Green Bridge in Brisbane: Planning

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SYNOPSIS

Brisbane City Council (BCC) invited Main Roads Department (MRD) to join a team identifying a preferred design concept for the new bridge spanning Brisbane River at Dutton Park. The proposed structure will become part of an essential link between the South East Busway and the University of Queensland at St. Lucia. One of the main objectives is to facilitate access to the campus without channelling large volumes of traffic through the university grounds. A number of road alignments as well as structural systems have been investigated in some detail. Structural systems included box girder, arch, cable stayed and suspension bridges. As the project will be highly visible, the visual impact and aesthetics received high priority. The team conducted extensive public consultations addressing the needs and concerns of various interest groups as part of the process. The preferred option takes the form of a twin tower cable stayed bridge with a 195m main span. Innovative solutions have been proposed for the design of the piers for ship impact in the 18m deep river. The project will go to tender in January 2004 as a design and construct contract. A number of leading local and overseas consortia have already expressed interest in submitting tenders.

1 INTRODUCTION

The Green Bridge Link aims to move high volumes of people efficiently along a purpose built public transport corridor. The corridor will run westward from the Buranda Bus/Rail Interchange. It crosses the Brisbane River at Dutton Park then enters the University of Queensland St Lucia campus grounds. Whilst some of the corridor is intended exclusively for busses, the Green Bridge itself will be available to other environmentally friendly transport modes (i.e. bicycles and pedestrians). Each mode will be provided with a separate, purpose-designed corridor across the Brisbane River.

2 PROJECT NEED AND OBJECTIVES

2.1 Project Need

Brisbane is the capital of Queensland and the State's administrative and commercial centre. Regionally, the city sits within South East Queensland. The proposed corridor for the Green Bridge Link is located about 3 km from Brisbane's CBD. From 1999 to 2000, Brisbane City recorded the largest numerical increment of growth of any Local Government Authority in Australia. The Transport Plan for Brisbane 2002-2016 identified that the population of the

Brisbane Metropolitan Sub-region will increase by 450,000 (27%) people by 2016. This will equate to an increased need in vehicle travel of 40% leading to congestion delays. Recent studies have shown that traffic congestion in the city has degenerated to become comparable to the traffic jams of Sydney and Melbourne. The Federal Government estimates the cost of urban congestion will increase from $2.6 billion each year to $9.3 billion (higher than Sydney and Melbourne) in 2015, if Brisbane's increasing transport needs are not addressed.

Brisbane's transport network, both road and rail, has developed around travel to the CBD. While travel to the CBD remains an important travel market, there is also significant demand for cross-town travel. Developing orbital public transport linkages will help to meet the cross-town demand. The present radial nature of the network, limited river crossings and dispersion of non-CBD destinations has made it difficult for public transport to penetrate the cross-town travel market. People generally have to travel into the CBD and then out on a different corridor to access a destination.

The University of Queensland St Lucia campus is the second largest traffic generator in the city after the CBD. It is difficult to access the campus from the southern and eastern sectors on the radial transport network. One of the key constraints facing the university is how to retain an accessible campus without the adverse impacts associated with increased private vehicle use.

Commuters from the south and east who currently access the St Lucia campus by bicycle are required to use the Dutton Park Ferry which involves fare and timetable constraints, or use the Bicentennial Bikeway, which drastically increases travel distance and time.

2.2 Project Objectives

The primary project objectives are to provide a direct link between the University of Queensland St Lucia campus for commuters from Brisbane's southern and eastern communities reducing private vehicle movements through the Brisbane CBD and enhance the effectiveness and sustainability of Brisbane's public transport network.

Other objectives include enhanced connectivity between rail, bus and ferry infrastructure; reduction of congestion on the inner-western road network; attenuation of parking demand within the University of Queensland campus; and encourage pedestrian and bicycle trips to the University of Queensland.

