NZ TRANSPORT AGENCY
WAKA KOTAHI

AWHC

Contents

1. Introduction

This Appendix sets out the design objectives and parameters of an AWHC Project, describes the design methodology adopted to achieve these objectives and provides details of the scope and design assumptions, and design standards that have guided the design process.

2. Objectives and Design Parameters

The engineering design objectives were to:

- refine the concept design presented in the 2010 Additional Waitemata Harbour Crossing Notices of Requirement (NoRs) through a more detailed engineering investigation of the NoRs road and rail tunnel concept design; and

- similarly develop other selected forms of crossing including consideration of costs, connectivity, constructability and functionality.

The broad parameters guiding the engineering design were the:

- **Study Corridor**: the 'Option 2' corridor described in the 2008 Additional Waitemata Harbour Crossing Report[1]; and
- **Form of the harbour crossing**: to comprise a tunnel or bridge or a combination of both forms that can provide for road, rail, buses, pedestrians and cyclists.

The design addressed specific issues for each form of crossing under three project evaluation criteria:

- **consentability or consenting risk**: criteria relating to the actual and potential effects of an option, encompassing land use, visual/ landscape, social/ community and environmental matters;

- **constructability**: criteria relating to the ease or difficulty of construction of an option, encompassing construction feasibility and complexity, traffic management, and infrastructure services protection and relocation; and

- **operability**: criteria relating to the operational aspects of the options, encompassing network capacity, network connectivity, network resilience, public transport, walking and cycling.

[1] The NoRs concept design alignment is a refinement of Option 2C from the 2008 Study which lies within this corridor.

3. Engineering Design Methodology

The engineering design methodology was structured to:

- develop designs for crossing forms that achieved the design objectives;
- effectively interface with the Transport and Toll Modelling Team in respect to network capacity and resilience; and
- provide the Economic Advisory Services Team with an accurate estimate the cost range for each form of crossing to enable the development of a Business Case for selection of a preferred crossing option.

Key features of the methodology are described below.

3.1 Project Design Work Breakdown Structure

The project design work breakdown structure included the key design elements appropriate for the concept design status required for the study and comprised:

- motorway (road elements including tunnel geometrics, connectivity and operability);
- rail (rail elements including rail geometrics);
- bridge (new harbour crossing bridge);
- tunnel (harbour crossing tunnels, cut and cover tunnels and trenches);
- fire life safety (road and rail harbour crossing tunnels and cut and cover tunnels);
- geotechnical (preliminary geotechnical appraisal report, earthworks, ground improvement and structure foundations);
- coastal marine (harbour bed movement and coastal protection);
- constructability;
- environmental mitigation;
- cost estimates;
- risk; and

- reviews.

3.2 Scope and Design Assumptions

During the initial stages of the design process, design elements of the NoRs concept design were redefined and scope and design assumptions were established. Scope and design assumptions were confirmed with NZTA and other study work streams at an objectives, principles, assumptions and scope workshop held on 9 July 2010. These are set out in Section 4 below.

The scope and design assumptions informed long list development, allowing for an initial shaping of options for each form of crossing without the need to consider all possible variants within each option. Scope and assumptions were revised as the operability and constructability issues for each option became apparent during short list option development and transport modelling progressed.

3.3 Long List Option Development

The optioneering process (described in Part B of the FASR) provided surety that all feasible options were identified and considered. The two leading considerations at this stage of the short listing process were motorway geometrics and constructability.

The long list was confirmed at a joint planning and engineering workshop and subsequently tested by a team of experts (internal and external), including representation from the Transport and Toll Modelling Team. For details of these workshops refer Appendix C of the FASR.

3.4 Long List Option Evaluation

In order to identify a short list of options the long list was evaluated using a multi-criteria evaluation system that included criteria relating to operability, constructability and consentability (refer Part B of the FASR for full details). Rough order cost estimates were also developed at this time but not specifically included as part of the evaluation process because 'form and functionality' was the primary focus of the options evaluation process at this stage.

