SUMMARY

Jacobs, in a joint venture with Parsons Brinckerhoff, provided the detailed design for an underpass on Australia’s busiest rail corridor, with minimal impacts on operations. A great team was created that navigated a number of technical and management complexities and applied an efficient and effective approach to delivery. By doing the basics well and consistently, establishing clear roles and accountabilities and developing systems and procedures to assist rather than encumber the design team in developing a robust design are outlined in the following paper.

1. INTRODUCTION

North Strathfield Rail Underpass (NSRU) is one of four Stage 1 projects to be carried out under the Northern Sydney Freight Corridor Program. The Sydney to Newcastle rail line is part of Australia’s busiest rail corridor and is also the most serious bottleneck on the east coast interstate rail network. The primary objective of the project is to enable additional paths for freight trains, reduce waiting times for freight trains and increase the reliability of both freight and passenger services.

The project involved the construction of a rail underpass for freight trains at North Strathfield eliminating an existing at grade crossing north of Concord West Station. Other key elements included a new Concord West Station, modifications to the existing North Strathfield Station footbridge, replacement of the Beronga Street services overbridge, extension of Pomeroy Street Overbridge and a new distribution substation at North Strathfield.

2. TEAM

A joint venture between Jacobs and Parsons Brinckerhoff (NSRU DJV) was formed to undertake the Technical Advisor (TA) role for the detailed design of North Strathfield Rail Underpass (NSRU). The team also included the following specialist subconsultants.

- Mott MacDonald – Tunnel design
- HBO+EMTB – Architecture, urban design and landscaping
- Performance Electrics – Earthing, bonding and electrolysis
- Scott Lister – Safety Assurance
- AECOM – Overhead wiring verification
- Defire – Fire engineering verification

Parsons Brinckerhoff had been the Technical Advisor for Definition Design. Jacobs had been the Technical Advisor for the Reference Design.

3. SCOPE

The TA was responsible for the detailed design of the following elements.

- 148m shallow driven tunnel with canopy tubes
- 600m dive structures consisting of pile walls up to 10m high
- Twin 2100mm diameter stormwater culvert pipe jacked under existing track
- 1,700m of combined services route (CSR)
- New Concord West Station
- Modifications to the existing North Strathfield Station footbridge
- Extension of the existing Pomeroy Street Overbridge
- Replacement of the existing Beronga Street services overbridge
- Adjustments to overhead wiring
- New distribution substation at North Strathfield
- Earthing, bonding and electrolysis

The scope also included provision of Alliance procurement support and construction support services.

4. INTERFACES

Management of interfaces was a critical part of the work to ensure overall design integration with including work by others. A summary of key interfaces is as follows.

- Signalling Technical Advisor (STA)
- Traction Supply Upgrade (TSU)
- Signalling Power Supply Upgrade (SPSU)
- Digital Train Radio System (DTRS)
- Automatic Train Protection (ATP)
5. CONTRACTURAL ARRANGEMENTS

TfNSW was initially the Principal with the TA later novated to a non-owner participant on the NSRU Alliance including Bouygues, John Holland and TfNSW.

The TA fee structure is outlined in Table 1.

<table>
<thead>
<tr>
<th>Description</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Packages</td>
<td>Lump Sum</td>
</tr>
<tr>
<td>Alliance Procurement</td>
<td>Upper Limiting Fee</td>
</tr>
<tr>
<td>Construction Support</td>
<td>Target Fee</td>
</tr>
<tr>
<td>Services</td>
<td>Budget</td>
</tr>
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</table>

6. CLIENT EXPECTATIONS

TfNSW identified a number of key success factors relating to designers and successful design and delivery outcomes related to alliances. These expectations included the following.

- Effectively manage the schedule for timely achievement of design approval to enable procurement and construction to proceed
- Quality of design produce to optimise the timeframes for design approval and minimise the cost and time impacts of rework
- Design product to meets the needs of construction not just approval
- Engagement to understand
- Designers accountable for meeting the budget, schedule and quality requirements
- Managers calling designers to account for meeting budget, schedule and quality requirements
- Strong scope change management
- Consequence of poor performance
- Minimise design package splitting to meet schedule dates (possession weeks)
- Quality design to facilitate timely approval
- Respect and manage to the requirements of the design approval process in recognition of the obligations of the asset owners

Feedback was provided by TfNSW during the tender and kick-off period in relation to the performance of designers on recent alliance projects, in particular in relation to the management of time of cost. As a consequence the designer was not included as a non-owner participant on the NSRU Alliance. The intent was to encourage alliance type behaviours in relation to collaboration and best-for-project outcomes with the commercial rigour associated with a lump sum design packages.

