NEW METRO RAIL
PERTH ‘B’ SERIES ELECTRIC MULTIPLE UNITS

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SUMMARY

In the city of Perth, Western Australia, rail rapid transit forms the core of a public transport system which includes rail, bus and ferry services that are highly integrated to improve the quality of service and meet land use and transport planning objectives.

The Perth urban rail network was recently significantly expanded with the opening of the new Southern Suburbs Railway from Perth to Mandurah on 23 December 2007. In preparation for the opening of the new railway and also to provide additional capacity to respond to growth on the existing Northern Suburbs Railway from Perth to Clarkson a fleet of new Electric Multiple Units (EMUs) was procured. The subject of this paper is the 31 x 3-car ‘B’ Series sets that were supplied to meet this need and which entered service from October 2004.

The topics addressed in the paper are:

1. Introduction;
2. A technical overview of the trains;
3. The benefits obtained from design evolution (as opposed to revolution) from the successful Perth ‘A’ Series EMUs introduced to service from 1992 onwards;
4. An overview of the Design, Build and Maintain (DBM) contract structure adopted and the reasons for its selection;
5. Discussion of the maintenance contract Key Performance Indicators (KPIs);
6. Review of the performance of the trains in passenger service; and
7. Conclusions.

Figure 1 : 'B' Series EMU in Operation on the Clarkson Line

NOTATION

AC	Alternating Current
ATP	Automatic Train Protection
CCTV	Closed Circuit Television
CGI	Computer Generated Image
DBM	Design, Build and Maintain
DMA	Driving Motor car 'A'
DMB	Driving Motor car 'B'
EMU	Electric Multiple Unit
GPS	Global Positioning System
HVAC	Heating, Ventilation and Air Conditioning
IGBT	Insulated Gate Bipolar Transistor
LCD	Liquid Crystal Display
LTI	Lost Time Incident
PTA	Public Transport Authority of Western Australia
TMS	Train Management System

1 INTRODUCTION

In the city of Perth, Western Australia, rail rapid transit forms the core of a public transport system which includes rail, bus and ferry services that are highly integrated to improve the quality of service and meet land use and transport planning objectives.

In this system rail is required to provide high speed and high capacity in key rapid transit corridors. To deliver the high average journey speed required for rapid transit it is necessary to minimise the number of stations. This is facilitated by providing a network of bus feeder services that bring passengers to the rapid transit corridor from surrounding areas.

The effectiveness of this integrated public transport approach was demonstrated by the success of the Northern Suburbs Railway, which opened in the early 1990s. The same underpinning requirements were adopted in the planning for the new Southern Suburbs Railway. Accordingly, it was a requirement that the new trains must have high acceleration and braking rates, as well as a high maximum service speed.

2 TECHNICAL OVERVIEW OF TRAINS

2.1 Supplier

The 'B' series EMUs are the second generation of electric railcar to be used on the Perth urban rail network and were supplied by Downer EDI Rail - Bombardier Transportation Pty Ltd. The railcars were constructed in Maryborough, Queensland.

The original 'A' series electric railcars were supplied in the early 1990s as part of the electrification of the Perth urban rail network. The A series were also supplied by Downer EDI Rail - Bombardier Transportation Pty Ltd from their Maryborough facility (although under a previous business name).

2.2 Unit Configuration

Whilst the A series railcars were formed of 2-car sets the decision was taken that the B series railcars would have a 3-car set configuration (refer Figure 2).

Figure 2 : 3-Car 'B' Series Set at Perth Station

This decision was taken for two reasons, the first being the cost saving from reducing the number of driving cabs, but the second and more important reason was due to the high patronage experienced on the existing Northern Suburbs line and the forecast patronage levels for the new Mandurah line.

These lines carry some 45 % of Perth's urban rail passengers and have outgrown a 2-car set configuration.

Key parameters of the B series railcars are shown in Figure 3.

Line voltage	25 kV
Line frequency	50 Hz
Gauge	1067 mm
Maximum service speed	130 km/h
Bogie centre distance (nominal)	17000 mm
Wheel centres (nominal)	2500 mm
Height of floor above rail (loaded)	1100 mm
Carbody width (at doors)	2910 mm
Passenger compartment door width	1300 mm
Passenger capacity (per 3-car unit)	
Seated	240
Standing	320
Maximum service brake rate	1.12 m/s²
Emergency brake rate	1.35 m/s²

Figure 3: Key Parameters of B Series EMUs

The B series railcars operate in service as both 3-car and 6-car sets with two units coupled together via a Scharfenberg automatic coupler.

2.3 Propulsion and Braking

The B series railcar propulsion system utilises water cooled IGBT propulsion converters and AC traction motors. The system produces a faster acceleration when compared to the A series railcars. The faster acceleration of the B series was needed in order to meet the required trip time to Mandurah.

The tractive effort versus speed curve of the B series vehicles at maximum service weight is shown in Figure 4. The lower curve shows the tractive effort at a line voltage of 19 kV, whilst the upper curve shows the performance for line voltages at and above 21 kV.

