3.4 metres to 3.7 metres high. The preferred height of the traction power contact wire is 5.5 metres minimum on street running sections with an absolute minimum clearance in emergency situations of 4.95 metres. In this situation special design and general traffic restrictions should apply and buses may not operate in the light rail corridor. While a single deck bus has a minimum height of about 3.0 metres, a clearance of 4.5 to 5.0 metres is preferred to allow for any future use of double-decker vehicles.

It is proposed that the heavy rail vertical clearance standard be applied to ensure future compatibility with both light rail and heavy rail using separate gantries or masts for carrying the overhead wire. Where over-bridges are likely to be required over the corridor, a 5.80 metre vertical clearance should therefore be provided between the top of the rail or road surface and the underside of the over-bridge

Alignment Standards

The design standards for light rail and busways were compiled from recent similar projects undertaken by Parsons Brinckerhoff, such as the Liverpool - Parramatta Transitway and the Gold Coast Light Rail (PB 2003 & PPK 2002).

Light rail vehicles require a minimum horizontal curve radius of 330 metres to maintain a speed of 70 kilometres per hour and this radius provides an equivalent busway design speed of 90 kilometres per hour. The absolute minimum curve radius for light rail at intersections is 25 metres (compared to 15 metres for buses) with a minimum radius of 70 metres applying elsewhere.

The maximum desirable longitudinal grade for a busway or light rail should not exceed eight percent, with busways potentially accommodating a ten percent grade. At stations the grade should not exceed 2.5 percent to ensure ease of access for wheelchair users.

Longitudinal grades should not be less than 0.35 percent on kerbed sections to ensure acceptable drainage. Gradient requirements for light rail are similar to those of the busway, with 7 percent gradients being the desirable maximum gradient for mainline track.

Stations

Indicative station locations are shown in *Figure 5.4* in the previous section. Busway stations are often staggered to reduce the right-of-way width requirement and this arrangement would require a total width of 17.5 m. However, the maximum width requirement is associated with a parallel platform arrangement as shown in *Figure 6.7*, where the width is 22 metres.

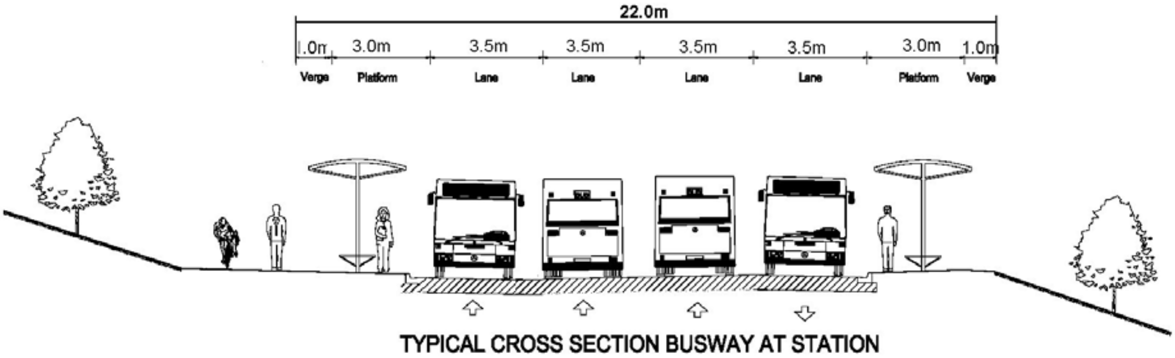


Figure 6.7: Cross-section of Staggered Busway Station

Experience has shown that passengers who cross tracks at or near a stop are exposed to a considerable degree of risk. For this reason, safe level crossings for light rail operation or bridges or underpasses for suburban or light rail operation have to be built. Interchange stations, serving passengers changing from buses or cars or bikes to the rail system, have to provide short and safe walkways equipped with good signage.

Light rail stations can be provided in either side or island platform configurations. An island platform should have a minimum width of 3.5 metres and is shown in *Figure 6.8*. The minimum corridor width at light rail stations is 10.4 metres.

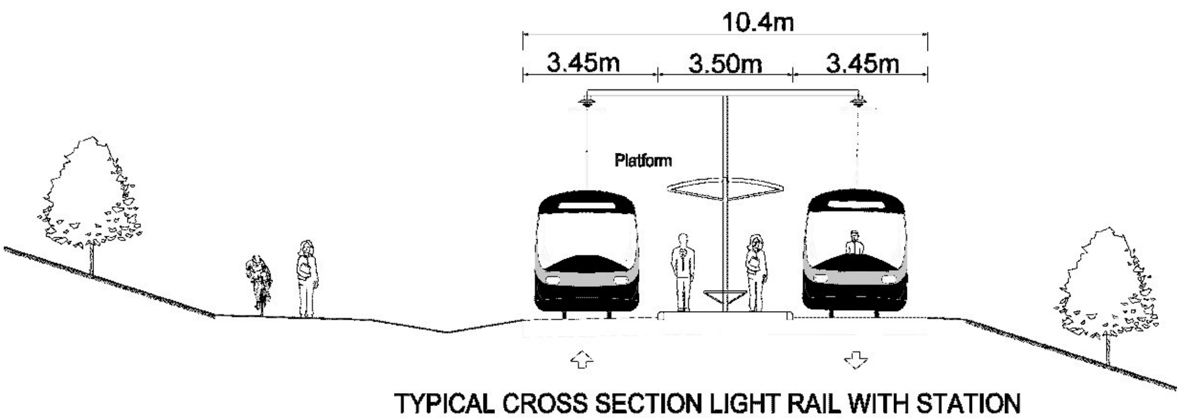


Figure 6.8: Cross-section of Light Rail Station with Island Platform

Other Infrastructure Requirements

If the F6 corridor is served by light rail, there will be a need to provide stabling facilities for secure storage, vehicle servicing and maintenance either at Cronulla or at Miranda for at least sixteen light rail train sets. A light rail train set consists of a maximum of three light rail vehicles, each with a maximum length of 25 metres. Inspection walkways will need to be provided between stabling roads and the minimum width of such a walkway is 1.5 metres. It is estimated that around 7,200 square metres for light rail stabling area will be required.

6.2.2 Land Requirements

If the future development of an exclusive busway or light rail system in the F6 Corridor is to be retained as an option, it would be necessary to provide a corridor of sufficient width to accommodate either the busway or light rail as well as the stations.

Ancillary needs such as parking and interchange facilities as well as stabling yards may be provided outside the corridor boundaries with property acquisition and more appropriately situated in the future when land use changes are apparent. The absolute minimum fence-to-fence rail corridor width for rail is based on the typical cross-sections in *Figure 6.5* and *Figure 6.6*:

- for general main line busway or light rail a minimum width would be 8.2 metres; and
- at stations with island platforms the minimum width would be 10.4 metres.

It should be recognised that no vertical alignment design was carried out for this study. Consequently it has not been possible to assess the space requirements of cut and fill batters or retaining structures. Allowance should also be made within or near the corridor for pedestrian and cycle access. The width required for footpaths and cycleways would vary depending on their configuration (shared or exclusive) and placement on the cut/fill batters.

Given that final station locations would be very difficult to identify during the current study, a corridor of adequate width should be reserved to retain full flexibility in siting stations. It would also be prudent to retain sufficient land to accommodate a footpath and/or cycleway as well as some reserve for earthworks (batters). It is proposed that a corridor width equivalent to that required for heavy rail (i.e. 40 metres) be retained to ensure that no public transport options are precluded. This would also retain adequate flexibility in placing stations, footpaths and cycleways and provide sufficient width for cut/fill batters. The final corridor boundary would be delineated during future studies after further detailed concept development has been undertaken.

6.2.3 Network and Service integration

A busway or light rail service in the F6 corridor would connect Miranda with Sydenham, and/or the Airport effectively running parallel with the Illawarra Line. The catchment of the service would potentially overlap with that of the Illawarra Line, particularly in the vicinity of Rockdale Station and northwards.

The key destinations for existing bus routes in this area are Kogarah and Rockdale rail stations. Ramsgate and Sans Souci are well served by buses to Rockdale and Kogarah rail stations and Rockdale Plaza, both in frequency and coverage. Frequent services operate between Brighton Le Sands and Rockdale rail station. Cross-regional services currently also operate between Miranda and Rockdale, Miranda and Hurstville, Burwood and Bondi Junction via Rockdale and Sydney Airport, Sans Souci and the CBD, Sutherland and Padstow. They provide key connections to the rail network and destinations between the major centres.

There are currently no bus priority initiatives in the area. The F6 corridor could potentially become a rapid transit sector for some of the cross-regional bus services. This is also recognised in the Unsworth Report as described in *Section 4.1.3* and would, if implemented, provide connectivity to the Sydney CBD and Bondi Junction.

Connectivity to the CBD may also be provided at Sydenham or International Terminal Station where passengers may interchange to a heavy rail service. Ideally this connectivity should be provided without requiring a mode change, but interchange requirements may need to be further assessed at these locations.

6.2.4 Engineering Considerations

The development of detailed alignments, vertical or horizontal, did not form part of this study. Parsons Brinckerhoff developed a typical cross-section for the light rail and busway and a right-of-way width of 22 metres was acknowledged by stakeholders as representing a practical corridor for a light rail or busway system, stations, shared footpath and cycleway and limited cut and fill batters.

A concept centreline was developed within the F6 Corridor using the design criteria described in *Section 6.2.1* and a corridor width of 22 metres was applied to this centreline. The route is described in *Section 5.5.3*, *Figure 5.4*.

A preliminary assessment of the potential geotechnical constraints that could be encountered along the alignment was also undertaken, based on a limited desktop study. From this conceptual development of the horizontal alignment it has been concluded that:

- the southern connection at Miranda Station will require on-street running along Kingsway and the traffic impacts of this arrangement needs to be assessed;
- the Captain Cook Bridge currently has a cantilevered footpath. Capacity reduction on the bridge due to replacement of traffic lanes with a public transport lane may not be acceptable therefore it may be required to widen the bridge with an extra public transport lane. As the footpath is currently already cantilevered, simply replacing the footpath is not an option. Under the busway option there is the potential to consider the approach whereby bus lanes are provided up to the bridge where buses then merge with normal traffic lanes. This may provide a reasonable compromise by delivering priority on approaches and trading off some measure of reduced performance while crossing the bridge against the substantial cost of modifying the bridge.

- from the Georges River to just south of the M5 motorway at Cooks Cove, adverse geotechnical conditions are likely to be encountered. These include existing landfill materials, watercourse and wetlands as well as alluvial sediments comprising peat, sandy peat and mud. Significant differential settlements are likely due to the loose and variable nature of the landfill materials and the low bearing capacity of the alluvial sediments;

- the alignment needs to cross over the M5 and the details of this crossing needs to be further investigated for obstacle clearance implications for the airport;

- a new crossing of the Cooks River will be required to connect to the International Airport Terminal Station. A bridge over the Cooks River would need to be at least the same height or higher than the existing Cooks River road bridge. However, the Cooks Cove development proposes to build a bridge over the Cooks River which includes provision for public transport and this may provide the appropriate link;

- a new bridge will be required over the Cooks River to provide for the connection to Tempe and Sydenham Station this would be within the F6 alignment at this point and its clearance requirements would need to be determined;

- the light rail or busway would share a corridor with the St Peters Industrial Route (SPIR) at St Peters (This is discussed further in *Section 6.4); and*

- the connection to Sydenham Station poses a number of constraints in terms of the road network conditions in the area. This link requires more detailed study should the option proceed and options to be considered should include use of the existing goods railway corridor.

It should be recognised that busways have some advantages in mixed-mode environment where the available transit space is shared with cars. At Sydney Airport for example, buses would be able to merge with other traffic.

6.2.5 Cost Estimate

An order of cost for the development of light rail and a busway in the F6 corridor was calculated using experience on other similar projects. Rates for the major elements such as were extracted from Parsons Brinckerhoff's current projects such as the Gold Coast Light Rail and the Western Sydney Transitways studies for the NSW Roads and Traffic Authority (PB 2003 & PPK 2002). Estimates were prepared for a busway and a light rail and are subject to the following assumptions:

1. GST is excluded and all costs are quoted in 2003 dollars;
2. at-grade crossings with signal priority will be provided at all road intersections except with the M5-East;
3. an overbridge over the M5-East will be required;
4. a new bridge over the Cooks River will be required; and
5. most of the permanent way/road construction will take place on existing landfill materials or alluvial sediments comprising peat, sandy peat and mud.

Based on these assumptions, our initial assessment indicates a unit cost of approximately $25 to $32 million per kilometre for twin track light rail in the corridor and between $14 and $19 million per kilometre for an exclusive busway with priority. The cost of a light rail link between Miranda and Sydenham or International Airport Stations is in the range of $350 million to $440 million and for a busway it is estimated between $200 and $260 million.

