# Chapter 12

## Public–Private Partnerships and Implications for a Circular Economy in Australia

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### 1. Introduction

Interest in the concept of public–private partnership (PPP) has intensified in recent decades. Essentially, PPP is an arrangement that brings the public and private sectors together in a long-term partnership for mutual benefit (Zen and Regan, 2014). It is seen as a specialised procurement method employed by a government to deliver public goods and infrastructure service (Ibid). The use of PPP is justified through a range of benefits such as improved focus on service; payment being made only when defined assets or services are delivered; better adherence to delivery schedules and budgets; ability to hold the provider financially accountable for performance; access to the best technical and management skills; improved outcomes through the use of competitive forces to stimulate creativity, pricing, and delivery; and access to infrastructure financing without additional borrowing by a government (Infrastructure Partnerships Australia, 2015).

Another concept that has recently attracted considerable attention is circular economy. The aim of a circular economy is to 'eradicate waste, not just from manufacturing processes, as lean management aspires to do, but systematically, throughout the various life-cycles and uses of products and their components' (Nguyen et al, 2014). It is being visualised as a new economic and business strategy that advocates a move from a take–make–dispose approach to a redesigned future where industrial systems are restorative and regenerative and are designed on closed-loop principles. In such a redesigned system, growth does not take place at the cost of environmental health. Furthermore, this new approach offers considerable potential for innovation, job creation, and sustainable economic development.

* The author acknowledges with gratitude the information and views provided by Mr Brad Johnson and Mr P. Jaishankar, both formerly with Downer EDI Rail (DEDIR). Mr Johnson was the Waratah Trains Project Director for the DEDIR–Hitachi joint venture. Mr Jaishankar was a senior manager in the same project. Their willingness to spare their valuable time to be interviewed is gratefully acknowledged. During the interviews, no confidential or classified information was sought. The focus of the interviews was to obtain their views on the complexities and challenges involved in the delivery of a public–private partnership.

This paper is a preliminary attempt to examine whether circular economy principles can be incorporated into PPP frameworks. Given the fact that many PPPs are large in scope and long-term in nature, the incorporation of these principles can yield substantial benefits to society as a whole. However, the paper confines itself to PPPs in Australia. The rest of this paper is presented in five parts. The next section provides a brief overview of PPPs in Australia, followed by a short section providing a justification for PPPs in Australia. Section 4 then examines PPPs and their implications for a circular economy. This is followed by a fairly detailed presentation of a PPP case study in Australia, namely, the Waratah Train PPP Project, where an attempt has been made to examine to what extent circular economy principles were adopted in the design and delivery of this PPP. The last section provides a discussion that examines whether PPPs have the potential to incorporate circular economy principles into the project structure. It should be noted that the conclusions here are only aimed at stimulating further examination and discussion since these are based only on the findings of one case study.

## 2. Public–Private Partnerships in Australia: An Overview

In recent times, across the world, partnerships between governments and private contractors are being seen as an important feature of what is popularly referred to as 'new public management' (English, 2006). According to Teicher et al. (2006), a PPP, as an element of new public management, is one where 'the government has a business relationship, which is long term, and where private business becomes involved in financing, designing, constructing, owning, or operating public facilities or services.' This implies that PPPs involve private finance and the bundling of design, construction, maintenance, operations, and other services into a single long-term 'whole of life' contract (Clayton Utz, 2013).

Taseka (2008) states that in Australia, the most common types of PPPs are (i) build–own–operate–transfer (BOOT); (ii) build–operate–transfer (BOT); (iii) build–own–operate (BOO); and (iv) design–build–finance–maintain (DBFM). These different types can be subsumed within two types of PPPs: a social infrastructure PPP and an economic infrastructure PPP (Clayton Utz, 2013).

In social infrastructure PPP, the government makes a regular service (or availability payment) which is the primary revenue stream for repaying the private sector for funds used to build a facility such as a school, hospital, prison, and other social (non-income producing) infrastructure. Yet, there have been instances where this model has been used in Australia to deliver economic infrastructure (roads and railways). This model is sometimes called a government-funded PPP (Ibid.). In economic infrastructure PPP, the revenue stream is generated by the users of the facility such as tolls paid by motorists who use a toll road. This is sometimes called a user-funded PPP (Ibid.). However, there are also hybrids and variants of these two models.

An infrastructure PPP formation in Australia generally follows the following sequence (Clayton Utz, 2013).