7. ALLIANCE PROCUREMENT PROCESS

The procurement process for the NSRU Alliance proceeded in parallel with the detailed design. Through a competitive selection process two proponents developed a Project Proposal with a Target Outturn Cost (TOC) from the Reference Design. The TA provided technical support to TfNSW during this process including the following.

- Guidance meetings – Opportunity for the Alliance proponent to ask questions and seek clarification.
- Alignment meetings – Opportunity for the Alliance proponent to meet with the TA and confirm the scope of work proposed once the TA is novated to the Alliance partner and the nature of the risks and opportunities that are present in that relationship.

It became apparent from the Guidance and Alignment meetings that the two proponents were considering different methodologies for the construction of the tunnel and Concord West Station. As the construction methodology was a key input into the design development TfNSW made a critical decision to put design of the tunnel and station packages on hold until after novation to the NSRU Alliance.

There were consequences for this decision. The design programme was extended by 3 months and design packages for the station had to be split to allow critical elements related to track possession work to be approved ahead of the construction programme. This allowed the successful proponent to incorporate their methodologies into the design development without requiring significant rework which was considered the best for project outcome. In particular it allowed time for collaboration between the design and construction teams to integrate the tunnel design and construction methodologies, essential for shallow driven tunnel under an operating rail corridor.

8. DESIGN PACKAGING

Design packaging was defined in the Services Brief with the intent of enabling progressive technical review throughout the detailed design process. This intent was also reflected in the design programme developed by the TA with a submission profile established around...
progressive issue of design packages rather than multiple design packages being submitted at the same time for review. The submission profile was developed on averaging around 10 submissions a month. A summary of planned and actual submissions is shown in Figure 1.

A number of the design packages defined in the Services Brief were split by the Principal during the course of design development outlined as follows.

- Permanent Way initially one design package was split into two separating alignment and track structure. This allowed approval of the alignment to be brought forward for interfacing with the signalling design by the STA.
- Signalling and CSR Relocations initially one design package was split into three to allow early works related to possessions to be approved ahead of the construction programme.
- Drainage initially one design package was split into two separating out works associated with connection to the existing Powells Creek channel which required approval from Sydney Water as the asset owner.
- Concord West Station Structural initially one design package was split into four to allow progressive approval of possession critical works ahead of the construction programme.
- Overhead Wiring initially one design package was split into two separating structures and the wiring to allow the approval of the structures to be brought forward as a number of structures were associated with critical possession works in the construction programme.

Whilst minimising design package splitting was one of the key success factors identified in the client expectations, the splitting outlined above was done in an informed and controlled manner with collaboration between the design and construction teams, well in advance of the dates the approved design was required by the construction programme. Mitigating impacts on the design programme was also taken into account by reducing the number of design review stages where practicable.

Key aspects of the design packaging include the following.

- 50 design packages
- 150 design package submissions


9. ROBUST DESIGN

Successful delivery, in particular facilitating timely review and close out of issues identified during the review process required robust design (ie. a design that could go through the review process with minimal comments and require few if any changes). Robust design was defined as follows.

- Integrated – all the different elements fitted and worked together spatially and on a system level
- Compliant – the design complied with the requirements of the Services Brief

Integrated design was achieved through developing the following tools and processes.

- Workshops early in the design development to identify coordination issues and determine workflows to assist the design team in resolving them before they became conflicts.
- Regular interdisciplinary design coordination sessions within the design team and including the STA where required.
- Documentation of relationships between design packages in Design Reports including key interfaces and evidencing how these interfaces had been addressed in the design development.
- Interdisciplinary Design Coordination (IDC) check as part of the internal review process prior to issue of design packages.

Compliance with the Services Brief was achieved through requirements management including the following.

- Identifying requirements in the Services Brief including; Systems Requirements Specification, Business Requirements Specification, Planning Approval and sustainability initiatives in a database and allocating them to design packages early in the design development.
Referencing evidence of where in the design documentation the requirements had been addressed.

• Documenting the requirements and evidence in the Design Report for each design package.

10. SAFETY ASSURANCE

Robust design was also supported by the implementation of progressive safety assurance during the design development. A key aspect was the early establishment of a Safety Assurance Plan (SAP) and Goal Structured Notation (GSN) outlining what safety assurance activities would be undertaken during the design development and the evidence produced to support the safety argument.