Table 6.2: Range of Costs for Light Rail or Busway in the F6 Corridor

Description	Light Rail	Busway
Length	16.4 km	16.4 km
Systems and/or track including stations	$170 to $200 million	$40 to $50 million
Civil works	$190 to $250 million	$170 to $220 million
Total	**$350 to $440 million**	**$200 to $260 million**
Cost per kilometre	$25 to $32 million	$14 to $19 million

The cost estimate assumes that grade separated road intersections will not be provided at any of the crossing roads except the M5-East. If grade separation were required at all intersections, up to eleven road overbridges would be required at eleven locations with associated property acquisition. The additional cost for these grade separated intersections, if incorporated during the initial construction, would be approximately $140 million.

A conservative approach for the development of costs has been adopted given the conceptual nature of the investigations to date. Consequently the range of costs in *Table 6.2* is indicative only and is subject to further project development.

6.3 Medium Capacity Modes: Light Rail or Busway on Street

6.3.1 Route Description

This is a road-based option that would have minimal diversions from the existing road network. The route would not be grade separated at junctions but would have signal priority. The conceptual alignment is shown in *Figure 5.5* in the previous section.

The route originates at Kiora Rd in Miranda, turns east down The Kingsway, north along Taren Point Rd, over the Captain Cook Bridge following Rocky Point Road and turning east along Sandringham St and north along Chuter Avenue, east President Avenue, north along Crawford Rd, at this point two options have been identified which show:-

c) east on Bay Street; and then north on Moate and Jacobson Avenue. The alignment would then cross over Muddy Creek and on a new bridge alignment or a tunnel depending on clearances around the airport runway envelope and the M5; and continue through the Cooks Cove development, before crossing the Cooks River to the international and domestic airport terminals; or

d) west on Bay Street to West Botany Street to Marsh Street to the F6 alignment where it would then cross the Cooks River before linking up with the proposed St Peters Industrial Route (SPIRE) from where it diverts to Sydenham Station.

It would be desirable to have a direct connection to the Sydney CBD rather than provide an interchange at the Airport Line or Sydenham Station.

Another potential extension that could be considered is a link to Rockdale station along Bay Street as a means of improving overall system integration.

6.3.2 Infrastructure Requirements

The infrastructure requirements for light rail and busways running on streets are similar to those for an exclusive corridor, with the exception that the infrastructure needs to be integrated into an existing road alignment.

Intersection treatment and priority arrangements would need to be carefully designed, particularly since light rail vehicles are not common on Sydney roads as they are in other cities (such as Melbourne).

Due to its application in the urban environment modern light rail vehicles run with 750 Volt DC and an overhead wire system would need to be provided.

Lateral Space Requirements

Busways would typically have two lanes, each 3.5 metres wide, one in each direction while a light rail system would be characterised by a double track alignment in a corridor width of 7.15 metres. The mast for the overhead wire would be placed between the tracks.

Vertical Clearances

The preferred minimum height of the traction power contact wire is 5.5 metres and structures would have to provide a minimum vertical clearance of 5.80 meters.

Alignment Standards

The absolute minimum curve radius for light rail at intersections is 25 metres (compared to 15 metres for buses) with a minimum desirable radius of 70 metres applying elsewhere.

The absolute maximum desirable longitudinal grade for a busway or light rail should not exceed ten percent. At stations the grade should not exceed 2.5 percent to ensure ease of access for wheelchair users.

Stations

Indicative station locations are shown in *Figure 5.5*. Stations can be provided in either side or island platform configurations depending on the road layout. The station locations are based on medium capacity modes with a station spacing of around 800m to 1 kilometre.

6.3.3 Engineering Issues

A list of engineering constraints is provided below for the on street option:

- features of the existing road network that may need to be altered or removed such as traffic control devices to accommodate a public transport option;
- the Captain Cook Bridge currently has a cantilevered footpath. Capacity reduction on the bridge due to replacement of traffic lanes with a public transport lane may not be acceptable therefore it may be required to widen the bridge with an extra public transport lane. As the footpath is currently already cantilevered, simply replacing the footpath is not an option. Under the busway option there is the potential to consider the approach whereby bus lanes are provided up to the bridge where buses then merge with normal traffic lanes. This may provide a reasonable compromise by delivering priority on approaches and trading off some measure of reduced performance while crossing the bridge against the substantial cost of modifying the bridge.
- a bridge over the Cooks River Bridge, would need to be at least the same height or higher than the existing Cooks River road bridge. The existing height of this bridge is approximately 4.5m from water level;
- the links to International Airport Station will require further investigation. Under Option A there is an option for a crossing to Tancred Avenue over Muddy Creek through the Cooks Cove development with a stop at this location (see *Figure 5.5*). Then there would be a crossing over the Cooks River to the airport via the proposed bridge included in the Cooks Cove development submission;
- there are significant engineering constraints at the Sydney International Airport terminal for a light rail or busway alignment operating through the airport. Elevated roadways serve the terminal, however an at-grade option could be sought to avoid the existing roadways. It should be accepted that on the way to and around the airport terminal the alignment would have to significantly deviate from the existing road alignments.

6.3.4 On-site Survey

An onsite survey was undertaken to assess the on road option for medium capacity modes. The survey aim was to assess the suitability of the existing road network to accommodate the inclusion of the medium capacity modes. Factors that were considered during the survey were:

- road widths;
- location of the light rail or busway within the available road space (centre of road or along kerb);
- existing traffic calming and traffic control devices;
- potential suitable locations for stations;
- intersection layouts; and

- method of river crossing. Existing bridge construction and the ability of the bridges to accept another lane.

South of the Georges River, the opportunities for on-road bus services are primarily on higher capacity arterial roads of up to six lanes. North of the Georges River, these opportunities would occur on lower capacity local roads of around 13 metre width with a large amount of traffic calming.

Roads along the on-road route are generally wide enough to accept the inclusion of a bus or light rail services within the existing road reservation. The exception to this was further to the north of the study area along Jacobson Avenue, which has a road width of 11 metres, and Tancred Avenue, Kyeemagh, where the road is 10.5 metres wide. Chuter Avenue, Sans Souci is currently a dual carriageway lay-out but does not function as a dual carriageway road ins some areas. This is apparent around the Ramsgate RSL, where the second carriageway has been made into a car park. This means that, at present, the single remaining carriageway would not be wide enough to accommodate the bus or light rail and these would have to use the wide median or, alternatively, the dual carriageway operation would have to be reinstated.

The roads on the route have quite a high level of traffic calming north of the Georges River. There are numerous roundabouts, refuge islands and squeeze points along the selected route. These traffic calming devices would need to be removed or altered to allow the operation of bus or light rail along the road.

The route also involves a number of short doglegs onto main roads running perpendicular to the F6 alignment. These doglegs using the main roads are ideal station locations allowing connections to east west running bus services to be much more legible and accessible.

Centre of road or kerbside options

It is likely that there is insufficient space for middle of road options considering stations. Locating stations at the kerbside would be more suitable with priority signalling at intersections to allow turning manoeuvres from the outside lane.

A number of optional road alignments were also assessed on site and it was found that:

- Francis Avenue, Brighton-Le-Sands would be unsuitable for public transport use due to its restrictive width.
- the option to divert the route off the roadway onto the F6 alignment just south of O'Connell Street, Monterey is feasible. The route would divert west off the road at A.S Tanner reserve and run along the back of the houses fronting Colson Cr, Monterey. The route could dogleg at President Avenue, Kogarah and then turn right onto West Botany Street, Kogarah or alternatively could join into the proposed off street F6 alignment.
- West Botany Street (Arncliffe) is a feasible option to the proposed on-street alignment. The grades would need to be further clarified for use by light rail. There are a number of pedestrian refuges that would need to be removed. The road width is sufficient being 4 lanes. However, there may be considerable impacts on traffic flow.

- Bestic Street, Kyeemagh is sufficiently wide except at the bridge at Muddy Creek where the road narrows.

The best option is expected to follow the proposed on road route up to O'Connell Street, Monterey, then divert west through the reserve left onto President Avenue, Kogarah, then Right onto West Botany Street, Kogarah or use the F6 alignment north from this diversion.

6.3.5 Cost Estimate

An order of cost for the development of light rail and a busway on road was calculated based on other similar projects. Rates for the major elements were extracted from Parsons Brinckerhoff's current projects such as the Gold Coast Light Rail and the Western Sydney Transitways studies for the NSW Roads and Traffic Authority (PB 2003 & PPK 2002). Estimates were prepared for a busway and a light rail.

Based on these assumptions, our initial assessment indicates a unit cost of approximately $17 to $21 million per kilometre for twin track light rail and between $7 and $10 million per kilometre for busways on streets. The cost of an on-street light rail link between Miranda and Sydenham or International Airport Stations is in the range of $280 million to $340 million and for a busway it is estimated between $120 and $150 million.

Table 6.3: Range of Costs for Light Rail or Busway on Street

Description	Light Rail	Busway
Length	18.5 km	18.5 km
Systems and/or track including stations	$190 to $230 million	$40 to $50 million
Civil works including bridges	$90 to $120 million	$80 to $100 million
Total	$280 to $340 million	$120 to $150 million
Cost per kilometre	$17 to $21 million	$7 to $10 million

A conservative approach for the development of costs has been adopted given the conceptual nature of the investigations to date. Consequently the range of costs in *Table 6.3* is indicative only and is subject to further project development.

6.4 Local Bus Concept

Bus services in the study area are provided by multiple operators with the largest of these being State Transit and Connex. Services are generally focused on railway stations with Miranda, Rockdale and Kogarah being the most significant, while Hurstville is also the destination for some services. Buses provide the sole public transport option for most people in the corridor for access to rail or local centres. Service frequencies vary significantly as do hours of operation, with generally poor levels of service outside peaks and on weekends. Existing bus service structures are shown in Section 4.1.3 above and *Appendix E*.

Traditionally the structure of services in the area has been largely built around contract areas. Removal of these often artificial barriers has the potential to improve the overall coverage and performance of the bus network. An example can be drawn from the area between Sans Souci and Brighton-Le-Sands where both STA and Connex operate either to Rockdale (STA) or Kogarah and Hurstville (Connex) on roads within about 400 metres of each other. Because of contract area restrictions some of the routes operate along General Holmes Drive on the shores of Botany Bay with a significantly reduced patronage potential because of the one sided catchment. This form of structural inefficiency is wasteful of scarce public transport resources. This problem is further exacerbated by the fact that STA cannot run services into the key regional centre of Hurstville from its area of operation.

More specifically, STA routes 303 (to City) and 478 (to Rockdale) use General Holmes Drive, while Connex's route 947 travels along Chuter Avenue (400 metres back from the Bay). Common use of Chuter Avenue and a rationalisation of route structures could increase the overall effectiveness of services in this area leading to increased frequencies, improved patronage potential and lower operating costs.

However, recent changes to bus contract areas being instituted by the government in response to the recommendations of the "Review of Bus Services in NSW, Unsworth Report" (MOT 2004) indicate that the contract for the area along the F6 corridor (north of the Georges River) will come under the control of STA. In his report, Unsworth recognised that the structure of contract areas is a key impediment to improved bus services in Sydney. This should open the way to a restructuring of services to remove some of the impediments to bus travel in the corridor.

In conceptual terms the bus network in the corridor could be expected to respond to the operational requirements of any mode which was selected to operate along the F6 corridor in the following way:-

- Under a heavy rail option buses would be restructured to serve new railway stations and provide an interconnection with the existing Illawarra Line stations.
- A light rail system could see similar changes, however, the closer spacing of stations would increase the walk catchment of the line and potentially reduce the need for bus services in the area.
- A BRT system, either in an exclusive corridor or on road would be the catalyst for a major restructuring of the bus network in the area. Service integration would be expected to deliver a combination of service types which would feed through residential areas before joining the F6 public transport corridor to run to a destination either on or off the corridor (e.g. Rockdale, Sydney Airport, Central Sydney etc).

The Unsworth report identifies three Strategic Bus Routes within this corridor. These are shown on Figure 4.5 above. One route (No. 21) parallels the alignment of the corridor and could conceptually, be seen as the "first stage" of the F6 public transport corridor with later stages making use of the F6 corridor to deliver high priority public transport services. As demand grows the system could transition to light rail. Issues of staging are addressed later in this report.

