REGIONAL FAST RAIL PROJECT - DESIGN AND DELIVERY CHALLENGES

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SUMMARY

The Victorian Government's visionary Regional Fast Rail Project delivered the greatest revitalisation of regional rail in Victoria in over 120 years. The project involved the upgrading of rail infrastructure to facilitate significant reduction in journey times along four rail corridors which radiate from Melbourne – Ballarat, Bendigo, Geelong and Traralgon.

Thiess Pty Ltd and ALSTOM Australia's Transport Division (now part of the United Group) formed a 50/50 unincorporated Joint Venture (commonly referred to as TAJV) to bid for the works. TAJV entered into 2 separate performance-based design and construct contracts with the Victorian Department of Infrastructure to upgrade the Geelong and Ballarat corridors. The contract scopes included the design and construction of new and upgraded rail infrastructure, necessary to allow the new V/Locity 160km/h trains to achieve the mandated run times. A significant element in the upgrade of the Ballarat corridor was the construction of 2 major deviations, which were required to "straighten" the track.

TAJV set a new benchmark in the delivery of upgraded infrastructure on both the Ballarat and Geelong rail lines. Where lengthy and disruptive line closures were expected over a number of years, TAJV brought about a paradigm shift in the approach to the delivery of these multidiscipline projects. An innovative delivery methodology resulted in a series of short, sequenced rail shuts. Record levels of construction work were achieved within the shuts and travel disruptions for rail passengers were reduced to the absolute minimum.

The projects required the management of a large and intricate web of competing and changing stakeholder groups over the four year delivery period. The contracts were awarded at a time of significant uncertainty, with the Safety Regulator looking to improve the level of safety achieved at speeds which had not previously been seen in Victoria. The franchisee who was responsible for the asset was also uncertain about the benefits that the upgrade would provide, as they only operated freight trains on the corridors. The uncertainty contributed to numerous changes to the original specification to ensure that all the needs of the asset owner, franchisee, train operators, the safety regulator, affected land owners and rail passengers were met. Despite a 30% change in the project scopes following contract award, TAJV delivered both rail corridors within agreed timescales and achieved all the safety, performance and reliability requirements for the project.

Over 1.5+ million man hours were expended on the project without major incident. TAJV safely inducted over 900 staff on both rail corridors, all of whom worked successfully beside live rail for the life of the project. The long linear nature of the two rail corridors meant that multiple environmental bio-sites needed careful management. TAJV completed the works without adverse affect to any bio-site and the project team also restored the heritage listed Portland Flat Road Bridge.

As of January 2006, travel time from the outskirts of Melbourne to Geelong takes 19 minutes with a city centre to regional centre timetable of 45 minutes, and the respective trip from Melbourne to Ballarat takes 47 minutes with a timetable of 64 minutes.

The integrated and innovative approach of the Thiess ALSTOM Joint Venture has established the benchmark for the successful delivery of rail infrastructure projects in Australia.

1 INTRODUCTION

A run time of 19 minutes in either direction had to be achieved between Werribee and Geelong to facilitate time-tabling of Melbourne - Geelong services at a minimum 45 minutes, in accordance with the Government's published goals.
Respectively, a run time of 47 minutes was required for the trip from Sunshine to Ballarat to achieve a 64 minutes timetable of Melbourne – Ballarat.

TAJV used the latest international technology with the SIMU++ train simulation package, to develop the optimum track alignment and signalling spacing and aspect sequences to achieve the required run times while maintaining the density of trains on the corridor.

The scope to deliver the required operations included the upgrading of track, level crossings, new and innovative signalling systems, a new centralised train control system and the design and construction of two of Australia's largest rail bridges as well as the 8.2km Bungaree deviation.