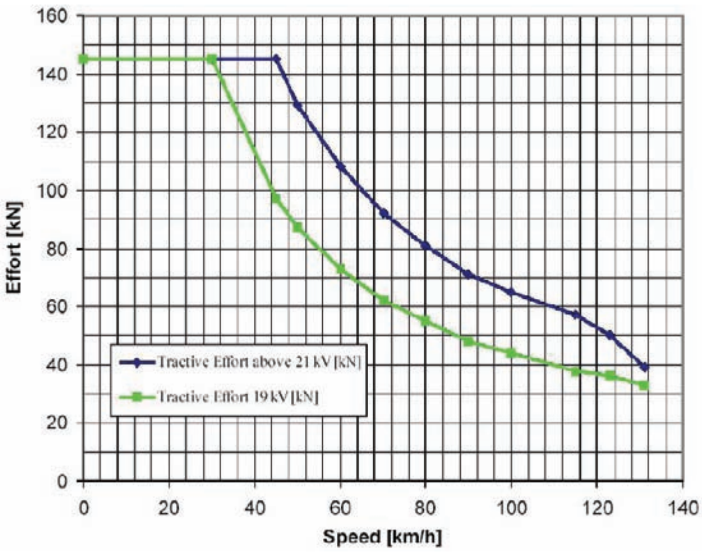


Figure 4 : Tractive Effort Curve

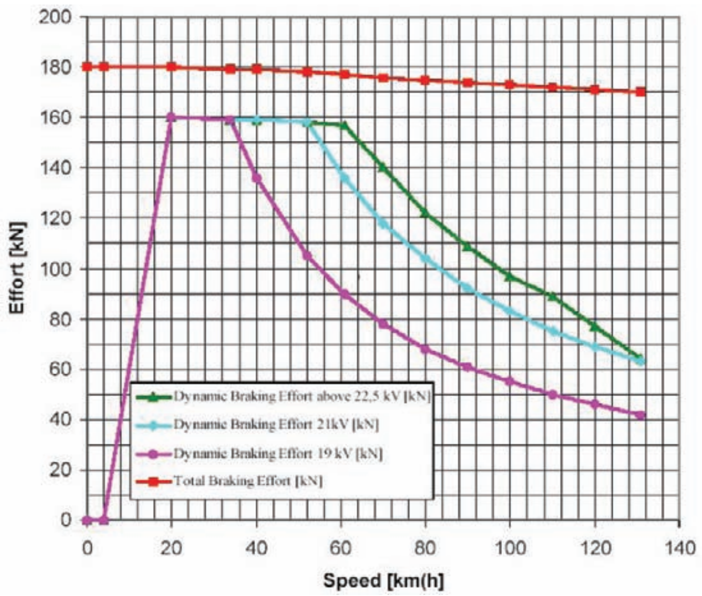


Figure 5 : Braking Effort Curve

The brake is a blended electric and electro-pneumatic type. Utilisation of the electric brake occurs is maximised in order to minimise pad and disc wear. Power generated during electric braking is regenerated back into the overhead system resulting in an estimated saving on power costs of approximately 20 %. The braking effort curve of the railcars at maximum service weight is shown in Figure 5 for a range of line voltage conditions.

The vehicles have a tractive effort versus line voltage characteristic which reduces the power drawn from the overhead line under both low and high line voltage conditions.

Under low line voltage conditions (<21 kV) this ensures sharing of available power between all trains operating in the section and reduces the risk of significant service disruption.

The progressive limiting of power drawn from the line at voltages greater than 27.5 kV serves to protect the railcar propulsion equipment from overload conditions.

In the early days of the B series design process work was done to optimise the power consumed by the railcar in terms of minimising power supply system costs (system installed capacity), whilst maintaining a performance that left the railcars still capable of the required trip time to Mandurah.

In addition to journey time simulations completed by the supplier, the PTA obtained independent assessments of train performance. These assessments were carried out for train masses greater than those initially proposed by the supplier, as it was recognised that the original design mass target was ambitious.

As a result of this work the power vs. line voltage characteristic of the trains was reduced from that shown as the dashed line in Figure 6 to that of the solid line.

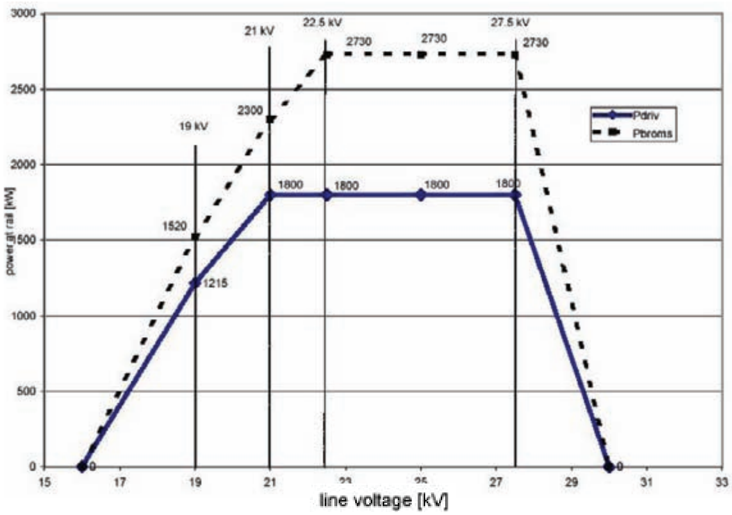


Figure 6 : Tractive Effort versus Line Voltage

The railcars are arranged so that the two motored cars (DMA and DMB) can be controlled independently in the event of a fault. This means the railcars can continue to operate on half power, which gives even a 3-car set a high degree of redundancy. The middle car of each 3-car set is unpowered.