6.5 Road Network Context

6.5.1 Potential Road Network Impacts

The F6 alignment crosses major roads at the following locations:

- Marsh Street, Arncliffe
- Bestic Street, Banksia;
- Bay St, Brighton-Le-Sands;
- President Avenue, Kogarah;
- Barton St, Monterey;
- Sandringham St, Sans Souci;
- Taren Point Road, Taren Point;
- Port Hacking Road, Sylvania;
- The Boulevarde, Miranda;
- The Kingsway, Miranda;

These road crossings have implications for the design of any public transport options that require an exclusive right-of-way in the F6 corridor above ground (heavy rail and light rail/bus options). The indicative alignments have broadly taken into consideration the need for grade separation at these intersections. However, there will be a need to consider local road closures but these would only happen where there is viable alternative public access available.

The preliminary concept shows that the roads that may need to be closed at the point where they cross the alignment inlcude:-

- Wingello Road, Miranda
- Tuffy Avenue, Sans Souci
- Ritchie Street, Sans Souci
- Park Road, Sans Souci
- Meurants Lane, Ramsgate
- Clarkes Road, Ramsgate
- Margate Street, Ramsgate
- Bruce Street, Brighton-Le-Sands

These roads are shown graphically in *Appendix D*, Any potential road closure is subject to a detailed traffic study that would need to be undertaken to assess the traffic impacts and to devise mitigation measures. Such a detailed local area traffic study was not part of this investigation. However, it should be recognised that road closures and the introduction of transit priority (under some options) could potentially increase road congestion on arterial and other roads, and therefore increase road user costs.

The RTA has undertaken preliminary modelling to establish an indicative measure of road network impacts. The measures are dependant on the public transport option tested and the level of priority provided on arterial roads. The results show that between 500 and 1,000 hours of additional vehicle delay in the two hour morning peak could be experienced on the wider road network. The differentiating factor between these figures is the assumption regarding the level of priority provided on Captain Cook Bridge. The lower figure assumes no impact on road capacity while the higher figure assumes removal of capacity to accommodate a public transport system. The comparative costs are in the range of $14 million to $36 million per annum. (see also *Section 7.3.1*)

The construction cost estimates for bus and light rail services in the F6 corridor do not allow for road overbridges (at-grade intersections are provided) where crossing roads are to remain open. For the heavy rail option, the cost of grade separated crossings, including property acquisition that may be necessary on the bridge approaches, are included in the estimates.

The detailed studies that would be required to support further consideration of a public transport option for this corridor would include development of a detailed road strategy which would address road network implications and local access needs as discussed above.

6.5.2 The St Peters Industrial Route

The alignment of the proposed St Peters Industrial Route (SPIR) is shown on *Figure 6.9*. This has been plotted from information provided by the RTA and includes the recent Marrickville Council adjustment to cater for the proposed retail development in Tempe fronting Bellevue Street and the Princes Highway to the west of the F6 corridor. It is noted that electronic data was not available so the boundaries as shown are scaled only and would be subject to detailed survey.

An *Overview Report* prepared by Kinhill Pty Ltd in 1999 identified the need for a six lane carriageway and a reserve width of 50 metres minimum. The proposed carriageway cross section shows a total width of 34.8 metres kerb to kerb.

The only public transport option that is affected by the SPIR route is the busway / light rail option which links to Sydenham Station. The following are among the key considerations for this section of the corridor:

- in theory, there could be enough space to co-locate the busway / light rail line with the a four-lane roadway within the 50 metre minimum, SPIR reserve width. However, this would need to be investigated in more detail and may require widening of the reserve.
- if the busway / light rail option becomes the preferred option then traffic demands should be re-evaluated to confirm the lane requirements. A reduction to four lanes would ensure the required space to co-locate the two modes within the 50 metre

reserve without widening. It is noted that there are a number of closely spaced intersections along this route that may require flaring to cater for traffic demand.

- the optimum option for access to Sydenham station lies within the existing rail corridor. However, this requires further investigation to confirm viability. If confirmed, the busway / light rail alignment would need to deviate from the SPIR reserve in order to pass under the bridge which will carry the road over the Botany goods line.

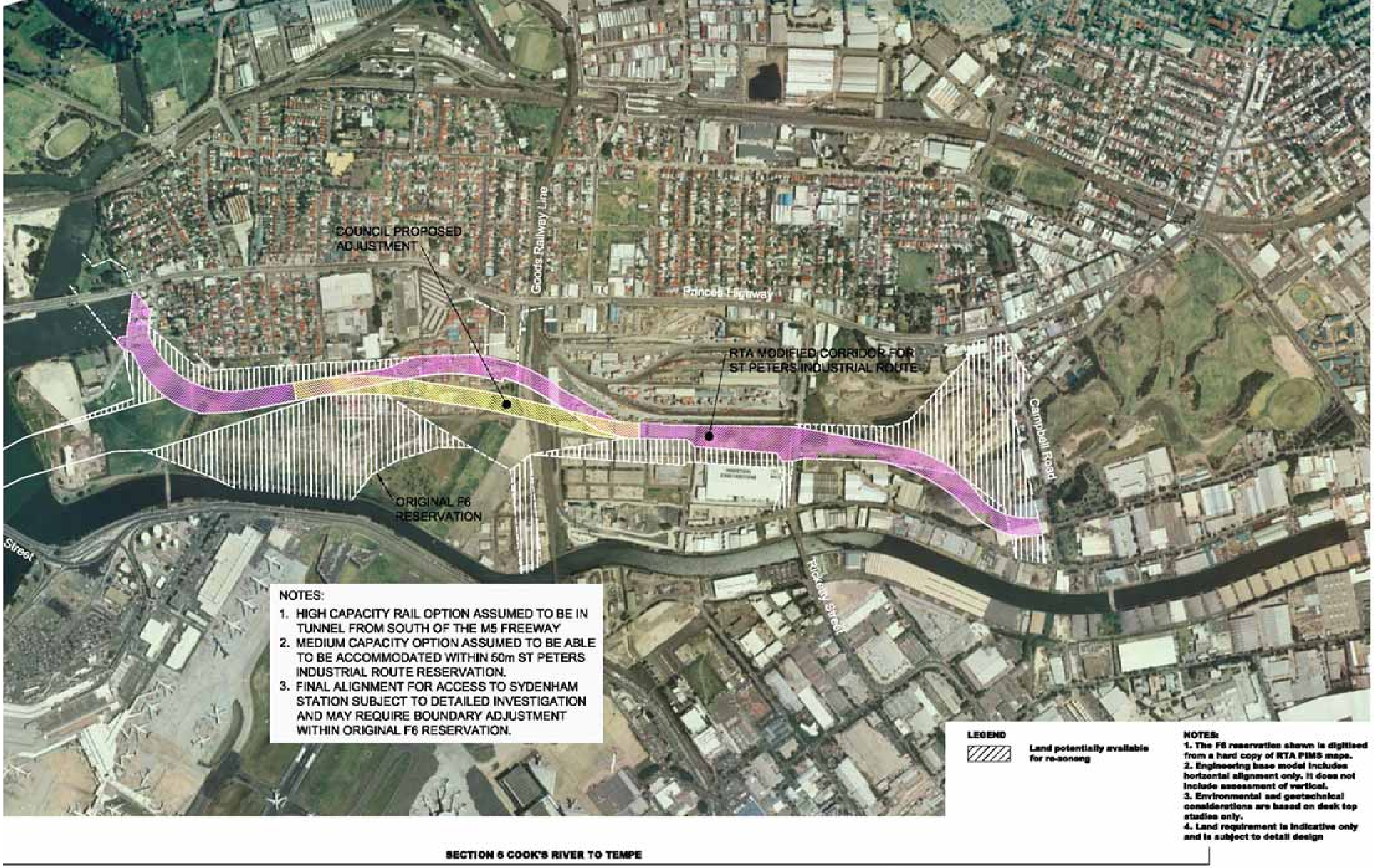


FIG 6.9 ST Peters Industrial Route Reservation

- The alignment falls within the area of influence of the airport approach paths. A review of the *Obstacle Limitation Surface Plan* provided by SACL indicates a maximum height of about 16 metres AHD for any structure of passing vehicle under the flight path at the SPIR route. There is no data which shows the surface levels along the SPIR route however, a review of contour information suggests that the level where it crosses the flight path may be in the order of 5 to 8 metres AHD. Assuming that a maximum structure clearance of 6 metres would be associated with a light rail system then the overall height 'envelope' would be in the order of 11 to 14 metres AHD. In this regard the RTA has advised that it's investigations indicate the need to lower the road to comply with flight path restrictions. It is noted that this issue may also impact on the crossing of the railway by the SPIR route.

In summary, it may be feasible to co-locate the busway / light rail alignment with a four lane road within the 50 metre wide SPIR corridor. However, this should be confirmed through design of the SPIR route and the busway / light rail. This design must also consider the constraint of the flight path on vertical elements of both the road and the public transport facilities.

7. Assessment of Options

7.1 Assessment Approach

7.1.1 Travel and Accessibility

The Patronage Model

Modelling was carried out to determine the likely patronage for the various public transport options under consideration in this assessment. This was based on current population and employment projections for 2021 supplied by the Transport and Population Data Centre (TPDC) of Department of Infrastructure, Planning and Natural Resources (DIPNR).

Three heavy rail options and two light rail options were modelled:

- Heavy Rail – Base Option: Wynyard to Waterfall (via Sydenham);
- Heavy Rail – Option 1: Wynyard to Cronulla (via Sydenham);
- Heavy Rail – Option 2: Town Hall to Cronulla (via Airport and Museum);
- Light Rail – Option 1: Sydenham to Miranda (via F6 corridor); and
- Light Rail – Option 2: Domestic Airport to Miranda (via road network).

The Sydney Strategic Travel Model (STM) was used for undertaking patronage forecasts and assessment of various public transport options within the F6 Corridor. The STM is a combined destination-mode choice model and is used extensively for public transport modelling in Sydney and was developed and run by the TPDC.

At the time of this study only Stage 1 of the STM's development process was completed and available for use. Stage 1 of the STM involves a mode/destination choice model for home to work (commute) trips and models for estimating inputs to this model (such as models for license holding, vehicle ownership etc). Stage 1 STM uses a factoring process to develop the purpose "other" trip table based on "commute" trips. The factors for purpose "other" have been developed based on observed trip length distribution in Household Travel Survey (HTS) data.

The mode/destination model can be run in an iterative process to include feedback from network assignment to network skims input to mode choice model. The model is currently set up for up to four cycles. Detailed information on structure and parameters of STM can be obtained from TPDC.

As the F6 corridor would be a new public transport corridor, additional nodes and links were required to be coded for the heavy rail alignment and the light rail (Option 1) alignment that are within this corridor. While the Light Rail Option 2 alignment predominantly uses the existing public transport road network, some additional links were required. Where new nodes and links were required, these were developed using the same coding conventions with regards to link types and other user defined parameters for the rail network and public transport road network respectively.

Model Assumptions

In developing the transit service distributions for the heavy rail and light rail options, the stopping patterns and travel times need to be given. For the rail options, the travel time between each rail station is required while for the light rail options the average travel time for the service is required.

For the heavy rail options, PB formulated the stopping patterns and travel time between heavy rail stations along the F6 corridor. The stopping patterns and travel time between heavy rail stations for the existing rail corridors were based on the existing rail services along these corridors (i.e. Eastern Suburbs/Illawarra line and the Airport/East Hills line). For the light rail options, PB formulated the stopping patterns and the model determined the travel time between light rail stations based on the link speeds of the network.

The new heavy rail options were proposed to have a 15-minute frequency with a potential seated capacity of 3,360 passengers and a total capacity of 4,800 passengers per hour. The medium capacity (light rail) options were proposed to have a 5 minute frequency and a travel speed of 35 kilometres per hour, with a seated capacity of 1,800 passengers and a total capacity of 2,400 passengers per hour.

The STM model does not explicitly code dwell time at the heavy rail or light rail stations or a layover time period at the end of each route, but these are included in the overall run times specified in the model.

The patronage outputs are outlined in the following sections for each option.

Potential Land Use Changes due to Public Transport in the F6 Corridor

While recognising the intention to retain open space opportunities in the corridor, it is believed that there may be some potential for an increase in population density and increases in employment in the catchment of the F6 Corridor should public transport be developed in it (the F6 Corridor). Consequently, high land use assumptions were developed within the corridor catchment on the basis of the public transport line influencing land use densification near stations. Transit Oriented Development (TOD) oppportunities have been assessed in the corridor at key station locations, both at existing stations such as Cronulla and Caringbah and the new stations suggested along the corridor.

The purpose of developing the forecasts was to derive an upper bound for densification around stations. In producing a “bullish” forecast, some assumptions were made regarding development potential. Accordingly, in the case of residential development potential it was assumed that the overall potential residential density on land that is developable would be as follows:

- 1-200 m from a station, 50 dwellings per hectare;
- 200-400 m from a station, 30 dwellings per hectare;
- 400-800 metres from a station, 20 dwellings per hectare; and

- for the remainder of the corridor, densities either matching prevailing or 10 dwellings per hectare, whichever is the greater.