3.5 Development of Defined Option

Motorway geometrics and constructability were the two leading considerations in developing the design of the defined options (as with design development during the optioneering process). Further design development at this stage incorporated transport modelling outputs and a second review by experts. Where the defined options that did not meet safety standards or could not be constructed they were discarded or reworked (refer Part C of the FASR). Cost estimating packages for each design element were prepared for costing and delivered to the Economic Advisory Services Team. The design standards that informed the design are set out in Section 5 below.

3.6 Cost Estimates

Cost estimates were determined through establishing a set of costs in the following progressive order.

Property estimates were based on property acquisition and disposal within a nominal 25m wide design either side of the extent of the proposed construction works and retention, in full or part, after completion of construction.

I&R, D&PD and MSQA fee estimates were based on previous similar projects. The geotechnical investigation component of the I&R fee was scoped specially for the tunnel and bridge options developed by this study.

Construction direct cost estimates were produced from the sum of calculated quantities established from estimating packages prepared by the Planning and Engineering Team and multiplied by the current market rates for each work item and /or a set of lump allowances. Market rates were based on cost data for projects of a similar nature (local and international projects as appropriate). Where possible, rates were based on first principles and provisional allowances were made for items of work that were not specifically included in the estimating packages. No contingencies were allowed for at that stage.

Indirect cost estimates (preliminary, general and contractors design) were taken as 25% of direct costs and as for previous similar projects. Similarly, contractors off-site overheads and margin was taken as 15% of total direct and indirect costs.

Base Estimates summed the elements that make up the total estimate. Elements included Land Purchase Costs, I&R, D&PD, NoRs and Planning, Specimen Design, Design & Build Tender and Construction (Design, MSQA and Physical Works).

Expected Estimates were determined from the Base Estimate plus an allowance for contingency. Contingency was developed from a project specific risk assessment that calculated the statistical average cost (mean or P50).

Five and 95 Percentile Project Estimates were produced based on the Expected Estimates plus an allowance for funding risk produced from a quantitative risk analysis using @Risk.

3.7 Reviews

Design development and cost estimates were validated by reviews during the design and estimating process. The reviews ensured reliability of design and accuracy of cost estimates. Reviews included: internal technical reviews of each design element; expert reviews; internal road and rail safety audits; and internal cost estimate reviews. Additionally, NZTA commissioned independent bridge and tunnel technical reviews and cost estimates.

Internal reviews were documented and reviewer's recommendations implemented during design development and cost estimate preparation. Independent reviews and cost estimate preparation proceeded in parallel.

Independent review comments were accommodated where practicable and agreement reached on independent estimates.

3.8 Risk

A study risk register was developed and was regularly updated with NZTA. The register informed design and cost estimating and was updated for risks separately identified through development of the design and cost estimates. The risk management process was internally reviewed and used to develop the Expected Estimates (P50) and 95th Percentile Project Estimates (P95).

4. Scope and Design Assumptions

The scope and design assumptions that guided long list and defined option design development are set out in Table 4.1 and Table 4.2 below.

Table 4.1: Scope Assumptions

No.	Scope Assumption
1.	New & existing motorway route Esmonde Road to the CMJ.
2.	Northern motorway widening to 4 lanes from Northcote Road to Esmonde Road included.
3.	Rail route between Akoranga station (at grade) and Gaunt Street Station (underground).
4.	Extent of rail infrastructure: No station at Onewa. Akorange & Gaunt Street stations not included. Study stops at south extent of Akoranga station and north extent of Gaunt Street station. Gaunt Street station box not included. Gaunt Street station termination common to all options.
5.	(RFT, p62, item 1.2(ii)) Retention of existing bridge. 1st & 2nd bullet points. Provision of additional capacity with a separate adjacent structure. Reconfiguration of lanes on existing bridge included.
6.	Options generally follow concepts covered by Option 2 in the 2008 study but form & location flexible. Options consider compatibility with VPT.
7.	General traffic, rail PT, bus PT and pedestrian/cycle modes provided for.
8.	Tolling includes cost estimates capital and operational work. Existing Toll System (Northern