The Design Report for each design package included a section on safety-in-design demonstration. This section identified what safety assurance activities had been undertaken and the evidence produced. It also identified what safety assurance activities would be undertaken in future design stages which was as useful tool for the Team Leads and reviewers in planning these activities and ensuring the evidence was produced for incorporation in the Design Report.

11. SYSTEMS AND PROCEDURES

A Design Management Plan (DMP) was developed early in the detailed design based on the requirements outlined in the Services Brief. Getting the design team to read and implement the systems and processes in the DMP had proven difficult based on past experience. Rather than repeat the lessons learnt from the past the systems and processes in the DMP were implemented through the Design Report.

A standard Design Report template was developed for all design packages. Each section of the Design was linked to a system or process in the DMP. As a result the Design Report became a useful tool for the Team Lead to record and monitor design development, and compile evidence of compliance progressively between design stages, rather than an onerous task left until immediately prior to the submission. Key aspects of the Design Report included the following.

• Scope of the design package and relationship with other design packages
• Design description and methodology
• Design departures and changes from the previous design stage

12. DESIGN REVIEW PROCESS

The design review process was outlined in the Services Brief based on the following design stages.

• Systems Definition Review (SDR)
• Preliminary Design Review (PDR)
• Critical Design Review (CDR)
• Approved for Construction (AFC)

Importantly review timeframes were also specified in the Services Brief outlined as follows.

• The stages at which each design package was to be submitted (as not every design package was required to be submitted at each stage)
• The review time for each design stage including period for review and comment (10 days for TfNSW with an additional 15 days for RailCorp were applicable) and close out by the TA (5 days).
• The reviewer of each design package (ie. TfNSW and/or RailCorp).
• The purpose of each submission (ie. for review and comment or information only).

Only 6 of the 50 design packages were specified to be reviewed by RailCorp. Notwithstanding, initially the majority of design packages were provided to RailCorp for review resulting in additional review comments. This generated some robust discussions between the TA and TfNSW in relation to who was responsible for responding to and closing out of these additional review comments. A compromise was reached by the TA only
responding to issues relating to compliance with the Services Brief.

To minimise the number of review comments and facilitate timely close out of issues training was provided to designers in how to interpret and respond to review comments. Importance was placed on reading and understanding the intent of the comment and providing a clear and concise response. Importance was also placed on referencing where in the design documentation the comment had been addressed. If no further action was proposed justification had to be provided confirming compliance with the Services Brief.

Tracking of comments and responses was also carried out to monitor how long it was taking to receive, respond and close out comments. A tracking chart was developed (refer Figure 2) which was a valuable tool used to keep everyone involved in the process accountable.

A summary of key review comment statistics is provided in Table 2.

<table>
<thead>
<tr>
<th>Description</th>
<th></th>
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<tbody>
<tr>
<td>Total Review Comments</td>
<td>2,908</td>
</tr>
<tr>
<td>Average Review Comments/Design</td>
<td>58</td>
</tr>
<tr>
<td>Package</td>
<td></td>
</tr>
<tr>
<td>Average Review Comments/Drawing</td>
<td>&lt; 2</td>
</tr>
</tbody>
</table>

Construction of a shallow driven tunnel under an operating rail corridor was considered high risk and the design package for the tunnel structure was subject to a number of reviews including the following.

- Internal Checking
- Internal Verification
- Interdisciplinary Design Coordination
- Independent Proof Engineer
- Construction Team Review
- Engineering Assurance Review by TfNSW and their technical advisors

A canopy tube design methodology had not been used for this application in Sydney before (refer Plate 1). Concerns in relation to this became evident after the Engineering Assurance review by TfNSW of the SDR which received 40 comments many of which related to a lack of familiarity in the design methodology proposed. It took 2 weeks to receive the comments on the SDR and a further 7 months to close them out. Collaboration was required between the design and construction teams to demonstrate that all the issues identified by the reviewers had been addressed in an integrated design and construction methodology. TfNSW also engaged Jacobs Associates with recognised expertise and experience in shallow driven tunnel methodologies to provide a further independent review of the design to satisfy the concerns of the review team.

13. ORGANISATION STRUCTURE

Creating a great team began with the following definition.

- Great teams do the basics things really well, much better than everyone else.
- Great teams have endurance, they consistently do the basics really well.