2.4 Interface Compliance

With an electrified rail network a number of interfaces between the rolling stock and infrastructure exist. These include;

- Structural gauge;
- Wheel to rail;
- Signalling compatibility, and
- Overhead interface.

Whilst it is important that all interface elements are considered in detail the supply of the B series railcars was particularity significant in relation to signalling compatibility and structural gauge.

The New MetroRail Project was to be the first time that jointless AC track circuits would be used in Perth. Significant work was therefore completed by the propulsion system supplier Bombardier Transportation Sweden to ensure that the railcar was able to operate properly with such track circuits.

This involved completing detailed modelling to ensure return currents from the railcars would not interfere with the track circuits. After some negotiation, the railcar supplier and the infrastructure designer agreed limits to return current at the particular operating frequencies of the selected track circuit.

In relation to structural gauge with the proposal to construct a bored tunnel under Perth being a major part of the New MetroRail Project it was critical that the railcar structural dimensions and kinematic performance fully complied with the PTA's gauge diagrams.

Detailed design work was completed, with the railcar designers talking directly with infrastructure providers. As a result a high degree of confidence was obtained at an early stage of the design process that no issues of gauge infringement would occur (refer Figure 7).

2.5 Passenger Compartment

The passenger compartment of the B series railcars (Figure 8) is air conditioned, carpeted and utilises upholstered seating. A fully automated message announcement system provides both audible and visual messages to passengers.

The railcars have electric plug type passenger doors and, in an emergency, passengers are able to open the doors via a handle that is located behind a panel that is opened by pressing on a red disc.

The railcars do not have internal doors between the 3 cars so passengers are able to move through the vehicle easily and quickly. The wide openings between cars also serve to enhance passenger security.

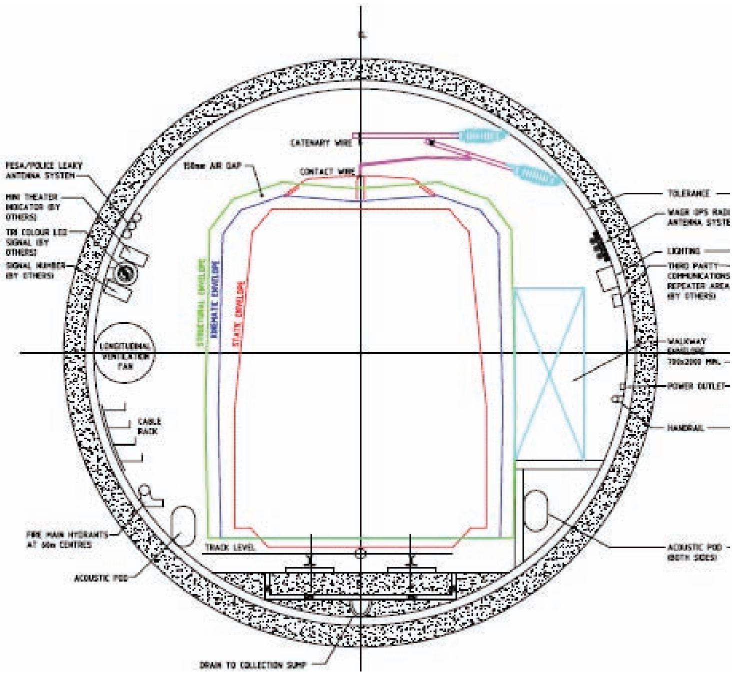


Figure 7 : Clearance in City Tunnel

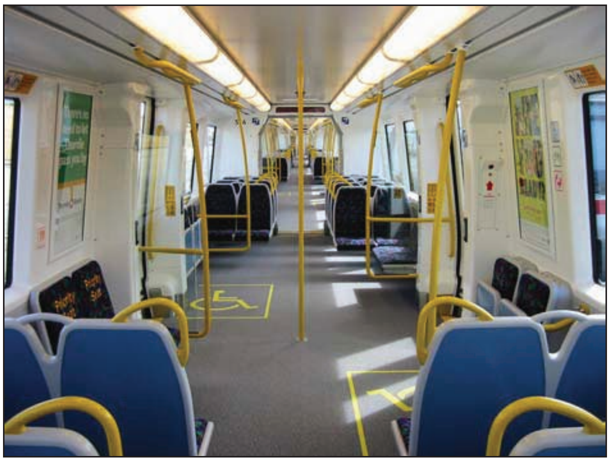


Figure 8 : Passenger Compartment

In order to maximise seating the wheel chair bays also include fold up seats. These seats remain folded up when not in use and in this configuration they intrude less far into the saloon than the adjacent column which houses the plug door mechanism.

Considerable effort was devoted to determining the optimum seating configuration for the trains. Maximising capacity during peak periods is always a key criterion for urban passenger trains and this tends to suggest maximising standing space. PTA had modified the seating on the majority of the A series cars to an all-longitudinal configuration for this reason.

However, for the relatively longer journeys on the Southern Suburbs Railway (72 km from Perth to

Mandurah) survey data indicated a passenger preference for transverse seating.

The selected seating configuration represents a balance of these competing objectives and is shown in Figure 9.

Driving Motor Car

Intermediate Trailer Car

Figure 9 : Seating Layout

However, the railcars have been designed to be modular to allow the PTA to re-configure the seating quickly and easily. All seating which is cantilevered from the wall of the railcar (see Figure 10) is mounted on a rail along the wall, permitting ready conversion of transverse seating to longitudinal seating and vice versa.