For the purposes of identifying developable land, the following land uses were excluded from residential redevelopment areas:

- the current corridor
- industrial areas
- schools, playing fields and parks; and
- high density commercial areas around Miranda and Cronulla stations.

It was assumed that there is potential for shop-top redevelopment in the Caringbah shopping area.

The total population potential was based on an average household size of 2.9 persons and is expressed as an increase over the most recent TPDC forecasts (TPDC 2003v1). In these forecasts, TPDC has already adopted quite intensive growth in Cronulla, Woolooware, Miranda and Ramsgate, Brighton-Le-Sands and the aggressive TOD assumptions result in only small further increases in these areas. The major potential is seen in Burraneer, Miranda, Sandringham and Arncliffe around the new Cooks Cove development. The "bullish" forecasts for residential population in the F6 Corridor catchment for 2021 thus developed is some 13 percent higher that the TPDC's current forecasts for the same timeframe. Given that this bullish forecast applies to the F6 Corridor catchment, the patronage forecasts for public transport options in the corridor could be increased by a similar proportion to represent the impact of higher than forecast land use change. However, for the purposes of this study the current TPDC forecasts have been applied for the evaluation of options.

Employment changes are significantly more difficult to quantify. The Sydney Airport Preliminary Draft Masterplan alludes to the development of additional airport-related employment, but the anticipated growth is not quantified. We have therefore adopted a sensitivity approach, assuming that for travel zones within one kilometre of the corridor, employment could increase by 10-20%.

The recent TPDC forecasts show, compared to employment in 2001:

- increases in employment in Cronulla, Miranda and Sandringham;
- decreases in employment in the Ramsgate-Kyeemagh area;
- an increase in Airport employment of around 5,000; and
- a net increase in employment of around 6% in the corridor from 2001.

The sensitivity approach results in lower and upper limit increases of 16% and 27% respectively in total employment in the corridor compared to 2001.

7.1.2 Social and Land Use

The social and land use assessment is aimed at establishing to what extent the different options:

- ensure equitable access to social and economic activities; and/or
- reduce journey times for all journeys to, from and within the corridor.

The performance of each option was evaluated against the following criteria:

- relative and subjective assessment of potential travel times to CBD from the catchment;
- the number of intra or inter mode transfers that may be required; and
- the estimated population within walking distance of stations

7.1.3 Environmental Impacts

Environmental opportunities and constraints may arise for the community with the development of public transport in the F6 corridor, and these are discussed in more detail in *Section 3* of this report.

An attempt was made to asses the potential for each option to enhance the potential beneficial effects and manage potential adverse environmental impacts. The assessment criteria were based on the extent to which each option potentially:

- conserves biological diversity and ecological integrity
- improves air quality and reduces greenhouse gas emissions
- minimises the use of energy and non-renewable resources

Measures of performance against the criteria are based primarily on:

- potential of each option to encourage mode shift from car based travel to public transport, as measured by the potential change in vehicle kilometres travelled (vkt's);
- the opportunity to avoid sensitive natural environments and to mitigate adverse effects resulting from public transport development through design of appropriate alignments. As all alignments follow the same route the best basis for comparison would be the width of the corridor used by the transport infrastructure; and
- the subjective energy use and emission impacts of the different modes

Consideration was also given to the relative potential for each option to maintain connectivity across the corridor, particularly for pedestrians and cyclists.

7.1.4 Economic and Financial

The economic and financial performance of the various options was assessed by calculating the cost per passenger for each option. The costs are restricted to operations in the corridor itself and are at a fairly broad level in that no detailed operational planning has been undertaken.

Costs

Infrastructure costs were estimated as part of the study. The lowest cost of the ranges estimated was used in the cost estimates for each mode. An annual value was estimated using asset lives and a discount rate of 7 per cent. The following costs were used:

- CityRail provided unit costs for operating suburban trains and the capital costs of trains. An annual value was estimated using an asset life of 35 years and a discount rate of 7 per cent. No costs are included for station operations. CityRail costs are available for existing stations but it is not clear that they would be appropriate for the F6 corridor where the stations would be small and have low operating costs;
- light rail operating costs were estimated from tram operating costs in Melbourne. The unit costs used are below those in Melbourne as a new system in an off street environment is being costed. The cost of new articulated low floor trams in Melbourne was used for the light rail car costs. An annual value was estimated using an asset life of 30 years and a discount rate of 7 per cent;
- bus costs were estimated for the evaluation of the western Sydney Transitways. Because these costs assumed services would be provided by a private operator, or a contracting approach would deliver private operator cost structures, the bus costs will be underestimated if bus services in the F6 corridor are provided by the public operator. The capital cost of new buses was converted to an annual value using an asset life of 15 years and a discount rate of 7 per cent. No operating cost estimates are available for stations on a busway or light rail, but these are likely to be low compared to other operating costs; and
- infrastructure maintenance costs are estimated as 1 per cent of the capital costs of systems/track/stations. No maintenance costs are included for civil works. All costs exclude GST but include other taxes such as payroll tax and fuel excise, ie they are financial, not resource, costs.

Patronage

The demand modelling gave results for 2-hour peak passenger flows in the peak and contra peak direction. The contra flow direction for busway and light rail modes was about 40 per cent of the peak direction flow, and 50 per cent for heavy rail, and 65 per cent for bus and light rail on street. Those percentages are used to estimate total 2 hour peak flows. Only the peak direction flow is used to estimate the number of vehicles required to meet demand.

Using this method implies that all modes of transport attract the same level of patronage. However, in this strategic study the assumption has been that the medium capacity modes (light rail and bus transit) will be afforded the same level of design and priority and will therefore attract similar levels of demand. Nevertheless it is recognised that there is some evidence that rail modes generate more trips than on-street buses.

Whether this preference for rail modes holds for busway services, which are intended to mimic the characteristics of rail modes, is less certain.

The 2-hour peak demand and costs need to be extrapolated to give annual figures to estimate costs/passenger on an appropriate basis. A factor of 1,000 was used to extrapolate passengers in the 2-hour peak to an annual total and a factor of 1,400 was used to calculate the annualised costs from 2-hour peak costs per passenger. These factors are based on analysis of bus services in western Sydney and were used in the evaluation of the Transitways. Other factors may be more appropriate for rail services, depending on the level of peaking; a brief check against data in the CityRail document "A Compendium of CityRail Travel Statistics, July 2001" suggests that any differences are unlikely to affect the overall analysis.

Basis for Calculation

The cost per passenger were estimated on an incremental basis to arrive at the total cost for each mode:

- vehicle operating costs were calculated first, and these include crew/drivers, fuel/electricity, vehicle maintenance, vehicle cleaning, etc;
- the capital cost of the vehicles were then calculated and added to the operating costs;
- the infrastructure maintenance cost was then added, which provided an indication of the total recurring operating cost of a given mode system excluding the capital cost of the infrastructure; and finally
- the infrastructure costs were added to the operating costs to provide the total cost for each mode per passenger. The capital cost was distributed over the total patronage over an assessment period 35, 30 and 15 years for heavy rail, light rail and bus respectively.

The costs per passenger were estimated for 2-hour peak direction patronage of between 1,000 to 10,000. The demand modelling patronage estimates indicated that the 2-hour peak direction demand would be around:

- 1,200 passengers in the 2-hour peak direction for heavy rail;
- 4,000 passengers in the 2-hour peak direction for busway/light rail in an exclusive corridor; and
- 3,700 passengers in the 2-hour peak direction for on-street bus/light rail.

These levels of patronage demand are shown as vertical lines on the graphs of cost vs demand in *Figure 7.1*, *Figure 7.2* and *Figure 7.3*.

Calculations

Figure 7.1 below shows the vehicle operating cost per passenger (excluding capital cost of infrastructure and vehicles and infrastructure maintenance costs).

It shows that light rail in the F6 reservation generally has the lowest operating cost of the modes over the range of passenger numbers between 1,000 and 1,000 in the peak 2-

hour. However, above 6,000 passengers per peak direction, the heavy rail and light rail operating costs are virtually the same.

There is little variation in the bus and light rail costs with the number of passengers carried as the operating costs for these modes are almost directly related to the number of passengers carried. This is due to the small capacity of the vehicles; vehicles are essentially all travelling full and more passengers mean more vehicles are required. The heavy rail costs vary with passengers carried because operating costs are significant for each train set and the number of seats per train is large; costs decrease as demand increases (as more seats are filled) but at some point the costs increase again as a new train set is added (i.e. the train seats are filled and another train is added to cater for the next passenger). The effect is not so marked for the lower capacities of buses and light rail vehicles. This explains why the cost graphs for heavy rail fluctuates up and down with increased passenger numbers. This fluctuation is visible in all three the cost graphs below.

The differences between costs for operations on street and in the reservation are due to speed of services, with 25 kilometres per hour used for on street operations and 30 kilometres per hour for operations in the F6 reservation. A speed of 40 kilometres per hour was used for heavy rail as fewer stations are proposed.

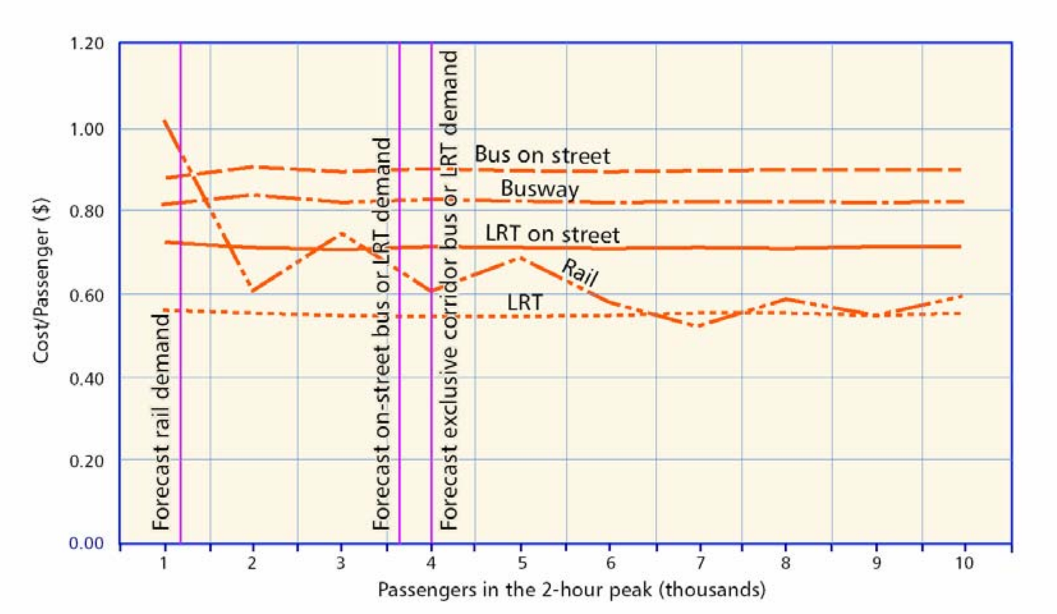


Figure 7.1: Operating Costs per Passenger by Mode

The assumptions underlying the capital cost of vehicles for each mode estimates are shown in *Table 7.1* below. The last row shows that light rail vehicles have the highest purchase cost per passenger. *Figure 7.2* shows how costs per passenger by mode change when vehicle captial costs are added to the equation.