The basics started with development of an organisation structure. Various options were considered and a discipline based structure adopted. Each discipline had a Team Lead responsible for delivery of the design packages assigned to that discipline. Key features of the organisation structure are outlined as follows.

- Role based organisation structure linked to the Engineering Authority Application (EAA) to ensure personnel nominated for a role were assessed as competent for that role and authorised by TfNSW. It also provided clarity to personnel in team as to what their role was, particularly in relation to personnel that had multiple roles.
- Fully integrated design team. Being a joint venture, the team was structured so that design done by a person from one of the joint venture partners was checked by a person from the other. The intent was to share risk/responsibility to ensure the team focus was on finding solutions rather than blame (as both joint venture partners were involved in all aspects of the design).

160 roles were identified in the organisation structure including designers, checkers and verifiers which required a team of 120 personnel. Around 50 Equivalent Full Time (EFT) personnel were required for the peak period of the detailed design.

One of the key success factors was continuity of key personnel. In particular the core management team including the Project Manager, Design Manager, Interface Manager, Commercial Manager and Team Leads remaining relatively unchanged for majority of the detailed design delivery. Continuity of personnel from the Reference Design into the detailed design was also an advantage.
14. ACCOUNTABILITY

Getting individuals within the design team to understand what they were accountable for was an important part of the team development and performance. During the early stages of formation of the design team it became evident that there were significantly different opinions between individuals on who was accountable for what. The key roles that required clarification are outlined as follows.

- **Team Lead** – delivery of integrated design packages on time and on budget
- **Designer** – design and preparation of deliverables for design packages
- **Design Checker** – design compliance, independent to the preparation of the design
- **Design Verifier** – identifying and reviewing safety or system critical elements of the design, independent to the preparation of the design

The greatest misalignment within the team was in relation to the checking and verification roles with some of the Design Checkers and Verifiers having strong personnel opinions about what their role should be and what they were and were not accountable for. These opinions varied and included the following:

- Some Design Checkers thinking they were Designers and should be involved in the preparation of the design
- Some Design Checkers thinking the Designer was the Design Checker and accountable for design compliance
- Some Design Verifiers thinking they were the Design Checker
- Some Design Checkers thinking they were the Design Verifier

To overcome these issues an induction process was developed for Design Checkers and Verifiers to outline the differences and expectations for each of the roles as defined in the Services Brief. Design Check and Design Verification certificates were also developed to include statements confirming these expectations had been met.

Nonconformance Reports (NCR) were another tool used to promote accountability within the design team. The intent of the NCR was less on what was wrong and how to fix it and more on why did it go wrong, how to prevent it happening again and linking it to a particular role in the design team (ie. if everyone in the team performs their role as intended there should be no nonconformances). This process was initially new and confronting for some members of the team (ie. it was perceived as a black mark against their performance) until the intent became understood.

15. TEAMWORK

Teamwork was another important factor in the successful delivery of the detailed design. A culture was developed around team performance rather than just individual performance. If the team won everyone won. If the team lost everyone lost irrespective of individual performance and accountabilities.

An example of this was the development of structural design for the dive structures (refer Plate 2). The design required consideration of a number of disciplines including structural, overhead wiring, drainage and rail systems along with staging and constructability inputs from the construction team. An integrated design was successfully developed. At the end of the process when the structural designer was being acknowledged for his individual contribution his response was without input from the design drafter, other designers and the construction team he could not have developed the solution on his own.

16. CONCLUSION

Design of complex multidiscipline rail infrastructure projects can be delivered on time, on budget and meet client expectations by creating a great team and doing the basics well. Key aspects include the following.

- Clear organisation structure
- Understanding of roles and accountabilities
- Implementing systems and procedures through a Design Report that becomes useful tool in the design development
- Holding designers to account
- Teamwork and collaboration within the design team and between the design team and construction team
- Robust design

The foundation for successful teamwork is trust. This is reflected in feedback received in a staff survey “... I have worked in many joint ventures in my time and the way the NSRU team worked together was by far the most enjoyable DJV I have been involved in. The team supported each other in delivering this challenging project and there was a high level of trust between each member which kept moral high and quality at the highest possible ...".
Figure 1

NSRU Submission Profile

![NSRU Submission Profile Graph](image1)

Baseline  Revised Baseline  Actual

Figure 2

Design Review Timeframes

![Design Review Timeframes Graph](image2)

TfNSW Review and Comment  Close Out