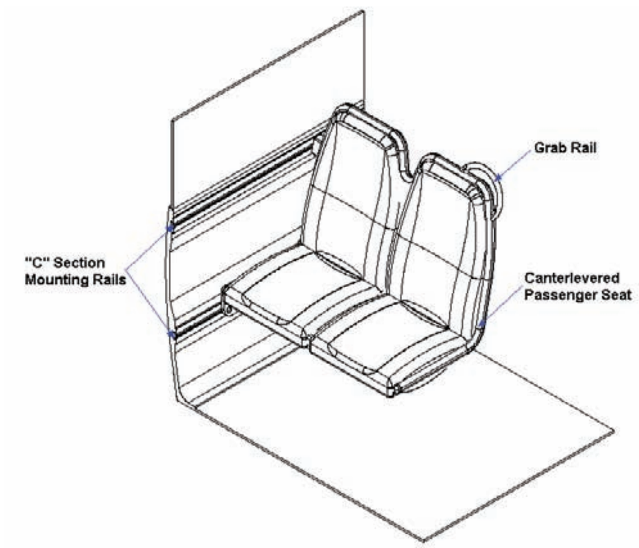


Figure 10 : Seat Mounting

To assist the seating conversion hand rails are mounted from a slot in the ceiling so they also can be easily re-positioned.

To allow easy access for wheel chairs each vestibule (refer Figure 8) has two diagonally opposite wheel chair bays. This ensures compliance with the latest Disability Standards for Accessible Public Transport.

2.6 Ergonomic Cab Design

The railcar cab was designed with the assistance of the PTA's Cab Committee. This committee consisted of trades union and occupational health and safety representatives. Driver's experience and feedback on the layout of the A series railcars played a major part in determining the layout.

A requirement of the contract for the railcars was that an independent ergonomic assessment of the cab design be completed by a third party. This assessment was done by Transport Design International, who worked closely with the PTA's cab committee.

The process of determining the cab layout was commenced by ascertaining which controls should remain in the same position as on the A series. This was important given that the same drivers would be operating both fleets.

Assessment and determination of the cab layout was based upon information gathered during:

- Observation of drivers at work, in order to establish typical work patterns, habits and conditions;
- Review of Downer EDI Rail's 3D virtual model (as shown in Figure 11);
- Examination of 2D drawings derived from the 3D model; and
- Assessment of a cab mock-up.

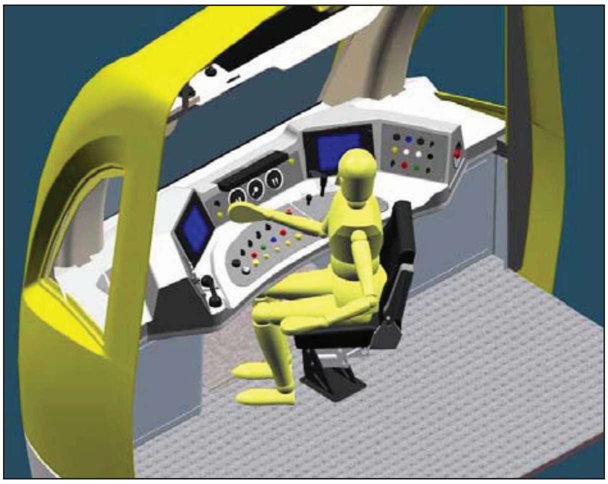


Figure 11 : 3D Virtual Model of Cab Layout

The principle features assessed were:

- Console layout including footwell;
- External lines-of-sight;
- Driver accommodation (cabin);
- External cabin access; and
- Human Machine Interface for Train Management and Communications systems (e.g. LCD screens).

The drivers to be accommodated ranged from the 5th percentile female to the 95th percentile male. The design of the cab was reviewed for consistency with data and recommendations from:

- Australian Standard SAA HB59 (1994);
- Stevenson (1998); and
- Dreyfuss and Associates (1974, 1995).

A cab mock-up (refer Figure 12) was constructed to test and validate the suitability of the design and facilitate final sign-off by he cab committee. Once the final cab layout was agreed the Cab Mock-up was then used as part of the CGI-based Drivers Simulator that also was procured as part of the contract.

Figure 12 : Cab Mock-Up

2.7 Train Management System

The Train Management System on the B Series railcars is the Bombardier Transportation MITRACS system. This is a distributed computer controlled system that is used on railcars in many locations throughout the world.

The MITRACS system is built around a 32-bit microprocessor. The system is mechanically and electrically designed for operation in the temperature range between -40°C and +70°C and to withstand the high levels of shock and vibration experienced in traction applications. The units are self-ventilated and no forced cooling is required. The main microprocessors used in the system are selected from the Motorola 68000 family.

A key component of any train management system is fault indication to drivers. The main screen of the drivers display on the B series is shown in Figure 13. This is displayed on the monitor to the drivers left.