2.3 Other Considerations

The Brisbane River separates the University of Queensland from several existing and proposed facilities. Linking other facilities and the university is an important consideration.

The Princess Alexandra Hospital is a major health facility that provides a broad range of medical services and is the second largest public hospital complex in the State. Directly linking to the university will promote the interaction and synergy.

The Boggo Road Precinct development is a state government project designed to redevelop the old Brisbane Gaol grounds into a mixed-use, residential and knowledge-based industry zone. The viability of this knowledge-based development would be greatly enhanced if it were directly linked to the University of Queensland.

Queensland Rail has two south eastern rail corridors, the Cleveland and Gold Coast/Beenleigh lines. The university has no direct links to rail corridors. Directly linking southern and eastern rail lines to the university will enable a significant expansion of the rail market.

The South East Busway, opened in 2002, has made substantial improvements to the quality of public transport, attracting a 45% increase in patronage on core services. This busway operates along the major southern arterial. Directly linking this busway to the university would dramatically reduce travel times and reduce passenger loading congestion in the City.

3 ROUTE SELECTION

3.1 Planning Process

The preliminary route evaluation adopted a broad, multi-disciplinary methodology and considered input from the major operational stakeholders, including input from various elected representatives. The preliminary evaluation involved four broad stages:

(a) identification of preliminary options
(b) development of evaluation criteria
(c) an evaluation workshop
(d) selection of the preferred approaches for inclusion in the IAS.

Further work was carried out in partnership with the University of Queensland to identify and address university site-planning aspirations. The outcome was an acceptable landing site and bus station within the campus.

3.2 Route Options

Preliminary options were identified starting with potential bridge sites. Three bridges locations were identified on the eastern side of the river. A total of twelve eastern bridge approaches were identified. A western (university) approach was only developed for the final bridge location.

Bridge sites were evaluated and a site selected. Assessment criteria included land use; pedestrian and bicycle linkage; bus travel times; rail links; engineering; staging; construction costs; operational costs; and linkage to Boggo Road Precinct and Princess Alexandra Hospital.

3.3 Recommended Alignment

After evaluation of option a recommended alignment was prepared for inclusion in the Draft Impact Assessment (DIA). The alignment is for an uninterrupted and exclusive transport corridor for buses from the South East Busway to the University of Queensland. Pedestrians and cyclists have separate, purpose-designed paths across the bridge. Two eastern approaches were presented in the DIA, the Cemetery Alignment and Ferry Alignment. After public consultation the cemetery option was selected. The final alignment is shown in Figure 1.