	Gateway) to be used.
9.	Property acquisition/effects cost estimates are provided by NZTA/The Property Group based on land take plans.
10.	"Base" options for consideration in long list: – all tunnel NOR alignment (driven/immersed tube options); – all bridge generally NoRs alignment(south landing options); – bridge and tunnel (road bridge east of and adjacent to existing AHB & rail tunnel); and – bridge and tunnel (on alignment to Wynyard).
11.	Full connectivity to be assumed (including Onewa connections).
12.	For modelling assume Gaunt Street rail station will connect to Sky City/Albert Street (CBD loop).

Table 4.2: Design Assumptions

No.	Scope Assumption
1.	Auckland Harbour Bridge won't be removed. Reasons for retention are documented by this study.
2.	Management of harbour dredging limitations/issues. POAL: maximum 50,000m³ per annum harbour dredging.
3.	New road tunnel/bridge crossing 3 lanes each way. Confirmed by Transport & Toll Modelling work stream during defined option design development for this study.
4.	NoRs concept design for Onewa Road and Esmonde Road interchanges best achieve project objectives. Layouts will be optimized in later preliminary & detailed design stages. Layouts were refined by this study during defined option design development.
5.	NoRs concept design for existing bridge and new crossing connections to Auckland CBD best achieve project objectives. Some network resilience is provided by slow speed traffic connections between existing bridge & SH1. Layout will be optimized in later preliminary & detailed design stages. The Transport & Toll Modelling work stream confirmed retention of the existing bridge and amended connections to CBD during defined option design development for this study.
6.	New bridge navigation clearances to match existing AHB &/or 52m to provide for Super Yachts at Wynyard Quarter.
7.	Pedestrian/cycle mode is not suited to a tunnel. Will be provided on existing bridge lane for road

	tunnel options or on new or existing bridge.
8.	A new control building located at old ATTOMS Stafford Road site will be required for road and tunnel controls. Rail tunnel/bridge controls and costs provided by KiwiRail.
9.	New rail crossing 1 commuter track each way.
10.	Electrified suburban rail vertical gradient between Akoranga & Gaunt Street is max 3.5% (EMU).
11.	General standards and type of rail and units are similar to the electrified suburban rail proposed for the CBD loop. Excludes freight.
12.	Earliest implementation consideration of rail is dependent on the CBD loop (as per RLTS 2021).
13.	Retrofitting road tunnel to accommodate rail is not practicable/cost effective.
14.	General traffic and bus PT continue on the existing bridge.
15.	Victoria Park Viaduct is ultimately removed.
16.	Design life for works represented in options and design standards will not be changed by modelling or economic assessment time periods.
17.	Cost estimates based on D&C construction method.
18.	Operating & maintenance cost estimates to be over 30 year period from completion of construction.

5. Design Standards

A number of design standards directed shortlist option development.

5.1 Motorway

The design standards and guidelines which directed the design of the motorway are set out in table 5.3 below.

Table 5.3: Motorway Design Standards

Geometric
Austroads, 2009 – Guide to Road Design Parts 3, 4A, 4B, 4C, 6A, 6B
Ramps comply with Traffic Control Devices Manual Part 10 (MOTSAM Part 3).
The difference in design speeds for successive elements is generally no greater than 10kph
Austroads, 2010 – AGRT03/10 Guide to Road Tunnels – Part 3: Operation and Maintenance
SKM Working Note 2: Option Design Standards, 2009 (for developing the NoRs conceptual design of preferred Option 2C from SKM 2008 study).
Pavement
Austroads, 2008 Pavement Design – Guide to Pavement Technology Part2 Pavement Structural design
Transit New Zealand, 2007 New Zealand Supplement To The Document, Pavement Design – A Guide to the Structural design of Pavements (AUSTROADS, 2004)
Austroads, 2004 Pavement Design – A Guide to the Structural design of Pavements
Design life 40 years for the pavement structure, and 8 to10 years for the asphaltic concrete surfacing.
Safety barriers
State Highway Geometric Design Manual
NZTA Specification for Road Safety Barrier Systems, M/23
Transit Bridge Manual