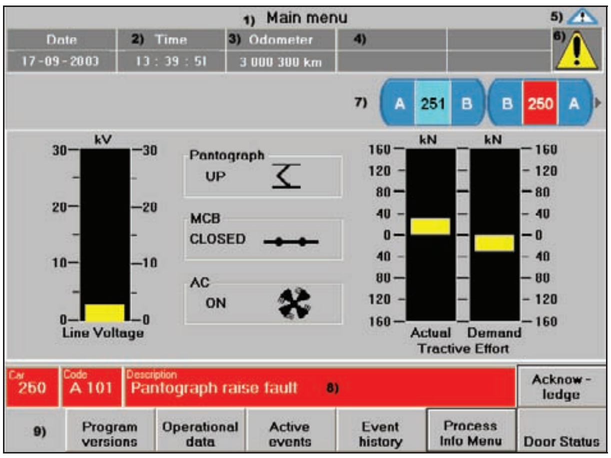


Figure 13 : Train Management System Display

Faults that occur are colour coded in order that the driver can easily assess the status of the vehicle. The colour coding is as follows;

- Red - The vehicle has no tractive power and cannot be moved as a single unit.
- Purple - The vehicle has limited drive time and should be removed from traffic immediately.
- Orange - The vehicle should be removed from traffic as soon as possible.
- Turquoise - The vehicle has a minor problem and can be left in traffic.

The system is based upon a Windows-type environment and presents information to drivers regarding a fault in a clear manner. This assists in minimising recovery time when a fault does occur. An example of the level of information provided to the driver by the system is shown in Figure 14.

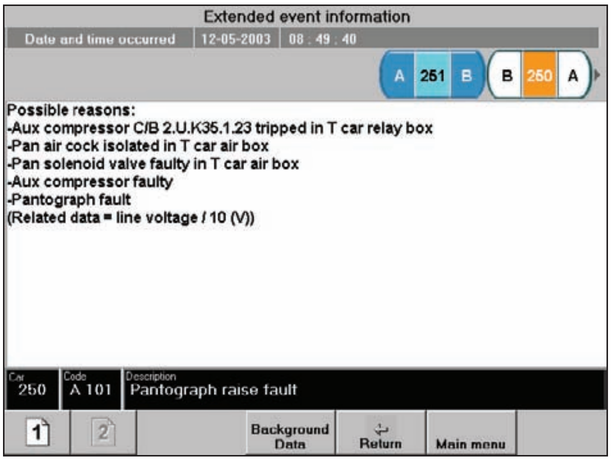


Figure 14 : TMS Fault Information

The MITRACS system also allows for detailed information to be provided to maintenance staff. Key components such as the converters have their own microprocessors that can be interrogated to determine system status.

Detailed monitoring of all train systems is centralised and able to be reviewed on the drivers screen. This ensures that maintenance staff can diagnose and repair a fault quickly. Key systems that are continually monitored by the Train Management System include;

- Propulsion;
- Braking;
- Doors;
- Auxiliaries; and
- Computer input/outputs.

3 DESIGN EVOLUTION

The PTA’s A series railcars have operated since 1990 when electrification of the Perth Urban Rail

Network was completed. The railcars have performed well in service and as such have been a key reason why patronage on the network has increased dramatically.

The PTA’s experience in converting from a non-electrified to an electrified railway in 1990 and in particular the experience in converting from a diesel railcar fleet with an average age of 25 years to a new electric fleet was fundamental when it came to ensuring the successful supply of a new generation of electric railcar.

In hindsight, whilst unavoidable, the radical change from diesels to new electric vehicles caused some issues. As an example, whilst the electric railcars had faster acceleration and higher brake rates the introduction of a modern wheel slide protection system coupled with higher brake rates caused some problems in low adhesion conditions.

When preparing the specification for the B series railcars, Westrail (now the PTA), had the benefit of 10 years of operation of the A series railcars. As such, staff such as drivers and maintenance personnel were consulted to determine what enhancements were required and also to confirm what has worked and therefore should remain similar.

The successful performance of the A series meant that the B series should be an evolution of these vehicles rather than a radical or evolutionary new design. By taking this approach it was felt that the vehicles should provide a high degree of reliability from start of operation. This evolution process was assisted by the fact that the same supplier was involved in both fleets. Their knowledge of the previous design, coupled with the knowledge they obtained during the years of operation of the A series was of benefit.

3.1 Proven Parameters

It was realised at an early stage that certain key parameters between the new B series railcars and the existing A series railcars needed to be the same to minimise the learning curve for drivers and other operational staff. Also, where systems had worked successfully there was a need to maintain them. These parameters included;

- Brake rates;
- Layout and operation of key cab controls;
- General car body dimensions;
- Passenger compartment layout;
- Bogie design;
- Operation of emergency devices such as passenger door releases; and
- Crashworthiness.

Brake Rates – in changing from diesel to electric vehicles the full service brake rate of PTA trains increased significantly from approximately 0.7 m/s² to 1.12 m/s². The emergency brake rate of the A series is 1.35 m/s². The same brake rates were therefore used on the B series. Further, a similar combined power/brake controller was used.

Cab Layout – The PTA driver’s cab committee worked to ensure consistency between fleets. This included commonality of operation of powering, braking and door control commands. Also, it was important that the Automatic Train Protection (ATP) panel and key gauges, such as the speedometer and bogie brake pressures, were maintained in the same location (see Figure 15).