2 NOTATION

KM	Kilometres
m^3	Cubic metres
m	Metres
CFA	Continuous Flight Auger
LED	Light Emitting Diode

3 PROJECT SCOPE

3.1 SIGNALLING AND TRAIN CONTROL

3.1.1 Requirements for Change

The increase of maximum line speed from 130 km/h to 160 km/h required a change to the signalling system to account for the increased braking distance and the need for drivers to sight signals at a greater distance. The signalling system that existed on the line was a mixture of equipment installed over the past 80 years including:

- Pre-first world war mechanical signalling with semaphore signal arms and rod operated points
- 1950's relay interlockings with open aerial conductors
- Various 1980's remote control systems (SCADA) for small parts of the corridor

Prior to the project, the control of the signalling on both corridors was performed by localised signal boxes - each operator controlling a limited area of the corridor using simple unit lever panels and mechanical lever frames. Train control was performed at Melbourne via hand drawn graphs and a telephone to the operator in the local signal boxes. The increase in speed and train density meant this antiquated system needed to be upgraded with a whole of corridor system to provide increased train visibility and control.

3.2 SIGNAL SIGHTING

The SIMU++ train simulation provided the calculated location for signals, however local topography which affected these locations could not be included in the model and field inspections and refinement of locations was an essential element of the design development process. The field planning process included the necessary procedures for determining the optimum placement of signals so that they were visible to the drivers and positioned so that there was a sufficient margin to allow drivers and trains to react and bring their train safely under control. This process involved the *temporary placement of trial signals* for observation under various conditions and also relied heavily upon the experience of senior drivers. All signals were sighted and the placement agreed between all parties before the signalling system was installed.
All signals were replaced with LED signal light units which have improved visibility and provided a longer life cycle than incandescent lamps.

Figure 1 LED Signal

3.3 LEVEL CROSSING CHALLENGES / INNOVATIONS

TAJV was also responsible for designing, constructing and commissioning the upgraded level crossings. Works had to be progressed amidst operating trains and road users which required extensive road detours and community relations management.

The level crossing protection on both corridors was upgraded on the basis of a risk analysis. The levels of upgrade available were:

- Flashing light protection
- Full boom barrier protection
- Pedestrian gates crossings

Integration of the level crossings into the signalling system was required and the train control system was utilised for remote monitoring.

TAJV delivered an innovation for level crossing road surfaces by introducing new rubber panels, previously never used in Australia.

The construction of the level crossing upgrades, where all signalling cable routes, mast bases and equipment box bases were installed as part of the civil construction provided an example of the TAJV integrated approach which was repeated at an additional 80 crossings.

3.4 TRAIN CONTROL CHALLENGES / INNOVATIONS

Prior to the RFR upgrade, the Train Controller had no real-time information regarding the position of trains. The Controller relied upon telephone messages from the local operator to manage the corridor. On conclusion of the works the new Train Control and Monitoring System (TCMS) included;

- A Regional Train Control System (at Geelong and Ballarat) that provided improved operational control of the corridors and increased train visibility.
- A Central Monitoring System (at Melbourne) that provided real time information about the position of trains and the condition of the infrastructure on both corridors for the Train Controllers
- A Fault Management System (at Melbourne) that provided remote monitoring and alarm management of all active signalling equipment including level crossings

The heart of the TCMS is the Regional Control System (RCS) SigView, a ‘Point and Click’ Graphical User Interface (GUI) based train control system run on a ‘commercial off the shelf’ PC operating system.

Real time displays show the train location and the status of the signalling equipment across a number of LCD monitors and it includes a large feature set from individual commands to automatic route setting.

Dual servers were used for redundancy and all events are logged and backed up for fault finding and maintenance. With its introduction at Ballarat and Geelong, the multiple local signal boxes were rationalized into one regional control centre with a single operator.

Figure 2 Regional Control System

The Central Monitoring System (CMS) allows the Train Controller at V/Line’s headquarters in Melbourne to see real time information about the positioning of trains and the status of the signalling equipment on both corridors. Whereas before, the train controller relied upon verbal information, the CMS displays now allow the operator to make appropriate decisions and minimize delays on the corridor by predicting future conflicts between trains.