NCHRP Report 350. Barrier Test Level definitions/specifications shall be those given in NCHRP Report 350
AS/NZS 3845:1999 Road Safety Barrier Systems.
Traffic signage
Section A1, TNZ P/24:2008, RSMA "Compliance Standard for Traffic Signs", and MOTSAM Parts I, and the Traffic Control Devices (TCD) Manual Part 10.
Stormwater treatment
ARC TP10
ARC TP108
Tunnel harbour crossing
Design speed. Proposed posted speed for the tunnel and the approaches is 80km/hr as this matches the existing posted speed between the CMJ and Onewa Interchange and that on the existing harbour bridge. As such, the desirable minimum design speed for all alignments is 90km/hr, or better where practically achievable.
Cross section: • 3 x 3.5m lanes • Vertical Clearance in bored and cut and cover tunnels. 5.4m minimum (VPT 5.4m). • Horizontal clearance in bored and cut and cover tunnels. Shoulders minimum 1m (VPT 0.5m to 1m). • Horizontal Clearance (working width) in bored and cut and cover tunnels from face of barrier to tunnel wall. 650mm (VPT 650mm) • Pavement uniform crossfall bored tunnel 3% • Existing harbour bridge lane layout. 1 pedestrian/cycle and 1 bus PT lane on east extension bridge, 1 bus lane and 5 general traffic lanes on remainder of bridge. Moveable lane barrier required.
Shared pedestrian/cycle path

New bridge harbour crossing
Design speed. Proposed posted speed for the bridge and the approaches is 80km/hr as this matches the existing posted speed between the CMJ and Onewa Road Interchange and that on the existing harbour bridge. The operating speed for the northern sector and on the new bridge is expected to be 100kph. Therefore the desirable minimum design speed for the new bridge alignments has been set at 100km/hr except as it approaches VPT where it is dropped to 90kph. The design speed through VPT and CMJ is 80kph.
Cross section: • 3 x 3.5m lanes • Left shoulder 2.5m and right shoulder 2.0m • Vertical clearance in cut and cover tunnels. 5.4m minimum (VPT 5.4m). • Vertical clearance Fanshawe Street ramps. 6.0m for over-dimension route • Horizontal clearance in cut and cover tunnels. Shoulders minimum 1m (VPT 0.5m to 1m). • Horizontal clearance (working width) in cut and cover tunnels from face of barrier to tunnel wall. 650mm (VPT 650mm) • Shared pedestrian/cycle path. 3m wide footpath on the eastern side of bridge and a 3m wide cycle path on the western side • Pavement nominal crossfall 3% • Existing harbour bridge lane layout. 1 bus lane and 3 general traffic lanes in each direction. Moveable lane barrier not required.
Separate shared pedestrian/pedestrian path

5.2 Rail

The geometric standards and guidelines which directed rail design are:

- KiwiRail document CSP/33 Curves: Design Criteria, Speeds and Records;
- SKM Working Note 2: Option Design Standards, 2009 (for developing the NoRs conceptual design of preferred Option 2C from SKM 2008 study); and

- ONTRACK T200 Infrastructure Handbook 2000.