Table 7.1: Calculation of vehicle Capital Costs per Passenger

Description	Buses	Light Rail	Heavy Rail
Purchase cost per vehicle	$350,000	$3 million	$3.4 million
Purchase cost per consist	$350,000	$6 million	$27.2 million

Seated passengers per consist	50	150	840
Total passenger capacity	65	202	1,100
Purchase cost per passenger	$5,385	$29,702	$24,727

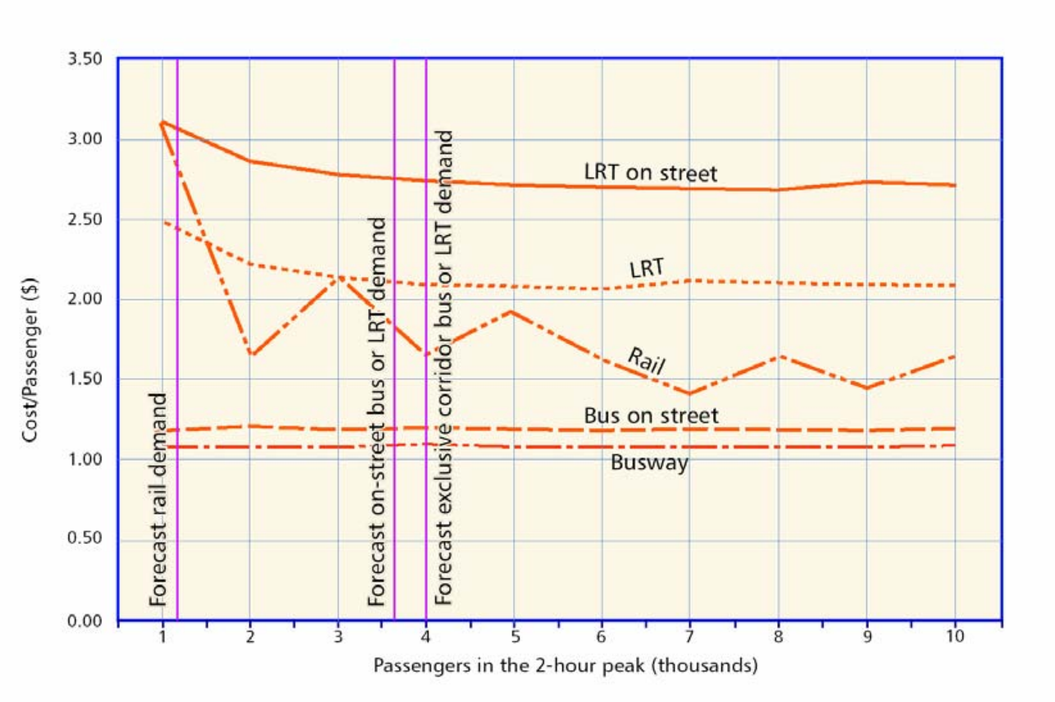


Figure 7.2: Operating Costs per Passenger by Mode, including Vehicle Capital Cost

The inclusion of infrastructure maintenance costs makes little difference to the pattern of costs by mode. At lower levels of passengers carried costs of both of the rail modes increase somewhat but the effect decreases with increases in the number of passengers carried. Buses remain the lowest cost mode.

When the costs of infrastructure capital are included, heavy rail becomes the highest cost mode at all levels of passengers carried. The two bus modes have the lowest cost, and on street costs are lower than corridor costs for both bus and light rail. The latter is to be expected as less new infrastructure is required for on street operation. The effect of more passengers on cost per passenger carried is clearly shown in the downward sloping curves, with the effect more marked the higher the infrastructure costs. *Figure 7.3* shows the dramatic effect on cost per passenger that the addition of infrastructure costs has on the financial and economic assessment. Because the infrastructure costs are fixed and relatively large compared to the operating costs, the cost per passenger becomes very sensitive to the forecast total passenger demand.

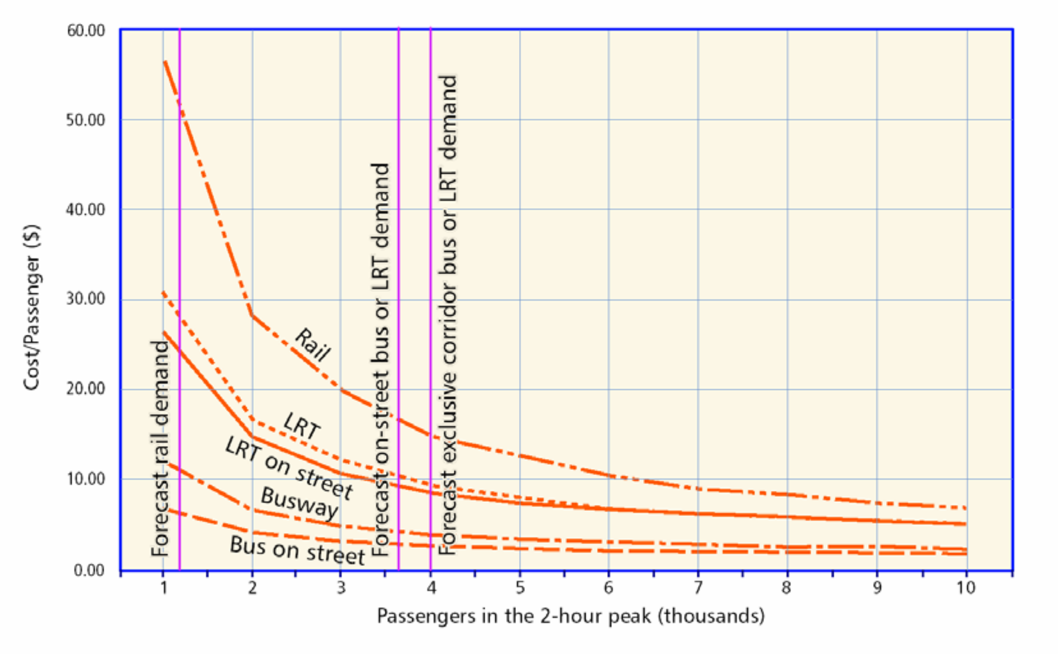


Figure 7.3: Total Cost per Passenger

7.2 Assessment by Option

7.2.1 Heavy Rail

Travel and Accessibility

Demand figures based on 2021 TPDC strategic model forecast a relatively low level of patronage demand for both rail options, with a maximum demand of approximately 1,200 passengers in the peak two hours being predicted. The following should be considered in the evaluation of this demand prediction:

- the demand of 1,200 passengers in the peak two-hour would fill the seats on a 12 heavy rail carriages (i.e. one and a half 8-car sets). The Illawarra Line, by comparison, is acknowledged to be at capacity with the worst overcrowding in the CityRail network. CityRail patronage numbers indicate that the dual-track section between Sutherland and Hurstville would be carrying in excess of 20,000 passengers in the peak 2-hour;
- a minimum level of service in the F6 Corridor of four trains per hour has been adopted for this analysis (two trains per hour from Cronulla would still be routed via Sutherland and the Illawarra Line) even at this low frequency the line would still provide seated capacity in the peak period of up to eight times the forecast demand in 2021;
- the patronage model does not take account of the capacity constraints on the Illawarra Line which are expected to become a significant issue towards the end of the next decade, even with the completion of identified works (now called the "Clearways") to increase capacity. While heavy rail in the F6 Corridor would provide some relief between Sutherland and Sydenham, the Illawarra Line would

become a constraint to capacity north of Sydenham if a heavy rail line in the F6 Corridor were to join the Illawarra Line at Sydenham;

- the Airport Line is also subject to capacity constraints, particularly given that additional traffic will be diverted to this Line as quadruplication of the East Hills Line continues; and
- the patronage demand modelling is considered to underestimate potential demand because it does not fully reflect the adjustments that would be made to the feeder network (local bus routes, for example) should a railway line be implemented.

When considering the future public transport role for the corridor a much longer view is required than reflected in the available 2021 modelling. It is reasonable that thinking should project beyond a 50 horizon as has been reflected in the "Christie Report", which identifies the potential for a "commuter" (or Metro style) rail line in this corridor.

The following factors should also be taken into account in the assessment:

- heavy rail would provide for about five stations, requiring the restructuring of the local bus network and provision for other access modes including a drop-off zone, commuter parking and bus and taxi interchange;
- while the heavy rail options could divert some Cronulla Line passengers off the Illawarra Line, the northern section of the alignment parallels the Illawarra Line (within about 1.5 kilometres) and therefore a rail line in the F6 Corridor would share its catchment with the Illawarra Line in this section;
- if a rail line in the F6 Corridor is connected to the Airport Line, it has the potential to provide improved access to Sydney Airport from the south. This access is, however, also currently potentially[5] possible through interchange at Wolli Creek Station; and
- heavy rail has the best potential to deliver travel time advantage over the car. All road intersections will be grade-separated and widely spaced stations contribute to maximum possible travel speeds.

Social and Land Use

Heavy rail has the best potential to provide a relatively fast and interchange free public transport service to the Sydney CBD and other major employment centres to residents in the catchment area. However, the relatively low patronage forecasts (compared to other modes) reflect the fact that:

- the heavy rail stations would be widely spaced and in the middle of a rather wide open space corridor, making pedestrian access less attractive;
- the service frequency would be no more than four trains per hour during the two-hour peak, and even this frequency can not be justified given the low demand; and

The patronage assessment does not take account of the fact that station localities are likely to become nodes for higher density residential development and employment creation which would increase demand.

[5] *Cronulla trains do not currently stop at Wolli Creek*

However, a heavy rail corridor would act as a barrier to pedestrians, cyclists and other traffic, except at locations where grade separated crossings are provided. Furthermore, the relative isolation of the stations within a public open space may lead to security concerns for passengers, particularly outside the peak periods.

Environmental Impacts

Over much of its length, heavy rail in the F6 Corridor would require an easement width of around 14.5 metres. This is narrower than a road corridor with the same potential capacity but wider that that required for a busway. The rail corridor would also be inaccessible to pedestrians and cyclists and would not be able to be maintained as a public open space. Furthermore, stations are large in area and will require more land while other facilities such as turnbacks and stabling tracks may increase the land requirement even further. The resulting corridor could be up to 40 metres wide in some areas.

Trains are generally expected to perform better than buses and cars in terms of greenhouse emissions but this benefit may be offset by the low patronage forecast for heavy rail which may result in low load factors in the corridor at the required minimum service frequency.

Heavy rail may also generate significant noise levels that may require mitigation.

As the heavy rail option generates the lowest forecast demand of the assessed options, it also performs worst in terms of mode shift from car to public transport.

Economic and Financial

The economic and financial assessment clearly shows up the high fixed costs that would be incurred by heavy rail (both infrastructure and rollingstock). The low patronage demand forecast for this mode means that the total cost per passenger is in excess of $50 per passenger at the forecast demand of approximately 1,200 passengers in the two-hour peak.

Heavy rail becomes more cost effective as the patronage increases, but it needs to carry upwards of 10,000 passengers in the peak two-hour before it becomes cost effective. In the case of the F6 corridor, this appears unlikely to be achieved given the current modelling results.

7.2.2 Medium Capacity Modes in Exclusive Corridor

Travel and Accessibility

This option assumes that bus or light rail services would link to rail at Miranda in the south and at either Sydenham or International Airport at the northern end of the corridor. There is also the potential to develop a service structure that connects to both Sydenham and the Airport.

In the longer term, a bus or light rail service may connect to a larger network of services. In the case of bus services this is also contemplated in the Unsworth report. The existing Sydney light rail system may also expand in the long term to allow the integration of light rail in the F6 corridor with a wider network. Consideration of these future integration options was beyond the scope of this study

It is also possible that services could extend beyond the airport to the north to connect to destinations such as Green Square and Redfern but these options have not been investigated in detail as part of the current study.

Demand figures based on 2021 TPDC strategic model show moderate levels of demand in the order of a maximum of 4,000 in the two hour morning peak period city bound and 1,700 in the opposite direction. This demand applies to the busiest link towards the northern end of the corridor. The peak two-hour demand south of the Georges River is in the order of 1,400 passengers city-bound and 1,200 in the opposite direction. This level of demand is achieved using an approximate 5-minute service frequency for light rail and 2 minutes for a bus based system (assuming peak vehicle loads) north of the river and 10 minutes and 3.5 minutes for light rail and bus respectively, south of the river.

Operation in an exclusive corridor offers the greatest potential to maximise travel speeds. The optimum arrangement would be provided through grade-separation at road intersections. However, the most cost effective arrangement would be provided through a combination of grade separated and priority controlled signalised intersections.

The development of an alignment within an exclusive corridor offers the advantage of permanent infrastructure and traffic free operation. The travel way would be defined by rail tracks and overhead wiring in the case of light rail and exclusive bus roadway in the case of a bus based system. In lower density environments busways offer greater flexibility through the ability of the vehicle to feed onto the corridor from adjacent neighbourhoods anywhere along the corridor. Conversely, they can use only a section of the corridor before leaving to gain access to an intermediate destination such as, for example, Rockdale Station.

Social and Land Use

In an exclusive corridor, the medium capacity modes still have a high potential to provide a relatively fast public transport service to the Sydney CBD and other major employment and commercial centres. However, without express links to the CBD, mode change at major interchanges may be required to transfer to city-bound trains. This could be achieved at stations such as Sydenham, but the available capacity of trains at these locations may make it difficult for passengers to find a seat, reducing the attraction of the service.

Medium capacity modes will provide frequent opportunities for passenger access by virtue of station spacing of around 800 metres to 2 kilometres, providing about 16 to 20 stations. Consequently, the medium capacity modes provide higher levels of local accessibility and would normally attract a relatively high proportion of walk-up passengers. However, pedestrian access to stations under this option will be potentially restricted because of the relative remoteness of some sites from adjacent residential development. This relates to the fact that land use in this corridor has historically “turned its back” on this former road reservation.