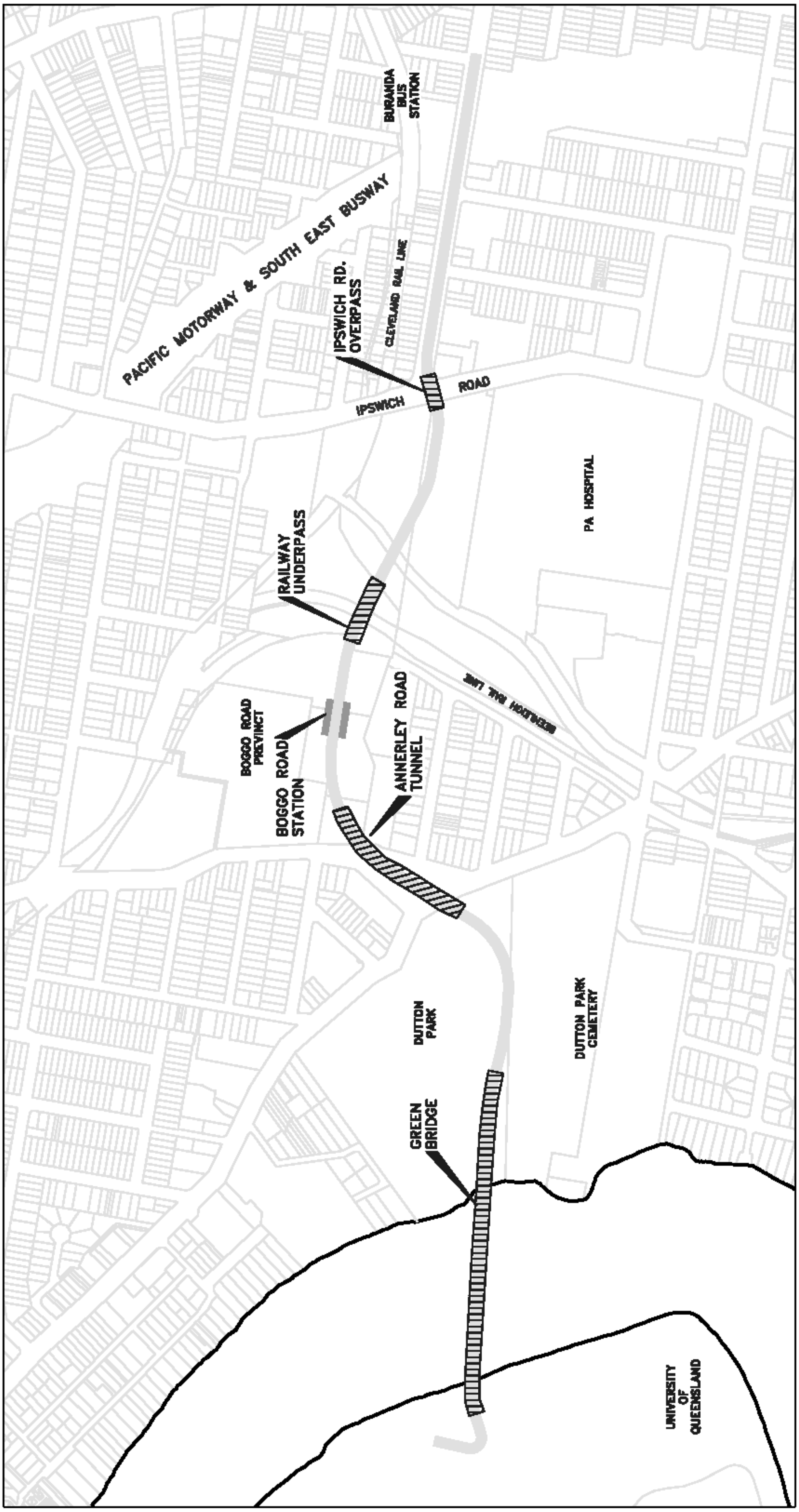

Figure 1: Final Busway Alignment

4 COMMUNITY INVOLVEMENT AND FINDINGS

From 18 November 2002 to 7 March 2003, Brisbane City Council implemented an extensive community involvement and communication strategy to gather and evaluate community and stakeholder feedback on the proposed Green Bridge Link and in particular, the IAS.

The project and a draft of the IAS were released to the public and feedback requested. A total of 3149 responses were received. 66% of respondants supported the project and 27% did not support the project. The most significant concerns included:

(a) Impact on Dutton Park parkland
(b) Future conversion to use by private vehicles.
(c) Potential impacts on campus amenity
(d) Local residents strongly favoured the Cemetery Alignment.

5 BRIDGE DESIGN CONSIDERATIONS

5.1 Brisbane River Context

A cross-river bridge lasts for generations and represents a significant investment by the community. Bridging the Brisbane River is costly because of its width and only a small number of significant bridges have been built; four of these are listed on heritage registers. Thus, when designing the Green Bridge, the longevity of the asset and its potential contribution to Brisbane's identity must be considered.

5.2 Design Standards

The Green Bridge will be designed to AUSTROADS Australian Bridge Design Code (ABDC). ABDC was not written to cover bus and pedestrian only bridges or light rail. Additional loading requirements were identified and included in the design requirements.