A Series

B Series

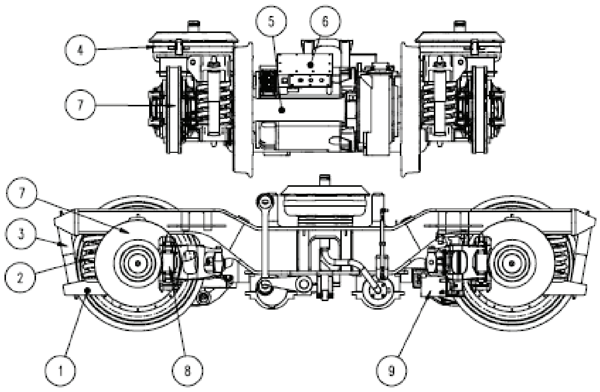
Figure 15 : A Series and B Series Cabs

General Car Body Dimensions – the length of a car, bogie centres and wheel base are very similar between the A and the B series. Also, the two vehicles are almost identical in body shape.

Passenger Compartment – The PTA had worked diligently with representatives of people with disabilities to maximise compliance with the Disability Standards for Accessible Public Transport. Therefore, it was decided that the passenger compartment layout would be based upon the A series layout. The same level of comfort with air conditioning, carpeted floors and upholstered seats was provided on the B series fleet.

Bogie Design – the B series railcars utilise the same basic design of bogie as the A series. Bogie frames are fabricated in an "H" configuration, which allows both ease of fitting of equipment and good maintenance accessibility.

Motor Bogies are fitted to the DMA and DMB cars and each axle of the bogie is driven by a dedicated traction motor. Motor bogie wheel sets are fitted with outboard mounted brake disc rotors and spring applied parking brakes are also fitted to these bogies. A general arrangement of the B series motor bogie is shown in Figure 16.



1	Radial arm	6	Traction motor
2	Primary suspension coil spring	7	Brake disc
3	Primary suspension damper	8	Brake caliper
4	Secondary suspension air bag	9	Brake cylinder
5	Axle		

Figure 16 : B Series Motor Bogie

Trailer bogie wheelsets are fitted with larger, inboard, axle-mounted disc rotors. The primary suspension consists of a swing arm axle box, with a double coil spring arrangement outboard of the axle. The longitudinal and yaw stiffness is provided by the rubber bush in the radial arm pivot. Primary vertical hydraulic dampers are fitted at the ends of the radial arm axle boxes.

The secondary suspension consists of air springs in series with auxiliary rubber springs. These air springs, when inflated, support the body weight and provide the vertical, lateral and rotational freedom between bogie and body.

The traction centre features a "Watts Linkage" with rubber lateral bump stops. Rubber bushes are used at interfaces where significant movement occurs.

Two lateral telescopic dampers are fitted from the traction centre to the bogie frame to control the lateral body motion.

The main differences between A and B series bogies is that the B series traction motors are bogie mounted rather than axle hung and the B series have a softer lateral suspension for improved performance through curves.

Operation of Emergency Devices – fire extinguishers are located in the same place in the drivers cab on both the A and B series. This ensures that PTA staff need only to know one location.

The internal passenger emergency door release is operated by pushing a red plastic disc. Although the door release mechanism differs between the A and B series, both railcars require a similar red disc to be pushed in to access their emergency door release.

Crashworthiness – The PTA has a long history of stipulating a stainless steel body for railcars. A number of collisions over the years have shown that the theoretical performance of the A series in a collision has been proven.

In the early days of A series operation a number of slow-speed collisions occurred due to low adhesion conditions and the car bodies performed well. Hence, when materials of construction and strength requirements were determined for the B series it was decided that these should follow the design of the A series fleet.

Also, from a durability perspective, the PTA's experience with stainless steel car bodies has been a positive one. Vehicles bodies on other vehicle types have lasted well beyond the nominal service life of 30 years. Stainless steel's advantages as a car body material include:

- Corrosion resistance;
- Crashworthiness, due to it's larger elongation to fracture when compared with other materials such as aluminium and carbon steel;
- Ease of graffiti removal;
- Resistance to chemical attack;
- Aesthetic qualities; and
- Low maintenance requirements (e.g. no need to repaint regularly).

3.2 Technology Enhancements

It was recognised that technology had moved on significantly in the fifteen years between procurement of the A and B series railcars. As such areas that were identified as able to benefit from the more modern technology included:

- Propulsion system;
- Braking system;
- Train management system; and
- Passenger information system.

Propulsion System – through the use of AC traction coupled with IGBT converters and power regeneration the B series have utilised the latest technology to ensure a highly efficient train.

Braking System – is a microprocessor controlled system that includes an electric code demand transmission system that is used to control both acceleration and deceleration of the train.

The motor cars are provided with both regenerative electric braking and electro-pneumatic friction brakes, while the trailer cars are equipped with friction brakes only. A blended braking system is incorporated, which gives preference to electric braking at all times. This ensures that brake pad wear is kept to a minimum.

Train Management – through the use of a more modern distributed computer controlled train management system the information provided to both drivers and maintenance personnel greatly assists in fault rectification. A Windows-based interface presents information in a neat and concise manner. An event recorder is also utilised to ensure key data is logged over certain time periods.

Passenger Information – an automatic passenger information system that provides both audible and visual messages to passengers is installed. This system uses both distance measuring and GPS to ensure messages play at correct locations. A digital CCTV system is installed with four cameras per passenger compartment and one front view camera, all recorded to a digital video recorder.

3.3 Major Differences between A & B Series

As a result of the design process and the fact that the B series are a newer railcars there are significant differences between the A and B series railcars. A summary of these differences is provided in Figure 17.