Headways of between 2 (buses in the peak) and 10 minutes (light rail in the peak) will provide a higher service level than a relatively infrequent heavy rail service (15 minutes in the peak and hourly in the off-peak).

Bus or light rail infrastructure would present a lesser barrier to pedestrians and cyclists than a heavy rail line or a busy road, even at its peak headway of two minutes. The relative isolation of the stations within a public open space may again lead to security concerns for passengers, particularly outside the peak periods.

Environmental Impacts

Medium capacity modes such as bus or light rail in the F6 Corridor would require an easement width of less than 10 metres. This is narrower than a road corridor with the same potential capacity and narrower than the easement required for a heavy rail system. Light rail and bus corridors also do not need to be isolated to the same extent as a heavy rail corridor and can form part of the public open space. Stations are less intrusive than those required for heavy rail, requiring less infrastructure and land take.

Light rail and busway systems as a whole also do not present a significant barrier to pedestrians and cyclists.

Light rail vehicles are low energy consumers and consequently produce low emission levels. While buses are still viewed as being less environmentally friendly, modern low-emission natural gas buses are increasingly being introduced and future trends point to technologies such as fuel cell powered buses which are for all intents and purposes, emission free. Light rail vehicles have a different noise signature to buses and are generally considered to have lower noise impacts than both buses or heavy rail.

Economic and Financial

The economic and financial assessment clearly shows up the effectiveness of medium capacity modes in corridors where patronage is likely to be at the lower end of the scale. In terms of operating cost only, light rail is the most cost efficient mode but the capitalisation of the vehicle costs reduces the cost effectiveness, with bus-based modes becoming the most cost effective.

At the forecast patronage for the medium capacity systems (approximately 4,000 passengers in the two-hour peak), light rail in an exclusive corridor has a total cost per passenger of just over $9 per passenger while busways are expected to cost under $4 per passenger.

7.2.3 Medium Capacity Modes on Street

Travel and Accessibility

This option assumes priority operations on roads generally parallel to the F6 corridor. The operational characteristics are similar to those discussed in *Section 7.2.2* for medium capacity modes in exclusive corridors.

The key points of difference are:

- operation on street in priority lanes;
- stations located closer to residential areas than for exclusive corridors, providing shorter walks and potential higher level of natural surveillance;
- station spacing is assumed to be similar at 800 metres to 1 kilometre. However there is greater flexibility in the positioning of the stations under this option and more homes will be within walking distance of stations than for the exclusive corridor options; and
- slower average operating speeds (than for the inclusive alignment) leading to a potentially less attractive service.

Demand figures based on 2021 TPDC strategic model show moderate levels of demand similar to the exclusive corridor option. Demand in the northern section of the corridor is similar at 3,800 passengers in the two hour morning peak period city bound. However, this option exhibits higher levels of contra peak demand at 2,700 passengers. Demand south of the Georges River is significantly higher, at around 2,300 passengers city bound, and 2,300 in the opposite direction. The closer proximity of this alignment to trip generators, such as the Taren Point employment area, appears to be a key factor in the higher level of demand south of the Georges River.

This level of demand represents an approximate 5 minute service frequency for light rail and 2 minutes for a bus based system (assuming peak vehicle loads) north of the river and 6.5 minutes and 2 minutes for light rail and bus respectively, south of the river.

The major risk in meeting these levels of demand will be potential conflict with traffic and the ability to ensure priority:

- typically, the light rail or busway vehicles would operate in exclusive lanes either at the kerbside or on a centre alignment;
- there are not likely to be any opportunities to provide grade separation at intersections. Priority would be afforded by signal priority;
- traffic flows in Taren Point Road represent a level of demand that may require three lanes at its northern end towards Captain Cook Bridge;
- more detailed traffic study is required to determine the level of traffic impact associated with providing public transport priority; however
- the level of demand highlighted in the modelling shows that, for the section south of the Georges River, there may be significant advantages associated with following the street based alignment on the Kingsway and Taren Point Road; and
- should this option be considered further there may be value in including an option to use some sections of the F6 corridor (between Holt Road and Kingsway, Miranda) for general traffic in order to provide a high quality public transport outcome of the Kingsway and Taren Point Road. For this reason it would be prudent to ensure that the corridor reserved for public transport should be wide enough for use as a local road.

The light rail and bus medium capacity modes operating on streets offer the following characteristics:

- light rail offers advantages of permanence and an unambiguous operating environment; and
- bus priority in an on-road environment would be provided by bus lanes or potentially transit lanes (T2 or T3). These have the advantage of flexibility in balancing traffic and bus demands but lack the high level of system legibility associated with a light rail line. Enforcement can also be a problem under bus lane/transit lane conditions;

Social and Land Use

When operating on-street, the medium capacity modes have reduced potential to provide a fast public transport service to the Sydney CBD and other major employment nodes. Furthermore, mode change at major interchanges may be required to transfer to city-bound trains. This could be achieved at stations such as Rockdale or Sydenham, but the available capacity of trains at these locations may make it difficult for passengers to find a seat, reducing the attraction of the service.

Medium capacity modes on street will have stations located closer to residential areas than for exclusive corridors, providing shorter walks and potential higher level of natural surveillance. There would also be greater flexibility in the positioning of the stations under this option and more homes will be within walking distance of stations than for the exclusive corridor options.

As for the exclusive corridor, headways of between 2 and 10 minutes will provide a higher service level than a relatively infrequent heavy rail service.

Bus or light rail infrastructure would be constructed within existing road easements and will therefore not result in a barrier to pedestrians and cyclists in the F6 Corridor.

Environmental Impacts

Because the bus or light rail infrastructure would not be constructed within the F6 Corridor the land take would be minimised and the impacts on environmentally sensitive areas would be avoided. Instead, the bus or light rail system would be placed in an area already occupied by transport infrastructure.

The lower level of priority afforded by on-street running would reduce the efficiency of the light rail vehicles and buses compared with running in an exclusive corridor.

Economic and Financial

This option is the most cost effective of the three options considered. Adding infrastructure to road reservations already developed for transport use allows re-use of a lot of the basic civil engineering features such as earthworks and drainage. Consequently, the total cost per passenger for medium capacity modes developed on street could be under $9 per passenger for light rail and under $3 per passenger for a bus system.

7.3 Comparison of Options

7.3.1 Comparative Assessment

The assessment of the various options as described in Section 6.2 are collated in this section to provide a comparative assessment.

Travel and Accessibility

A relatively low level of patronage demand is forecast for both heavy rail options, with a maximum demand of approximately 1,200 passengers in the peak two hours being predicted. Both the medium capacity modes fare significantly better, with modelling predicting a maximum patronage of up to 4,000 passengers in the two-hour peak.

The service level for heavy rail would be relatively low, with 15-minute headways during the peak period being the best that can realistically be justified. Bus or light rail would be servicing the corridor at headways as short as two minutes during the peak, resulting in a very frequent service.

Heavy rail has the potential to provide better connections to the Sydney CBD however, provided capacity is made available on either the Illawarra Line or the Airport Line to accommodate services via the F6 Corridor.

Light rail services may be more difficult to connect to the CBD and would, at least initially, be reliant on interchange with heavy rail at locations such as Sydenham. The shortage of available capacity on trains at these locations may make it difficult for passengers to find a seat, reducing the attraction of the service. Bus services would face similar interchange issues unless buses were able to run an express service into the CBD, through the introduction of priority lanes or use of the Eastern Distributor.

Social and Land Use

Heavy rail has the best potential to provide a relatively fast and interchange free public transport service to the Sydney CBD and other major employment nodes to residents in the catchment area. Light rail and bus services would, as described above, be reliant on interchange with heavy rail unless suitable express services can be provided.

Public transport developed in the F6 Corridor would be relatively remote from adjacent residential development because land use in this corridor has historically “turned its back” on this former road reservation. The relative isolation of the stations may also lead to security concerns for passengers, particularly outside the peak periods. Medium capacity modes developed on existing streets would overcome these issues.

Medium capacity modes, either on street or in the F6 Corridor, would potentially provide a higher service level than heavy rail services.

Environmental Impacts

The lowest impact on environmentally sensitive areas would result from development of medium capacity modes on street as these result in virtually no land take from the F6

Corridor. These options also avoid the creation of barriers to pedestrian and cyclists wishing to cross the F6 Corridor. Heavy rail would have the highest environmental impact on the corridor and its surroundings as it requires the most land for tracks, stations and other infrastructure while the resulting railway easement would need to be securely fenced to prevent people and animals from entering onto the tracks.

In terms of greenhouse gas emissions light rail is potentially the mode with the lowest emissions per passenger. This is not because light rail vehicles are necessarily more efficient than heavy rail but because the energy use *per passenger* (and therefore emissions generated to produce that energy) is expected to be lower because the load factors on light rail would be higher, given that the low patronage forecast for heavy rail is likely to result in very low load factors in the corridor at the minimum service frequency. Emissions attributable to buses would be dependent on the composition of the bus fleet and the increasing proportion of low emission buses being deployed.

Economic and Financial

The economic and financial assessment has shown that light rail is the lowest cost mode when the only the direct operating cost is considered. When the total vehicle operating costs, including capitalised vehicle costs, are considered, buses become the lowest cost mode for proposed public transport services as their capital costs per passenger carried are lower than for light rail vehicles (and heavy rail). At higher levels of demand, light and heavy rail have similar costs per passenger carried.

The inclusion of infrastructure maintenance costs makes little difference to the pattern of costs by mode. At lower levels of passengers carried, costs of both of the rail modes increase somewhat but the effect decreases with increases in the number of passengers carried. Buses remain the lowest cost mode.

When the costs of infrastructure capital are included, the order of modal preference is unchanged. The cost per passenger carried for each mode/option combination at the forecast patronage for that option is shown in *Table 7.2*.

Table 7.2: Cost per Passenger[6] for Various Modes and Options at Forecast Patronage

Mode/Option Description	Total Cost per Passenger
Heavy rail	$50.00
Light rail in exclusive corridor	$9.20
Bus in exclusive corridor	$3.80
Light rail on street	$9.00
Bus on street	$2.70

The financial and economic assessment of public transport in the corridor was undertaken without consideration of its flow-on and direct benefits beyond the study area. This may unfairly disadvantage the assessment of heavy rail services in the F6 Corridor which may have significant patronage and capacity benefits that extend to the rail network beyond the study area. Light rail services would be provided on a

[6] *Costs include all operating costs, maintenance costs, vehicle costs and infrastructure costs.*

standalone basis as there are no other light rail services in the vicinity. Bus services could be integrated with other bus services in the area of the F6 corridor but that possibility has not been considered in the estimated costs.

Table 7.3 provides a summary of the key findings of this comparison.

Table 7.3: Comparison of Options

Option Description	**Assessment by Criteria**			
	Travel and Accessibility	**Social and Land Use**	**Environmental Impacts**	**Economic and Financial**
Heavy Rail Options				
Miranda to Sydenham/Airport via F6 Corridor	Patronage of approximately 1,200 in the peak 2-hour (2021). Peak service frequency of 4 trains per hour.	Best potential to provide a fast and interchange free service. Low service frequency (4 trains per hour in peak). Isolated environment leads to poor access and security. Shares catchment with Illawarra Line. Creates barrier to cross-corridor travel.	Minimum easement for infrastructure 14.5 metres, but could be up to 40 metres wide at some locations due to stations, turnback/stabling needs and other facilities. Emission benefits may be offset by empty running (inefficiency). Noise impacts may require mitigation. Low patronage also means low mode shift from car	Low patronage results in a high cost per passenger in excess of $50 at the forecast demand. Is only likely to become viable if demand approaches 10,000 in 2-hour peak or more.
Medium Capacity in Corridor				
Busway or Light Rail	Maximum patronage of approximately 4,000 in the peak 2-hour. Peak service frequency of up to 30 buses per hour or 20 LRT services per hour. Exclusive corridor maximises speed and service reliability. LRT provides permanence and unambiguous environment. Bus provides operational flexibility and connects with local network.	Have a high potential to provide a relatively fast public transport service. Requires express bus services to CBD. LRT, and possibly bus, require interchange to heavy rail for journeys to CBD. Isolated environment leads to poor access and security. Less of a barrier in the corridor than heavy rail. High service levels.	Minimum easement for infrastructure of around 10 metres. Stations/bus stops are small and do not require much land. LRT has very low emissions. Bus emissions dependent on fleet mix. Higher patronage also means better mode shift from car	Medium capacity modes are more effective, with total cost per passenger of under $4 for busway and just over $9 per passenger for LRT

Option Description	Assessment by Criteria			
	Travel and Accessibility	**Social and Land Use**	**Environmental Impacts**	**Economic and Financial**
Medium Capacity on Street				
Bus or Light Rail	Maximum patronage of approximately 3,800 in the peak 2-hour. Higher patronage in contra-peak direction than options in the F6 Corridor. Peak service frequency of up to 30 buses per hour or 20 LRT services per hour. Potential conflict with traffic and loss of priority. Option to use some sections of the F6 corridor for general traffic.	Lowest potential to provide a fast/direct public transport service to CBD Requires express bus services to CBD. LRT, and possibly bus, require interchange to heavy rail for journeys to CBD. Best security and accessibility. No barrier in the F6 Corridor. High service levels.	No land take Stations/bus stops are small and do not require much land. LRT has very low emissions. Bus emissions dependent on fleet mix. Higher patronage means better mode shift from car	Medium capacity modes are more effective, with total cost per passenger of under $3 for busway and $9 per passenger for LRT

7.3.2 Relationship between Options and Staging

Chief among the findings of this strategic study are the following:

- it is important that a reservation be retained within the previous F6 corridor for the long term (beyond 20 to 50 years) development of a heavy rail or metro style rail line;
- there may be some potential for heavy rail to provide relief to the Illawarra Rail Line in the medium term (10 to 20 years), however, this would require network improvements north of Sydenham; and
- the demand analysis suggests that, within the next 10 to 20 years, a medium capacity mode could fulfil an effective public transport role in increasing the level of public transport use in the corridor.