5.3 Site Condition and Constraints

The Green Bridge is to span the river between Dutton Park and St Lucia. There are mangroves growing within the tidal zone along both banks. The tidal zone is an important environmental area for river health. Minimising intrusion into the tidal zone will reduce the environmental impact of the bridge. Part of the Dutton Park riverbank has been unstable and extensive work has been carried out to stabilise it. Piers should not be located within the tidal zone.

For a long time the riverbed in this reach was mined for sand, and the riverbed has become uneven. The river tries to return to equilibrium by re-depositing sand and silt. These deposits have a very low strength and can be easily washed away during a flood. The design of the foundations for the bridge piers must disregard the strength of this material.

Like a lot of the Brisbane River, the Dutton Park Reach is deep. In places there are very small alluvial deposits overlying rock. As river bridge piers typically sit on some type of piled foundation, these conditions will make piling difficult and expensive. Therefore longer span bridges are likely to be more cost-effective.

This reach of the river also carries significant river traffic, including several large barges. The bridge piers must be spaced widely enough to cater for river traffic. Another navigational consideration is the presence of an outcrop of rock in the river, Cemetery Rocks, just upstream of the proposed crossing. This outcrop forces river traffic away from the middle of the river and closer to the St Lucia bank. The Queensland Transport, Regional Harbour Master (Brisbane) has set minimum navigational requirements. The bottom of the bridge deck must be at least 11 metres above the water level at Highest Astronomical Tide. Presently the navigable channel is approximately 140 metres wide. A minimum of 30 metres near the centre of the navigable channel must be unobstructed. If possible this minimum unobstructed span requirement should be increased.

Founding and navigational conditions suggest minimising the number of river piers. This means favouring bridge types suitable for long spans.

5.4 Function of the Bridge

The primary function of the Green Bridge is to carry public transport vehicles, bicycles and pedestrians across the river. However, provisions for public services, such as power, water, sewerage and communications, have also been incorporated in its design. Also considered is the recreational potential of the bridge; the design includes a roof over the pedestrian path for shade and shelter, and viewing decks complete with seating and drinking fountains.

5.5 Bridge Cross-Section

The bridge has a central carriageway of 8.4 m for two way bus traffic. It has a footpath on one side and a bikeway on the other, both 4.0 m wide. There is a total barrier and handrail allocation of 1.5 m giving a minimum deck width of 17.9 m. A cable stay option with cables anchoring between busway and footpaths requires additional space for cable anchorage and clearance. The maximum cross section is shown in Figure 2.