B Series	A Series
3-Car set	2-car set
Max. speed 130 km/h	Max. speed 110 km/h
AC traction	DC traction
2 IGBT converters	1 GTO converter
2 Auxiliary converters	1 Auxiliary converter
1 large HVAC unit per car	2 smaller HVAC units per car
Separate cab air conditioning units	Cab air conditioning from saloon
No passenger saloon end doors	Passenger saloon end doors
All vital circuit breakers above floor level	Some vital circuit breakers below floor level
Passenger doors - electric plug	Passenger doors -air operated sliding
VESDA smoke detection system	No smoke detection System
Pantograph has overreach protection	Pantograph does not have overreach protection

Figure 17 : Major Differences between Fleets

4 DBM CONTRACT STRUCTURE

The B series EMU procurement formed part of the larger New MetroRail project, which also included construction of the new Southern Suburbs railway from Perth to Mandurah, construction of the new Thornlie spur and extension of the Northern Suburbs railway from Currambine to Clarkson.

Initially tenders were sought and received for a Design, Build, Finance and Maintain (DBFM) contract. However, following detailed evaluation it was decided that the cost premium for this structure (versus direct Government funding) was greater than the value of the risk transferred to the supplier.

As a result, the B series procurement was re-tendered as a government funded Design, Build and Maintain (DBM) contract.

4.1 Main Parts of the Contract

The DBM contract was structured in four main parts:

- Supply Agreement;
- Maintenance Agreement;
- Maintenance Facility Construction Agreement; and
- The Umbrella Agreement.

Supply Agreement – this agreement sets out all of the requirements relating to the specification, design, manufacture, testing, delivery, commissioning and handover of the railcars for passenger service. It contains the Performance Specification for the railcars.

Maintenance Agreement – this agreement describes the term and nature of the maintenance and cleaning services to be provided by the supplier. The agreement includes a number of KPIs (discussed further in Section 4 of this paper) and describes the performance regime and penalty payments for poor maintenance and cleaning performance.

Maintenance Facility Construction Agreement – covers the design, construction and commissioning of the new railcar stowage, cleaning and maintenance facility at Nowergup that was built by the supplier as part of the contract.

Umbrella Agreement – this agreement draws together the other agreements as a package, as well as containing certain provisions that were common across all agreements.

4.2 Reasons for adopting a DBM Structure

PTA had experienced considerable inconvenience and delay due to technical and commercial issues surrounding the design of the A series railcars and their suitability for service.

The A series railcars had been procured under a traditional Design and Build (DB) contract and the PTA had found that the warranty provisions under that contract were not always fully effective in addressing their concerns with regard to design and maintenance issues in a timely and cost-effective manner.

The key reason for adopting the DBM structure was therefore to avoid the risk inherent in separating design from maintenance and to incentivise the supplier to address maintainability and whole-of-life performance issues as an integrated part of the design process.

The contract encouraged a whole-of-life approach to the design, parts selection, construction and maintenance of the B series railcars by making the supplier subject to a performance regime under the Maintenance Agreement.

4.3 Maintenance Agreement Term

Considerable debate occurred as to the most suitable term for the Maintenance Agreement. A longer term was seen as providing greater stability and certainty of price, as well as emphasising the need for the supplier to consider all aspects of maintenance and overhaul in the design process.

On the other hand, a shorter term was seen as mitigating PTA's exposure to excessive risk pricing of future uncertainties (particularly with respect to major overhauls, which would not be scheduled to occur for many years after initial handover). A shorter term would also allow PTA to exit from a poorly performing contract more quickly, in the event that the arrangement broke down or failed to perform for some reason.

The final decision was to adopt a 15-year contract term (from the date of award of all contracts, which took place simultaneously in May 2002). However, the contract contains two review periods, which occur at two and five years after the date of acceptance of the last 3-car set, which in practice translates to 6 and 9 years after contract award.

The purpose of the review periods is to provide a mechanism for the PTA to obtain as many of the above benefits as possible.

4.4 Success of the DBM Contract Approach

On the whole, PTA has been satisfied with the performance of the supplier and maintainer under the DBM delivery structure. Management of testing, commissioning and initial service defects was improved relative to the 'A' series contract experience.

The 'B' series fleet did not experience the delays and technical design issues that affected the initial years of the 'A' series fleet.

5 MAINTENANCE CONTRACT KPIs

The maintenance contract KPIs can be divided into three main categories, namely:

- Availability;
- Service disruptions; and
- Cleaning.

5.1 Availability

Availability is measured daily in the morning and afternoon. Target weekday availability is 29 out of 31 sets (94 %), except for nominated 'special event days' on which the PTA can demand up to the full 31 sets to be available. The Maintenance Agreement allows for up to 30 special event days per year, on which up to the full 31 units can be required by PTA to be available for service.

5.2 Service Disruptions

Two primary measures of service disruption are used in measuring the performance of the fleet; Cancellations and Lost Time Incidents (LTIs).

A Cancellation is defined as any of the following:

1. Failure of any Diagram to commence operation from the Diagram starting point;
2. Failure to complete all parts of a Diagram; or
3. Failure to satisfy the specified Train Consist for any Diagram,

where caused by the act, neglect or default of the Contractor.

The target minimum interval between cancellations is 250,000 km per 3-car set, averaged across the whole fleet.