The Fault Management System (FMS) includes the same functionality as the CMS with an additional suite of maintenance and fault finding tools including a Replay Facility and a text based Event Recorder.

The Replay Facility allows a graphical play back of the event logs to show the status of the signalling equipment which can be played in real time, slow motion or at a high speed. The replay has been used to investigate faults and incidents on the system to determine the cause and thus allow steps to prevent recurrence of the incident.

Control and Indication data is gathered in the field through a variety of local interface equipment including point to point logic controllers; radio based remote terminal units and a direct interface into the vital signalling computers. The data is collected and processed at a dual multiplexer computer located at the main field control room, before being processed to the operator SigView via a fibre optic network.

3.5 SIGNALLING CHALLENGES / INNOVATIONS

The signalling required the installation of new signalling conduits, cables and equipment boxes which were installed along the length of both corridors and which were used to connect the 232 signals, 76 motor operated points, 484 train detectors, 18 sets of automatic pedestrian gates and 62 actively protected level road crossings. Wherever possible work was assigned to the group who were best placed to deliver the required outcomes and traditional demarcations between rail disciplines were broken down.

3.5.1 Supply

The TAJV team were presented with significant challenges with regards to the sourcing, assembly and installation of the signalling system along the two corridors. Componentry for the new system had to be sourced from multiple locations, both within and outside Australia, assembled and tested on site, within the confines of the project timelines.

Location equipment boxes containing the equipment used to operate the signalling system had to be wired for a specific location. The boxes were manufactured in Victoria and NSW and shipped to site in a fully tested condition – this process was carefully planned with careful attention to the overall project timelines.

After the boxes were erected on site they were connected to the Fibre Optic and Copper cables that were installed along the rail corridor and ultimately connected to the line side equipment.

3.5.2 Train Protection and Warning System

As part of the safety case to introduce 160 Km / hr train running, a new system was required that enforced the restrictive signal aspects to the train braking system.

The solution was the provision of the British TPWS (Train Protection Warning System). TPWS is an intermittent warning and enforcement system which is interfaced to traditional signalling systems. Together with the signalling system it provides a warning to train drivers at junctions, sidings and crossing loops to enable them to control the speed of their train, to prevent collisions and over speeding.

The TPWS system measures the speed of trains as they approach a restrictive or stop signal, and in the event that the driver does not adequately control the speed of the train, the TPWS automatically applies the brakes...

The TPWS formed the critical part for the safety case of the signalling system acceptance by the regulator and its application was another first in Australia.

3.5.3 Solid State Interlocking System

The signalling system was based upon the computer based Solid State Interlocking System (SSI), which was installed for the first time in Australia with fibre optic communication links driving the field signalling equipment.

The SSI operates on a triplicated computer system with the ability for each processor to compare its outputs with the other processors and if a difference is detected the system will fail the faulty processor and continue as long as two processors produce the same output.

The software design was carried out in Australia and was subject to a rigorous checking process followed by a full office simulation where each train movement and each operation was tested to ensure that the system installed was both safe and functional.

The use of fibre optic for communication between SSI modules was made possible by the use of Optic Data Link Interface Units (ODLIU) which were designed and manufactured in Australia and provide a direct FO interface between the trackside SSI data link modules and the dark FO cable with no changes required to the SSI system.

Figure 3 ODLIU

The Train Protection and Warning System (TPWS) was integrated into the SSI system both at the hardware interface and at the software data structure level. This was another Australian debut.