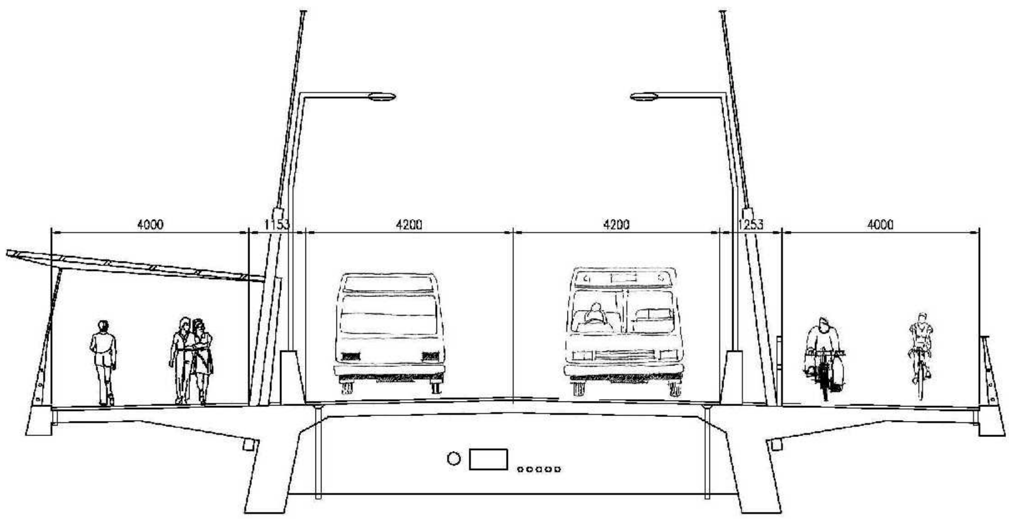

Figure 2: Bridge Cross Section

5.6 Span Arrangement

A range of factors has been assessed in the process of determining the position of piers and the length of spans. These included location of the load bearing rock strata in the river bed, navigation requirements downstream and upstream along the ‘City Reaches’, land utilisation on the river banks (university campus, parking lots, sport facilities, buildings, parks, monuments, access roads), constructability and cost .

5.6 Q2000 Flood Levels

Inundation of the bridge superstructure during floods produces large lateral loads, which can be minimised by ensuring that the bridge deck remains above Q2000 levels. The stability of the structure has been checked for load effects of the Q2000 flood determined at 12.0 m AHD. 3D hydraulic model for the bridge was prepared to refine design loads and flooding impacts.

6 DESIGN LOADS

6.1 Service vehicle

Fully laden compact trucks represented service vehicles used for bridge inspections. Inclusion of a particular specification was considered inappropriate, as the currently used models of service trucks will be withdrawn from service before the bridge is completed. Therefore a provision was made for a generic service vehicle modelled by a T44 truck axle configurations.

6.2 Ship impact on bridge piers

The piers have been designed to resist impact from a river craft travelling at normal navigable speed. The designer shall consider the probability and consequences of a collision with ships of various displacement mass at different water levels and assess the risk of the events. The following information supplied by the Harbour Master and used in the process: “The largest vessel presently navigating the “City Reaches” of the Brisbane River displaces approximately nine hundred (900) tonnes. However … … vessels between three thousand (3000) and four thousand five hundred (4500) tonnes may occasionally transit the “City Reaches”. The normal navigable speed shall be 12 knots”.

6.3 Load combinations

The basic load combinations will be in line with stipulations of the ABDC and in addition the loads identified will be applied in combinations representing the most likely and reasonable occurrence of simultaneous presence of various loads over the service life of the bridge.

7 BRIDGE STRUCTURAL OPTIONS

Table 1. Summary of bridge options

	OPTION	Length m	ADVANTAGES	DISADVANTAGES
FERRY ALIGNMEN	OPTION 1: Box girder bridge: 60+120+60+42m (See Figure 2)	322	Shortest route. Crossing perpendicular to the river. Long navigation span. Inconspicuous and well balanced structure. Low cost.	Two piers are exposed to the risk of flood water forces and debris as well as to ship impact. Deep girders over the Pier 1 are likely to be partially submerged under Q2000 flood conditions.
	OPTION 2: Box girder bridge: 70+70+70+70m	280	Shortest route. Crossing perpendicular to the river Shorter but adequate navigation span	As above. Poor visual impact: does not meet criteria of major metropolitan river crossing
	OPTION 3: Cable stayed bridge: 40 + 130 + 130m (See Figure 3)	300	Shortest route. Shortest bridge crossing perpendicular to the river. Only one pier in the river. Long navigation spans. The shallow girder is likely to remain clear of Q2000 flood level. A landmark structure with clear identity. A positive visual impact of a new and modern structure.	New construction methodology untested in Queensland on a bridge of this size. Limited construction expertise and specialised plant available locally. Lower probability but more serious consequences of ship impact. Dutton Park bridge approach close to residential dwellings. Visual impact. Difficult access to services.
	OPTION 8: Arch: 40+40+200+40m	320	One pier less in the river. Understandable and expressive structure.	Cost 25 to 35% higher than prestressed box girder. Additional risk of cost overruns. Substantial risks during erection. Arch protruding above deck. Obtrusive and heavy portal frames and arch bracing. Requires careful design to minimise visual impact. May restrict future modes of transport.
	OPTION 9: Suspension bridge: 40+40+200+40m	320		Uneconomical span. Positive visual impact diminished by short span. Unsuitable soil condition for cable block anchors
	OPTION 6: A single tower cable stayed footbridge: 40+130+130+25m	325	A novel structure creating positive visual impact. Tower legs straddle footpath	Fails to solve transportation problems. Long walking distances. Expensive facility for pedestrians.
	OPTION 6A: Twin tower cable stayed footbridge: 70+200+55m	325	As for Option 6	As for Option 6
	OPTION 7: OPTION 7: A single tower cable stayed busway bridge: 40 + 130 + 130 +25m	325	As for Option 3	As for Option 3