These findings point to the need to consider the staged development of public transport services in the corridor. The principles of a staged approach could include:

1. Preservation of the option to provide for long term needs by establishing a reservation capable of meeting the needs of a heavy or metro style rail line. In this way the potential to develop other, lower capacity systems would also be protected.
2. In the short term, rationalise the existing bus network to develop high quality, high frequency, feeder services to existing Illawarra line stations, Sydney Airport and the CBD. The consolidation of contract areas to remove structural anomalies is addressed in the *Review of Bus Services in NSW (March 2004)*.
3. Through this rationalisation process progressively develop a strategic bus service which mirrors the proposed corridor (a similar route is also referred to in *Review of Bus Services in NSW)*. Provide a high quality service at minimum levels of service of 10 to 15 minutes in peak periods. For example, this rationalisation could include the extension of the Route 303 City service beyond its current San Souci terminus to Miranda. In addition, consider improving catchment coverage by adjusting the service to use Chuter Avenue instead of the "one sided" route along General Holmes Drive.
4. The strategic bus route should be structured to take advantage of developments along the corridor. For example, consideration should be given to taking advantage of provisions within the Cooks Cove development for priority access to the airport across the Cooks River.
5. Develop priority systems on existing roads and where appropriate make use of the reserved exclusive public transport corridor to by-pass points of congestion.
6. Put in place a strategy to progressively develop a medium capacity transport system over the full corridor. This could be focused on either side of the Georges River in the initial stages of development and include connections to key transport nodes such as Rockdale and Miranda.
7. This strategy should firstly, fully investigate and recommend the most effective medium capacity mode (light rail, bus rapid transit system or other mode) to serve this corridor.

8. The strategy should include a schedule for development of the corridor over the next 10 to 20 years.

8. Residual Lands

The existing F6 freeway reservation occupies approximately 180 hectares of land (assuming a 20 km length and average width of 90 metres). Given that the maximum width for any public transport option is approximately 40 metres, a substantial area of the land would be able to be rezoned and be available for alternative uses.

8.1 Development of the Reservation Boundary

The total area of residual land that will ultimately be available will dependent on the type of public transport mode developed. The corridor is a strategic transport resource, however, and care should be taken not to preclude its use to cater for the growing transport demands of Sydney over the long term and beyond the 20 year assessment period used in this study.

The current patronage forecasts were undertaken to 2021. These forecasts indicate that the development of a heavy rail system in the F6 Corridor would not be justified by the anticipated demand by the end of the forecast period. The demand analysis suggests that within the next 10 to 20 years a medium capacity mode could fulfil an effective public transport role in increasing the level of public transport use in the corridor. However, it is important that a corridor be reserved for the long term (beyond 20 to 50 years) development of a heavy rail or metro style rail line. Furthermore, the current study did not undertake a sufficient level of design to accurately determine:

- the land requirements of grade separated road and river crossings;
- the impact of localised soil and groundwater conditions on the future alignment(s);
- the location and land requirements of stations, parking facilities, stabling yards and other associated infrastructure;
- the vertical alignment considerations such as cut and fill batters; and
- the location and land requirement of cycleways and footpaths.

As described in Section 5.1.2, a corridor width of 40 metres would allow for any of the public transport modes to be developed, including heavy rail. It would also allow full flexibility in the placement of stations, stabling yards, turnbacks and other associated infrastructure while providing an adequate allowance for batters, cycleways and footpaths.

In developing the boundary of the corridor care was therefore taken to ensure that a minimum corridor width of 40 metres was reserved. Furthermore, the corridor boundaries were adjusted to:

- provide land for constructing grade-separated crossings at major road intersections;

- selectively widen the corridor to provide better tolerance of localised uncertainty with respect to soil, groundwater and environmental conditions;
- include parcels of land that would be isolated between the corridor boundary and wetlands or creeks; and
- allow adequate land at boundary intersections to accommodate curved alignments, particularly at intersections with major roads.

The resulting corridor boundary is shown on the drawings attached as *Appendix D*. It should be noted that this work is limited by the accuracy of the existing corridor boundaries that were digitised from the RTA Property Information Management System (PIMS) database and are therefore of an indicative nature only.

8.2 Further Work to Develop the Corridor Boundary

The approach taken in this study was to adjust the corridor width to allow for the lack of available information and early stage of engineering development. This short term approach reduces the available land to be released from the current corridor. Ultimately, the accuracy and detail of the available information will have to be improved and it should be recognised that the accuracy of the proposed corridor width and location is constrained by the accuracy and detail of available information:

- the boundaries of the existing F6 corridor were digitised from RTA hardcopy Property Information Management System maps and are indicative only. No survey has been undertaken;
- no vertical alignment design was undertaken as part of the current study and cut/fill batters and retaining structures have not been identified or detailed;
- geotechnical information was obtained from a general desktop study of available information and specific zoning of the geotechnical conditions has not been undertaken; and
- no detailed assessment of environmental constraints has been undertaken.

In order to improve the level of confidence for future work we recommend that the following activities be undertaken:

- obtain more detailed survey of the study area. We have established that digital aerial photography is available that will allow the generation of DTM mapping to 2 metre contours and an ortho-rectified aerial photo base with 0.3 metre pixels;
- obtain a more accurate definition of the corridor boundary by obtaining the corridor coordinates from the RTA and plotting this on the cadastral base; and
- undertake sufficient field investigations to allow zoning of the corridor in terms of environmental constraints, geotechnical conditions and flooding.

This will allow the design to be developed within an accurately defined corridor to full horizontal and vertical alignment standard with all earthworks shown.

8.3 Alternative Land Use

The Minister for Roads, in his announcement on 6 September 2002 (NSW Government Gazette No 54, see *Appendix A*) directed that no road or transport development of any type would be allowed in the F6 corridor between the Royal National Park and the southern side of Gymea Station. The Minister further stated that he had asked the RTA and (the then) Transport NSW "to determine which parts of the corridor can be given back to the community for permanent open space".

The useability of land within some sections of the corridor is very limited, given the existing land uses surrounding. For example in the northern section of the corridor, within the Marrickville local government area, north of the Cooks River the majority of residual land would adjoin existing industrial areas. Hence, an appropriate land use may be to allow an extension of the industrial zoning.

Areas to the centre of the corridor within the Rockdale local government area offer many more opportunities to diversify land use and optimise the use of residual lands. For example in the section between Kings Road and Bruce Street in Brighton-Le-Sands there is potential for residential, commercial and retail development around Bay Street (a potential station location) and medium density residential on either side of the corridor. Other areas of land within this section would be suitable for open space or industrial uses.

The potential residual land opportunities in the F6 corridor can be divided into the following major categories:

Table 8.1: Use Categories in Residual Lands

Land Use	Potential Use in Residual Lands
Residential	Medium/high density residential, on reservation land adjoining residential zones adjacent to identified station locations. Low density residential (single occupied or vacant lots) on reservation land adjacent to an existing residential area.
Commercial & Retail	Higher density commercial and retail developments on reservation land adjacent to identified station locations. Commercial and retail developments on reservation land to adjacent to existing developments.
Industrial	Rezone reservation land adjacent to existing industrial employment areas to support expansion where appropriate.
Open Space and/or recreation	Rezone reservation land to open space and/or recreation space, where appropriate.

Hence, the possibilities and practical uses of residual lands is largely determined by the characteristics of the land and its compatibility with the public transport corridor/use and the surrounding area. Section 2.3 of this report discusses future land use scenarios within and adjacent to the corridor, particularly with reference to key nodes.

Table 8.2 provides an overview of possible residual land uses along specific sections of the F6 corridor.

Table 8.2: Land Use Opportunities in Residual Lands

Local Government Area	Corridor Section	Corridor Sub-Sections	Residual Land Use Opportunities	
			Potential Land Uses	**Comments**
Sutherland	Princes Hwy Loftus - Cronulla Rail Line - to be preserved, as much as possible, for open space[7]	Princes Hwy Loftus - Auburn St South Kirrawee	National Park	Corridor within existing National Park boundary
		Auburn St South Kirrawee - Forest Rd South Kirrawee	Open Space	Section of steep bushland and rocky terrain. Existing recreational uses (tennis courts). Adjacent to local housing residential zones.
		Forest Rd South Kirrawee - Cronulla Rail Line	Residential	Adjoins residential local housing zone up to President Avenue. Some residential dwellings within reservation. Medium density potential between Presidents Avenue & Gymea Station.
	Cronulla Rail Line - Georges River	Cronulla Rail Line - Georges River	Residential Commercial Industrial Open Space	Adjacent to predominantly low density residential. Existing caravan Park on Port Hacking Road. Commercial and industrial uses on Taren Point Road. Open space opportunities between Port Hacking Road and Taren Point Road. Potential for Taren Point station commercial development.
Rockdale	Georges River - Sandringham St	Georges River - Margate St Ramsgate	Residential Open Space	Adjoins residential zone. Existing residential dwellings within reservation.
	Sandringham St - Bay St	Margate St Ramsgate - Kings Rd Brighton-Le-Sands	Residential Open Space	Adjoins residential zone. Existing residential dwellings within reservation. Medium density residential potential.
	Bay St - Cooks River	Kings Rd Brighton-Le-Sands - Bruce St Brighton-Le-Sands	Residential Commercial Retail Industrial Open Space	Higher density potential near Bay St Station. Medium density residential potential. (east & west of reservation) Commercial opportunity (west of reservation).

[7] *NSW Government Gazette No. 54 Official Notices 28 February 2003*

Local Government Area	Corridor Section	Corridor Sub-Sections	Residual Land Use Opportunities	
			Potential Land Uses	**Comments**
Rockdale (cont'd)`	Bay Street – Cooks River (cont'd)	Bruce St Brighton-Le-Sands - Kogarah Golf Course	Residential Open Space	Residential zone to west of reservation. Open space uses (east of reservation).
		Kogarah Golf Course - Cooks River	Residential Commercial Open Space	Development opportunities in accordance with Cooks Cove master plan.
Marrickville	North of Cooks River	Cooks River - Bellevue St	Industrial Open Space	Adjoins existing industrial zone. Portion of reservation may only be suitable for open space.
		Bellevue St -Canal Rd	Industrial	Adjoins existing industrial zone.
City of Sydney		Canal Rd - Campbell Rd	Industrial	Adjoins existing industrial zone.

8.4 Determining Surplus Requirements

Table 8.3 summarises the potential changes to the existing reservation with the implementation of various high and medium capacity public transport options.

Table 8.3: Reservation Retention Implications

Local Government Area	Corridor Section	Corridor Sub-Sections	Reservation Retention Implications for Various Options	
			High Capacity-Rail	Medium Capacity-LRT/Busway-Exclusive and On Street
Sutherland	Princes Hwy Loftus - Cronulla Rail Line	Princes Hwy Loftus - Auburn St South Kirrawee	Remove Reservation	
		Auburn St South Kirrawee - Forest Rd South Kirrawee	Remove Reservation	
		Forest Rd South Kirrawee - Cronulla Rail Line	Remove Reservation	
	Cronulla Rail Line - Georges River	Cronulla Rail Line - Georges River	Reduce Reservation	
Rockdale	Georges River - Sandringham St	Georges River - Margate St Ramsgate	Reduce Reservation	
	Sandringham St - Bay St	Margate St Ramsgate - Kings Rd Brighton-Le-Sands	Reduce Reservation	
	Bay St - Cooks River	Kings Rd Brighton-Le-Sands - Bruce St Brighton-Le-Sands	Reduce Reservation	
		Bruce St Brighton-Le-Sands - Kogarah Golf Course	Reduce Reservation	
		Kogarah Golf Course - Cooks River	Reduce Reservation	
Marrickville	North of Cooks River	Cooks River - Bellevue St	Reduce Reservation	
		Bellevue St -Canal Rd	Remove Reservation	
City of Sydney		Canal Rd - Campbell Rd	Remove Reservation	

Appendix D contains plans which show the potential extent of land which could be released for other uses under the assumption that a 40 m corridor is reserved for long term public transport use.