A Lost Time Incident (LTI) means any event caused by the act, neglect or default of the Contractor which results in a Unit being delayed by more than 02:59 minutes on arrival or departure from a Designated Timing Point.

The target minimum interval between LTIs is 62,500 km per 3-car set, averaged across the whole fleet.

Service disruption and other performance data are collected on a daily basis and reported monthly.

The Maintenance Agreement sets out performance incentives, whereby liquidated damages are payable by the maintainer to PTA in the event that performance is below the target levels.

Actual service disruption performance against the targets is discussed and illustrated in Section 5 of this paper.

5.3 Cleaning

Cleaning standards are set out for the internal (cab and passenger saloon) and external cleanliness and presentation of the railcars.

The standards were developed by PTA based on its 10 years of experience in the cleaning and presentation of the 'A' Series railcar fleet. The standards use photographic references to illustrate acceptable presentational outcomes.

Typical cleaning methods from the PTA's experience are identified, but not mandated. This approach allows the maintainer to innovate and improve cleaning performance through the adoption of new products and techniques as and when these become available.

A penalty payment is due for each railcar where the cleaning standards are found not to have been met.

The cleanliness and presentation of the railcars is recorded on a daily basis by the maintainer and is subject to regular and random audit by the PTA. The PTA undertakes monthly customer surveys of many aspects of its service delivery, including the cleanliness and presentation of the railcars. Trends in the survey results are used to review whether cleaning standards are meeting customer expectations.

6 B SERIES PERFORMANCE IN SERVICE

The B series railcars commenced operation on 4 October 2004 with the opening of the extension of the Northern Suburbs rail line to Clarkson. Five 3-car sets had been accepted by this date, as that was the number required to service the extension.

The railcars started operation with some trepidation within the PTA. This was due to the fact that people remembered the start of operation of the A series was delayed for approximately a year due to technical and contractual issues.

This trepidation was unfounded and the operator of the Perth urban rail network, Transperth, found a high degree of reliability from first operation. This good performance was no doubt assisted by the fact that the railcars had been operating on test in both Queensland and Perth for almost a year before they entered service and this allowed for significant debugging to occur.

'B' Series railcar fleet availability has been excellent. Between August 2005 and April 2008 fleet availability was measured 1976 times and the target was met or exceeded on all but 11 of these occasions. This corresponds to the availability target being met 99.4 % of the time.

Also, to alleviate overcrowding problems on the Perth network, 30 of the 31 x 3 car sets available are operating during the AM and PM peak periods. In fact, on many days, all 31 units are available and used in service during the peak.

The fleet also generally meets or exceeds the KPI targets for service disruptions. This is despite the fact that they are completing very high annual kilometres, averaging around 275,000 km/unit/annum since the start of services to Mandurah on the Southern Suburbs line in December 2007.

Actual performance compared to the KPI targets is shown in Figure 18 (cancellations) and Figure 19 (LTIs). In each figure the solid horizontal line represents the KPI target performance level.

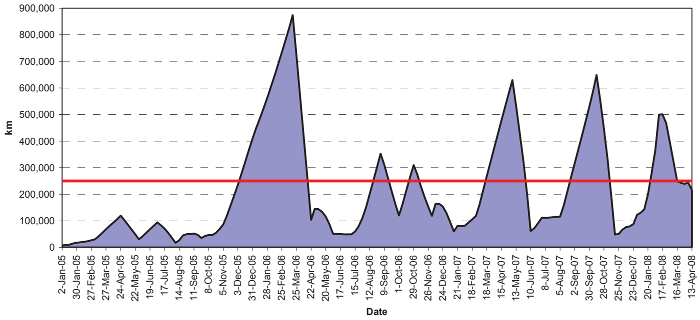


Figure 18 : 4-Week Moving Average km between Cancellations

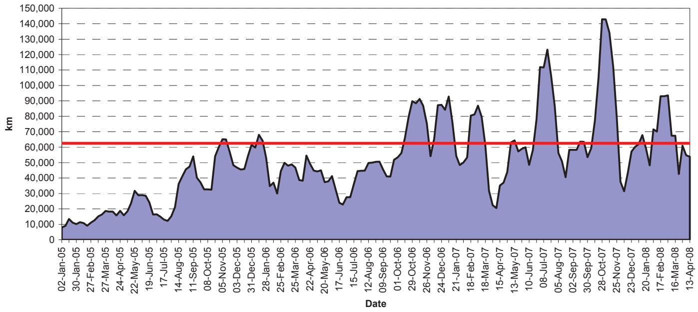


Figure 19 : 4-Week Moving Average km between LTIs

7 CONCLUSIONS

The B series railcars have proved to be highly successful since their introduction to the Perth rail network in 2004. A key factor in this success was the evolutionary nature of the specification, developed as part of the comprehensive Master Plan that was developed, reviewed and approved prior to commencement of the Southern Suburbs railway project and the railcar procurement.

The train design also benefited by being an evolution from the previous successful A series design, whilst integrating a number of important technology advances.

The DBM contract structure has been effective in increasing the exposure of the supplier to financial penalties in the event of poor service performance, incentivising a whole-of-life view of performance during the design process.

The service performance of the fleet also significantly benefited from the fleet being delivered well in advance of the opening of the Mandurah line. This provided the opportunity to gradually introduce cars to service providing extra capacity on the existing network and allowed a 'bedding-in' process to take place before regular squadron service of the new trains was required.

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