	OPTION 7A: Twin-tower cable stayed busway bridge: 70+200+55m	325	As for Option 3	As for Option 3
CEMETARY ALIGNMENT	OPTION 4: Box girder bridge: 60+130+75+70+70+48m	498	A grand and bold structure creating positive visual impact. Offers minimum interference with existing land utilisation. Removed from build up areas. The longest navigation span. Reduced risk of ship collision.	Deep girders over the Pier 1 are likely to be partially submerged under Q2000 flood conditions Substantially more expensive than OPTION 1 due to greater length. Creates visual impact over the city skyline. Need to recondition soccer field.
	OPTION 5: A single tower cable stayed bridge: 30 + 45 + 167.5 + 167.5 + 70 + 48m	498	A grand and bold structure creating positive visual impact. Modern structure with clear identity over the city skyline. Offers minimum interference with existing land utilisation Removed from built up areas Long navigation span. Reduced risk of ship collision Only one pier in the river Shallow girder is likely to remain clear of Q2000 flood level	New construction methodology untested in Queensland on a bridge of this size. Limited construction expertise and specialised plant available locally Lower probability but more serious consequences of ship impact Negative perception of visual impact may be voiced by some stakeholders Higher cost due to greater length Difficult access to services
	PREFERRED OPTION: OPTION 10: A twin tower cable stayed busway: 4x30+80+195+80+14+20+12 See Figure 4.	521	Similar to Option 5. In addition tower legs straddle busway effectively preventing changes to traffic composition. Lower towers. River piers away from navigation channel and in shallower water.	Similar to Option 5.