Subject to adoption of the preferred public transport option, a site specific study of the residual lands potential uses should be undertaken prior to any rezoning application and approval. An overview of the statutory planning process involved to rezone residual lands is discussed below.

8.5 Statutory Planning Process

Following the adoption of the report recommendations regarding the designation of the corridor width and the survey of a reduced corridor, the public transport corridor would be established under Section 3 of the of the *Environmental Planning and Assessment Act, 1979*.

The final boundary of the F6 reservation is unlikely to be defined until the full implications of detailed design and construction are known. This study proposes that the retention of a reservation no less than 40 metres wide should in the future allow the engineering of a public transport system (heavy rail, light rail or bus) within that reservation. It is likely that further land may be released from the proposed new reservation once public transport has been developed. Conversely, localised needs of the future public transport system may, in the future, require acquisition of some land (which may or may not have been part of the original F6 corridor) to facilitate the provision of ancillary infrastructure such as commuter car parks and interchanges.

Following the submission of rezoning applications to the various councils, the rezoning is the next step in handing over residual lands to local government and the community, in accordance with Part 3 of the *Environmental Planning and Assessment Act*, 1979 a draft local environmental plan will need to be prepared detailing the amendments to current zoning.

In accordance with Section 57 of this Act, where Council decides or is instructed by the Minister for Infrastructure and Planning to prepare a draft local environmental plan, an environmental assessment of the residual land needs to be prepared. The Director-General of the Department of Infrastructure, Planning and Natural Resources can notify councils as to the form, content and preparation of the study and may also agree to waive the need for an environmental assessment.

The local environmental study would usually have regard to matters such as:

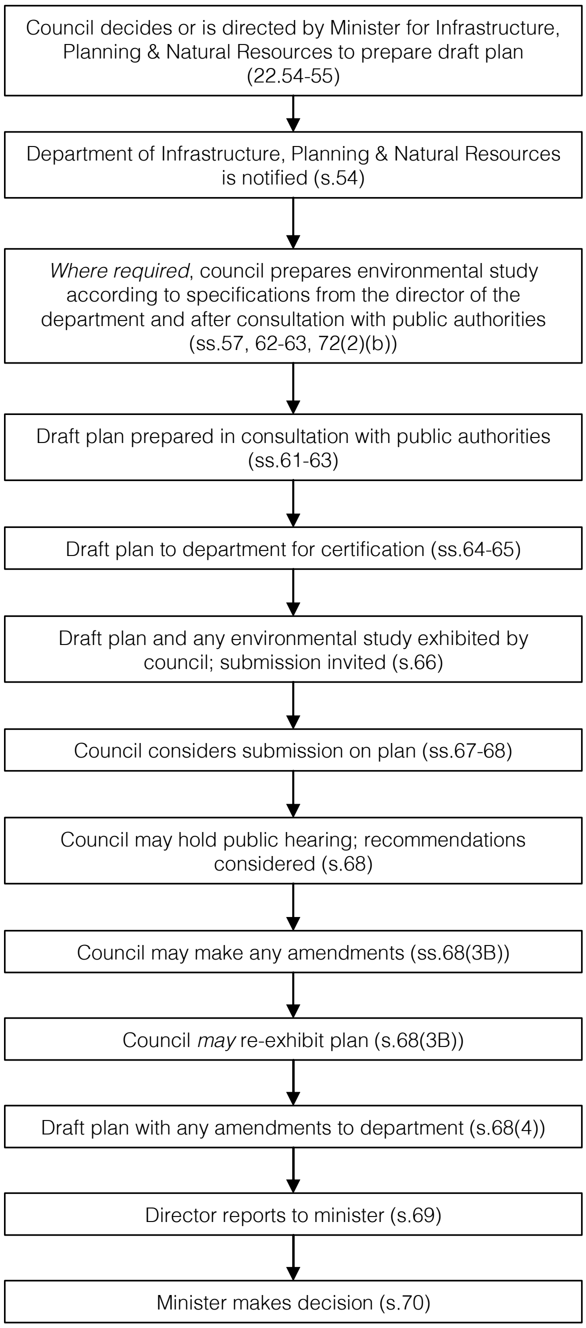
- land uses, zoning, ownership, demand and supply;
- public transport requirements;
- environmental issues;
- flora and fauna; and
- open space needs.

Due to the length of the reservation corridor in the Rockdale and Sutherland local government areas, it may be necessary to divide each of these studies into a number of sections or precincts.

In accordance with Section 64 of the *Environmental Planning and Assessment Act*, council is required to submit the draft LEP to the Director-General of the Department of

Infrastructure, Planning and Natural Resources for approval to publicly exhibit the document. *Figure 8.1* shows the process for preparing a new LEP.

A report reviewing submissions from the public exhibition should then be submitted to the Director-General of the Department of Infrastructure, Planning and Natural Resources. This report and the draft LEP will then be considered by the Minister who may make a Local Environmental Plan.



Source: Environment Planning and Assessment Act 1979

Figure 8.1: Process for LEP Preparation

9. Conclusions and Recommendations

9.1 Summary and Conclusions

The study has investigated a range of possible public transport uses for the F6 corridor. Options have been considered for both the alignment of the corridor and the mode which would best meet the needs of the population. It was not the intention of the brief to identify a sole mode for implementation at this stage, but rather to identify a preferred mode or modes, to provide a basis for decision making on the continued reservation of land for public transport purposes and the extent of residual land which may result.

The study has considered a range of options which include alignments within the F6 reservation and one that makes use of adjacent streets for public transport. The range of modes considered for use in the corridor included heavy rail, light rail and busways. Each mode was assessed in conceptual design terms with regards alignment, cross sectional width and station locations. For the purposes of this strategic study and because of their similar performance characteristics light rail and busways were grouped together as medium capacity modes for demand assessment purposes. Broad order of cost estimates were developed for each option. The options are summarised as:-

- Heavy Rail – there are two options, both linking to the Cronulla Line at Miranda and running via the F6 reservation. One option is to connect to the Illawarra Line near Sydenham and the other option connects to the Airport Line west of the International Airport station;
- Light Rail and Busway – starting from Miranda and running via the F6 reservation to link to Sydenham Station and/or the International Airport station; and
- Light Rail and Busway – starting from Miranda and running on-street, generally parallel to the F6 reservation to link to Sydenham Station and/or the International Airport station.

The medium capacity modes showed the best potential to attract passengers within the 2020 timeframe for this study with demands in the order of 4,000 peak direction passengers in the peak two hours. Within the two basic options, operation in an exclusive corridor was found to attract marginally more peak direction passengers. However, the on-street option attracted more contra-peak passengers and also has the potential for closer integration with the community.

These modes also exhibited least cost per passenger in comparison to heavy rail with the on-street option being the lowest cost overall in terms of passenger and capital costs. Table 9.1 summarises the cost per passenger for each mode and alignment option.

Table 9.1: Cost per Passenger for Various Modes and Options at Forecast Patronage

Mode/Option Description	Total Cost per Passenger
Heavy rail	$50.00
Light rail in exclusive corridor	$9.20
Bus in exclusive corridor	$3.80
Light rail on street	$9.00
Bus on street	$2.70

Heavy rail's high cost can be attributed to its high capital cost and relatively low patronage, which is below that which would support heavy rail within the 2020 timeframe for this study. However, when considering the requirement to reserve land within the corridor for future public transport the vision should be beyond 2020. The Illawarra Line is reaching capacity towards the end of the next decade and RailCorp's patronage forecasts for the South Coast and Illawarra Lines have shown the need for additional lines, including potential metro lines in this corridor and other parts of the metropolitan area. In this regard it is considered that any change to the F6 corridor reservation should not preclude the potential for future development of a high capacity mode and to this end an alignment width of 40 metres has been recommended.

A major challenge for the medium capacity system will be integration with the existing rail system. Whether the alignments connect with the Illawarra line at Sydenham or the Airport line there are potential problems in finding seats on already congested trains. Further studies should look closely at the potential for extension of these options towards the city and in this regard extensions via the Airport towards Green Square and the city may offer the best opportunities.

This study has found that within the next 10 to 20 years a medium capacity mode could fulfil an effective public transport role in increasing the level of public transport use in the corridor. These findings point to the need to consider the staged development of public transport services in the corridor. In principle, a staged approach could include:

1. Preservation of the option to provide for long term needs by establishing a reservation capable of meeting the needs of a heavy or metro style rail line. In this way the potential to develop other, lower capacity systems would also be protected.

2. In the short term, rationalise the existing bus network to develop high quality, high frequency, feeder services to existing Illawarra line stations, Sydney Airport and the CBD. The proposed initiatives under the *Review of Bus Services in NSW (March 2004)* could provide the basis for this rationalisation.

3. Through this rationalisation process progressively develop a strategic bus service *which* mirrors the proposed corridor (similar routes are referred to in *Review of Bus Services in NSW).* Provide a high quality service at minimum levels service of 10 to 15 minutes in peak periods. In addition, consider improving catchment coverage by adjusting the service to use Chuter Avenue instead of the "one sided" route along General Holmes Drive.

4. The strategic bus routes should be structured to take advantage of developments along the corridor. For example, consideration should be given to taking advantage of provisions within the Cooks Cove development for priority access to the airport across the Cooks River.

5. Develop priority systems on existing roads and where appropriate make use of the reserved exclusive public transport corridor to by-pass points of congestion.

6. Put in place a strategy to progressively develop a medium capacity transport system over the full corridor. This could be focused on either side of the Georges River in the initial stages of development and include connections to key transport nodes such as Rockdale and Miranda.

7. This strategy should firstly, fully investigate and recommend the most effective medium capacity mode (light rail, bus rapid transit system or other mode) to serve this corridor. The strategy should include a schedule for development of the corridor over the next 10 to 20 years.

9.2 Recommendations

The following key recommendations are made:-

- establish a reservation 40 metres wide to preserve the potential to develop a high capacity mode in the long term;
- undertake detailed network and patronage studies and a robust financial/economic assessment to confirm the most appropriate medium capacity mode and technology to serve the corridor;
- develop the engineering design, geotechnical studies and environmental assessment for the selected mode to confirm the reservation boundary to enable residual lands to be appropriately zoned for other uses.
- Undertake a detailed road network assessment of the selected public transport system including addressing potential by-pass opportunities (e.g. Miranda Town Centre) and their potential land requirements; and
- develop a detailed implementation strategy for progressive development of high quality public transport services in the F6 Corridor.

Future Actions

This study has addressed a wide range of issues associated with the development of a public transport system within the F6 corridor. The strategic nature of the study has highlighted the need for a range of additional studies and actions required to assist decision making with regards the ultimate medium capacity mode and the final reservation of the corridor lands. These future actions should include:-

- detailed public transport feasibility and operations study. The study scope should include:

  - a more detailed patronage assessment (based on the current assessment) to focus on the passenger needs in the catchment and to support final decision making on the most appropriate mode for the corridor;
  - determination of the long term medium capacity mode best suited to meeting the passenger needs within the corridor;
  - engineering feasibility study to develop an optimum long term alignment and staging plan;
  - traffic studies to identify the interaction with the road network and necessary works to establish public transport priority;
  - public transport operations plan which integrates all modes within the corridor; and
  - detailed staging strategy for the progressive implementation of the public transport strategy.

  The above scope could be undertaken as a single feasibility study or managed as a series of sequential studies.

- Land use and urban design studies should be undertaken at an appropriate stage to address the most appropriate use for residual lands and to identify the urban design solutions for future station locations and the corridor in general.
- In order to improve the level of confidence for the definition of the future reservation the following activities should be undertaken:
  - obtain more detailed survey of the study area. We have established that digital aerial photography is available that will allow the generation of DTM mapping to 2 metre contours and an ortho-rectified aerial photo base with 0.3 metre pixels;
  - obtain a more accurate definition of the corridor boundary by obtaining the corridor coordinates from the RTA and plotting this on the cadastral base (the RTA has advised that it may require up to two years to acquire this data); and
  - undertake sufficient field investigations to allow zoning of the corridor in terms of environmental constraints, geotechnical conditions and flooding.

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