5.3 Bridge

The standards that directed the design of the bridge are:

- Transit Bridge Manual second edition 2003 incorporating all amendments up to July 2005.
- NZS1170.5:2004, as referenced by Transit Bridge Manual.
- NZS3101:1995 (all sections except durability) for concrete design.
- NZS3101:2006 (durability requirements) for concrete.
- NZS3404:1997 for steel design.
- Post-tensioning Institute Recommendations for Stay Cable Design, Testing and Installation, fourth edition, 2001 for cable design.
- BD 49/01 Design Rules for Aerodynamic Effects on Bridges.
- Where the above documents do not specifically address a design issue, the design shall comply with AASHTO LRFD Bridge Design Specifications, 2007.
- Seismic design of bridge structure checked for 1 in 2500 year annual probability of exceedance.
- Harbour navigation span clearance minimum 41m air draft above mean high water spring tide level as for the existing Auckland Harbour Bridge.
- Ship impact from 50,000 tonne dead weight vessel at 2 knots for main pylons only.
- The design life for the structures shall be 100 years.
- New “replaceable” elements of a structure (proprietary movement joints, bearings, seismic restraints) shall have a minimum life of 25 years prior to major maintenance or replacement and shall be replaceable without the need for major modifications to adjacent elements.
- Services similar in weight to the existing harbour bridge are provided for on the new bridge with allowance for larger watermain and power cables in future.

5.4 Road Tunnels

The standards and guidelines which directed the design of the road tunnels, including cut and cover and trench sections are:

- Specification for Tunnelling, British Tunnelling Society and Institution of Civil Engineers, June 2000 or equivalent international, NZ or Australian standard.
- Tunnel Lining Design Guide, British Tunnelling Society; Institution of Civil Engineers 2004
- Finite element analysis (Rocscience Phase2)
- Settlement estimates – Mair et al 1996 "Prediction of ground movements and assessment of risk of building damage due to bored tunnelling" Geotechnical Aspects of Underground Construction in Soft Ground, Mair & Taylor (Eds), Balkema 1996 Rotterdam, ISBN 90 5140 856 8
- AS/NZS 1158.5:2007 Lighting for Roads and Public Spaces – Tunnels and Underpasses
- Fire:
  - PIARC Systems and Equipment, 2007. Design Fire based on 2 hr HCinc fire event as a minimum.
  - DR AS4825 Tunnel Fire Safety
  - AS1530 Methods for fire tests on building materials, components and structures.
  - Fire suppression to comprise a deluge system that can deliver 10mm/min over full width of tunnel for 30 minutes
- Emergency egress: cross passages or exit doors at 120m centres in bored tunnels and cut and cover tunnels.

5.5 Rail Tunnels

The standards and guidelines which directed the design of the road tunnels, including cut and cover and trench sections are:

- Specification for Tunnelling, British Tunnelling Society and Institution of Civil Engineers, June 2000 or equivalent international, NZ or Australian standard.
- Tunnel Lining Design Guide, British Tunnelling Society; Institution of Civil Engineers 2004
- Emergency egress: cross passages or exit doors at minimum 240m centres in bored tunnels and cut and cover sections.

5.6 Geotechnical

Methods of analysis used for the design of reclamation and embankment fills:

- Design of an AWHC embankment fills for the bridge approach and raising of the existing northern motorway section has included analyses using the software packages Slide and FoSSA; as well as manual calculations of settlement and wick drain spacing.

5.7 Coastal Engineering

The standards that directed the coastal engineering design are outlined below.

5.7.1 Temporary Reclamation Levels

Temporary platforms were designed to the following:

- 50 year return period combined wave/tidal event (which is probably conservative);
- 2% run-up during the design event (i.e. a wave event with about 3.5s wave period, some 24 waves/hour would overtop the structure);
- freeboard of 0.3m;
- no sea level rise;
- 0.5m storm surge; and
- bund slope of 2.5: 1 with an armoured surface.

5.7.2 Finished Reclamation Levels

Platforms were designed to the following:

- 100 year return period combined wave/tidal event;
- maximum run-up during the design event;
- 0.5m freeboard;
- 0.5m sea level rise;
- 0.5m storm surge; and
- bund slope of 2.5: 1 with an armoured surface.

5.7.3 Rock Armour

Rock Armour was designed to the Rock Manual (CIRIA, 2008).