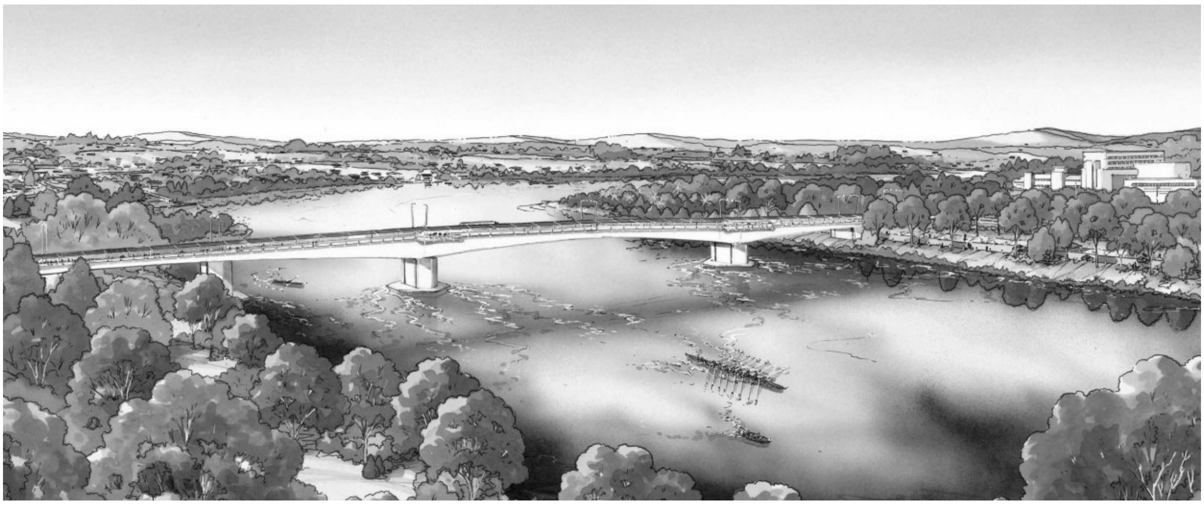

Figure 3: Option 1 - Box girder bridge

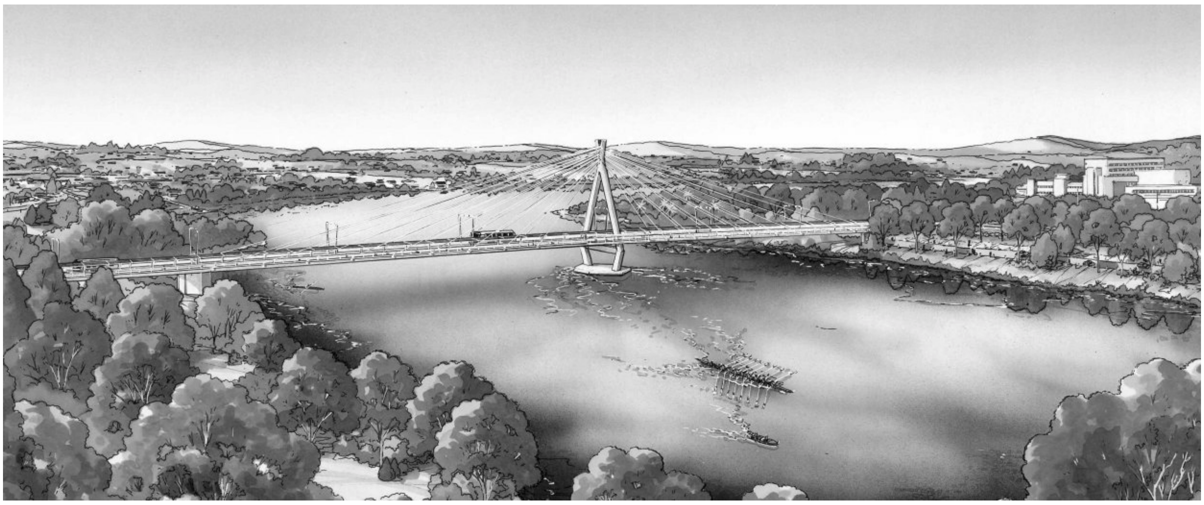

Figure 4: Option 3 - Single tower cable stayed bridge

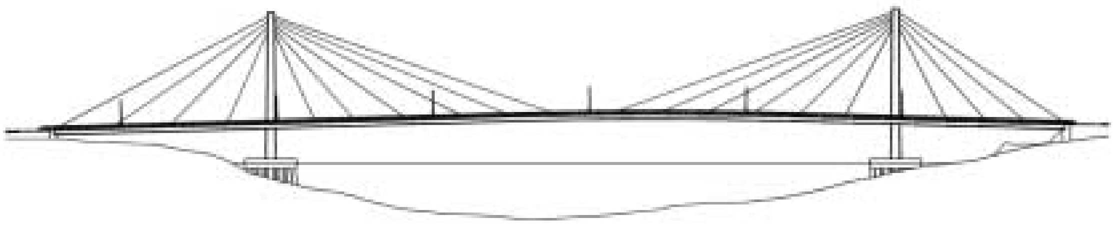

Figure 5: Option 10 - Twin tower cable stayed bridge

8 COMPUTER MODELLING AND ANALYSIS

The engineering assessment of various options resulted in identifying box girder as the preferred option. Therefore behaviour of the box girder bridge during balanced cantilever construction as well as in service has been modelled with a 3-D Space Gass model. Modelling of the whole bridge allowed for a more realistic assessment of the pier-deck interaction under the ship impact. A span-by-span construction as proposed for OPTION 2 has been also modelled and analysed in some detail. Each structure has been analysed for the total of 27 load combinations in line with the design loadings as outlined earlier in this paper.