3.6 SIGNALLING AND TRAIN CONTROL CHANGES SUMMARY

Werribee to Geelong	Before	After
Control Centres (Signal Boxes)	4	1
LED Signals (colour light type)	Nil	120
Track Circuits	209	234
Motor points	21	51
Automatic Pedestrian Gates	Nil	9
Boom Barrier crossings	10	12
Flashing Light Crossings	Nil	Nil
Route length	40.3km	40.3km

Table 1 Upgrade for the Geelong Corridor

Sunshine to Ballarat	Before	After
Control Centres (Signal Boxes)	3	1
LED Signals (colour light type)	Nil	112
Track Circuits	215	250
Motor points	13	25
Automatic Pedestrian Gates	Nil	9
Boom Barrier crossings	9	32
Flashing Light Crossings	21	18
Route length	105.3Km	100.3Km

Table 2 Upgrade for the Ballarat Corridor

4 BUNGAREE DEVIATION CHALLENGES

The Bungaree Deviation is an 8.2 km section of new rail alignment designed to eliminate a number of small radius curves and low speed track on the existing alignment. TAJV designed the deviation for the maximum permitted speed of 160km/h to achieve the required run time between Sunshine and Ballarat.

The constructed deviation comprises the following:

- 8.2 km in length from Sullivans Road in Millbrook to Torpeys Road in Dunnstown
- 380,000m^3 of cut to fill earthworks
- Construction of 4 road over rail bridges:
  - Sullivans Road (16m span)
  - Spread Eagle Road (12.5m span)
  - Peerewerrh Road (12.5m span)
  - Old Melbourne Road (18.5m span)
- Construction of 2 rail over bridges (amongst the largest rail bridges in Australia)

Moorobool Bridge	
Max height above ground	27m
Length	270m
No of Spans	10
Weight of largest Pier	25t
Weight of Beams (single lift)	62t
Weight of Steelwork in Piers	150t
Amount of in-situ concrete (excluding precast units)	900m^3
Lal Lal Bridge	
Max height above ground	40m
Length	363m
No of Spans	11
Weight of largest Pier	82t
Weight of Beams (dual lift)	76t
Weight of Steelwork in Piers	500t
Amount of in-situ concrete (excluding precast units)	1650m^3

Table 3 Rail Bridges

The new signalling system was designed and constructed for train movements on the deviation (in both directions) and along the existing loop line though Bungaree. The signalling system allows passing movements (with trains travelling in opposite directions) and overtaking movements (with trains travelling in the same direction) without the need to stop either train.

Although the Bungaree Deviation was a green field site and was able to be planned and built away from the frenetic construction activity necessary to achieve the infrastructure upgrades during the main line shut downs, construction of it proved to be one of the most significant challenges for the TAJV team. These issues included:

- Finalisation of the rail alignment to minimise impact on the local farming community where significant opposition to the Project was rife.
- The majority of the works being undertaken during winter in extremely cold and wet conditions.

- Minimise the amount of site works through design and construction methodology.

4.1 INNOVATION IN THE RAIL BRIDGES

The construction of the Moorabool River and Lal Lal Creek bridges on the Bungaree Deviation included many innovative design and construction solutions. The challenge for the design team was to develop an innovative design that would minimise the on-site works and therefore minimise risk for the construction phase of the project. The design and construction methodology included the following objectives:

- Minimise work at heights
- Prefabricate and preassemble as much as possible including access systems
- Assemble as much on the ground as possible
- Use of physical handrails rather than fall arrest systems

The adverse weather conditions expected during the construction period and the difficult site access resulted in detailed planning of the logistics for getting loads into site, the delivery and storage of beams and the sizes of cranes and lifting positions.

Following this detailed evaluation, a number of innovative design solutions were developed.

Foundation and connection design details for piers was targeted to suit the range of geotechnical conditions found during detailed investigations at the two sites.