9 AESTHETICS, VISUAL IMPACT AND PUBLIC PERCEPTION

The aesthetics is one of many criteria used in adjudicating a particular bridge form. In general, selection of the preferred structure will be based on the following factors: prime function, safety, cost, environmental impact, aesthetics and visual impact as perceived by the stakeholders and by the public in general. The structure's prime function, cost, environmental impact and the perception by the public are likely to govern in most cases. In addition aesthetics is a highly subjective attribute and the criteria used may be different when applied by different groups of stakeholders. A more conventional bridge, similar in form to existing structures in the city may be perceived as being in harmony with the built environment. On the other hand the same form may be viewed as dull and effectively turn public interest and support away from the project. The importance of the impact created by media reporting throughout the duration of the project should not be underestimated at both, preconstruction and finalisation stages. Apart from functional aspects the visual impact carried significant weight in selecting the bridge that will effectively become a gateway to the university campus. Universities, being institutions of higher education, are traditionally perceived as crucibles of technology and progress. A modern structure reflecting these values will be appropriate for this specific location. Furthermore, an innovative structure will reflect ingenuity and creativity of engineers, stimulate positive media reports and public interest.

10 COST ESTIMATE

The summary of costs is given in Table 3 below.

Table 3. Cost Estimate Summary[*]

Option	Span configuration	Length m	Deck width m	Cost $
OPTION 1	40+60+120+60+42+25	347	18.7	21,00,000
OPTION 3	40+130+130+25	325	18.7	26,000,000
OPTION 6	40+130+130+25	325	12.5	15,100,000
OPTION 6A	70+200+55	325	12.5	14,600,000
OPTION 7	40+130+130+25	325	19.8	27,000,000
OPTION 7A	70+200+55	325	19.8	26,000,000
OPTION 10 Twin tower busway	4x30+80+195+80+14+20+12	521	19,8	29,500,000

[*] Includes allowance for span over car park access road in Dutton Park

11 CONCLUSIONS AND RECOMMENDATIONS

The selected structure (Option 10: Twin tower cable stayed bridge) will constitute a major crossing in the capital city therefore it is expected to make a statement in terms of boldness in form and size. The prescribed form of the bridge towers constraining the roadway effectively precludes any alterations to future utilisation of the bridge. Such approach may be welcome by some interested parties but it may not necessarily fulfil the objectives of the Council's Transport Plan. In addition to achieving functional objectives a successful transportation project has to meet the needs of the community as a whole and enjoy public support. At the same time the interests of the stakeholders and local communities must be taken into account. However, these interests must be viewed in a broader context of the transportation needs of the city. In the final analysis the concept of a desired future form of the city transportation system must prevail while every effort should be made to minimise impact on local communities.

Therefore, in terms of the prime function, cost, safety and visual impact OPTION 1 (120m navigation span girder bridge) was initially identified as the preferred option. (See Figure 1). In addition to the lowest cost it satisfies the requirements as set out for this major river crossing. Both footbridge options offer river crossings for pedestrian traffic at an estimated cost of $15,000,000 i.e. at 60% of the cost of a busway and are not considered as cost effective alternatives. Setting aside functional constraints OPTION 3 has been initially regarded as the preferred cable stayed option (See Figure 2). The form and the size of the tower accentuate a landmark character of the bridge, its clear identity and positive and clear visual impact of a new and modern structure. The unrestricted roadway as seen from the deck level makes impression of space and strength. The twin tower cable stayed bridge, Option 10 satisfies the demands of major stakeholders, and while retaining most of the advantages of Option 3 emerged as the preferred bridge option.

12 REFERENCES

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