Moorobool Bridge Foundations
Bored piles that encountered a confined aquifer that required a dewatering solution
Spread footings with rock anchors. The rock anchors were used to resist wind loads, which cause overturning moments
Lal Lal Bridge Foundations
Spread Footings with rock anchors
Driven piles with pre-bored holes
Driven piles
CFA Piles where soft silts above the dense sands would cave in during excavation. Bored piles would have required bentonite or casing to stabilise the ground, which was expensive and environmentally unacceptable because of likely run-off into the creek
Bored piles

Pier to Foundation Connections
Preassembled holding down bolt (HD) cage delivered to site in one piece weighing up to 1 tonne. Each pier base and HD cage a unique size
Locating bolts incorporated in the cage to enable the steel pier to be located easily
Oversized base plate hole used again to ease locating the steel pier
Use of a template to match drill the base plate and anchor plate
Innovative concrete core fill to the bottom 1.5m of the steel pier and to form a plug connection to the pile cap. This eliminated the need for a second internal row of HD bolts for the pier

Table 4 Rail Bridges Design

A breakthrough in the design was the use of wind tower technology for the steel bridge columns.

Steel Columns
Fabricated by Keppel Prince in Portland
Lal Lal piers rolled from 32mm plate with a maximum length of 38m and maximum weight of 82 tonnes. Base diameter up to 4.5m tapering down to standard 1.5m at the top
Moorabool piers rolled from 20 – 25mm plate with a maximum length of 25m and maximum weight of 25 tonnes
All the piers were transported to site in one section including the platforms and access systems to enable piers to be erected straight off the truck

Table 5 Bridge Column Details

Figure 4 Lal Lal Bridge

During construction, the pre-cast concrete crossheads weighing 27 tonne were lifted onto each steel pier with the permanent access platforms installed on the crossheads on the ground prior to final erection.

Three super T pre-cast concrete beams (ranging from 62-76 tonne and 27-33 metres) were laid in parallel to span each gap between the columns. Each beam was fitted out on the ground prior to lifting into final position. The fit out included the installation of ballast walls incorporating permanent hand rails, drainage system and temporary handrails around lifting points. Additional lifting clutches were incorporated to take into account the change in centre of gravity due to the beam fit out.

The use of very large steel columns, precast beams, and crossheads required detailed planning for each lift. Mobile cranes were used for all the lifts and special attention was placed on prepared detailed engineering solutions for all lifts including access roads and the provision of piled support systems and embankment strengthening works for the crane positions.

5 CONCLUSION

One of the keys to the success of the Project was the integrated approached taken to the planning of the major construction tasks. With input from both the signalling and civil disciplines within the joint venture as well as the rail operators, a series of short sequence rail shuts was agreed. This allowed full access to the corridor to achieve record levels of productivity which in turn resulted in the delivery of the Project with the absolute minimum of rail disruptions.

The integration approach also meant that skilled people could be shared across tasks to overcome the issue of the shortage of railway experience personnel. Pre-fabricated signalling locations were built and installed by technicians with no prior railway experience under the supervision of experience staffed. This approach was also used in the field works for the conduit and cabling installations

The signalling and control system was seamlessly integrated with the existing signalling at the corridor boundaries. The signalling and train control system was installed complete with the following innovations;

- Train Protection and Warning System (TPWS) system to enforce train speed
- New FO based Solid State Interlocking (SSI) system enforcing speed proving of all restrictive signal aspects
- An improved real time Train Control System provided whole of corridor visibility at Ballarat, Geelong and Melbourne, including automated signalling controls, fault monitoring and management tools

The design and construction of the Bungaree Deviation and in particular the construction of the major bridges proved to be one of the most significant challenges for the TAJV team. The major risks of working at height, construction through the winter months, remote access and ground conditions, were meticulously planned and designed in detail such that the bridges were delivered safely, on time and below budget. The planning and execution of the bridge construction was described as ‘the most professional observed for such work’ by Client review.
As a legacy the access system incorporated into the design not only enabled a safe system for the bridge erection but also access for maintenance inspection of these remote bridges without the need for expensive access equipment.

The rail infrastructure and rolling stock upgrade allowed the following increase in the number of train services and reduced travel time.

- 91 more services per week for the Ballarat Line
- 38 more services per week for the Geelong Line
- 24 minutes reduction in travel time for the Ballarat Line
- 13 minutes reduction in travel time for the Geelong Line
- 30% patronage increase across both corridors

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PERMISSION

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Figure 5 V/locity train