- The government announces a project.
- Private sector construction contractors, operators, equity investors, debt financiers, and other relevant entities form a consortium to bid for the project.
- The equity investors in the successful consortium establish and take equity interests in a special purpose vehicle (SPV) that enters into the PPP contract with the relevant government agency. The design and construction of the facility is financed from equity and debt finance.
- The PPP contract requires the SPV to design and construct the infrastructure facility, maintain it, and provide others specified services over a specified period that is usually long term.
- If the PPP is government funded, the government pays the SPV a regular payment (monthly, quarterly, etc. as specified in the contract) once the construction is complete. For user-funded PPPs, the SPV can levy charges as agreed.

## 3. Justification for PPPs in Australia

Initially, a common argument for PPPs was that it would avoid public debt. A more compelling rationale now is that PPPs help achieve what is called 'value for money', defined by the New South Wales (NSW) Treasury as 'getting the best possible outcome at the lowest possible price.' It is argued that bundling of services provides consortiums with an incentive to deliver results more efficiently than what the state can because private money is at risk (English, 2006). Obligations such as providing asset-based services over the life of the contract are additional incentives to minimise life cycle costs (Ibid.).

To demonstrate how a PPP will save money compared to a publicly financed alternative, a public sector comparator is used to the net present cost of a hypothetical public provision of the infrastructure and the services. This value is used to compare bids.

Clayton Utz (2013) points out that a study in 2008 across Australia where 25 PPPs were compared to traditionally procured projects showed the following:

- PPPs had an average construction overrun of 4.3 percent compared to 18 percent for traditionally procured projects.
- Average construction delay for PPPs was 1.4 percent compared to 25.9 percent for traditionally procured projects.

Other advantages include (Clayton Utz, 2013):

- More rigorous due diligence and monitoring applied by debt financiers;
- Improved project scoping and risk assessment by government;
- Greater scope for the private sector to bid innovative solutions which can deliver the required services at a lower whole of life cost;
- Better allowance made for operation and maintenance costs;
- Optimal risk transfer; and
- Financial incentives drive timely completion.

## 4. PPPs and Implications for a Circular Economy

In PPPs in Australia, the public sector client normally encourages innovative ideas in the design, construction, technical, and commercial elements provided they are within the context of the key performance indicators (KPIs) specified by the contract. Adequate protection is also provided by clients to intellectual property generated by the private sector partners. However, not all innovative ideas will focus explicitly on circular economy principles.

Javed et al. (2013) provide an example of how, in a railway station redevelopment project in Victoria, the private sector partners were able to innovatively design platforms, escalators, and lifts that could clear a full-load metropolitan train in 90 seconds. They also give an example of how, in a South Australian hospital project, automatic guided vehicles were proposed by the contractor to reduce labour cost for handling materials and meals. However, these innovations are not explicitly linked to circular economy principles since the KPIs were linked to time and labour saving, respectively.

Javed et al. (2013) also provide an example from Queensland where a contractor introduced energy- and water-saving measures for an education project. These included a central energy unit rather than chillers in every building, rainwater storage for irrigating in education facilities, and building design relying on natural lighting. Bougrain (2012) gives an example from France (municipality of Tours) where an energy-saving performance contract was awarded as a PPP to modernise and optimise building automation installations and energy systems. This led to substantial energy savings (12 percent) and a reduction of carbon dioxide emissions (15.5 percent) and a win–win situation for all the parties. Similarly, Twigg (2012) gives an example from Assam, India, where the Guwahati Waste Management Company Private Ltd was set up as a PPP to develop a refuse-derived fuel plant to handle mixed municipal solid waste, to build a compost plant for organic and green waste, and to develop a power plant to generate 6 MW of electricity.

It thus appears that at present, unless a PPP project itself is based on circular economy principles, such as the Guwahati waste management example given above, it is not common for a public sector client of a PPP project to explicitly incorporate circular economy principles into the KPI framework.

## 5. Case Study: The Waratah Train Public–Private Partnership Project in NSW, Australia

To gain insights into the issues and challenges in incorporating circular economy principles in the launching and implementation of a PPP, a case study of a recently completed PPP in Australia – the Waratah Train Public Private Partnership Project in NSW – was undertaken. The PPP was implemented through an SPV called Reliance Rail. The case study focuses on the following:

- Overview of the PPP between Reliance Rail and Sydney Trains;
- An examination of whether circular economy principles were explicitly incorporated in the PPP contract and the KPIs for measuring performance;
- Approaches adopted by Downer EDI and its technical partners as the entity contracted to design, manufacture, and maintain the project assets, to incorporate circular economy principles in the design, manufacture, and maintenance of the Waratah trains;
- Challenges faced by the SPV in incorporating circular economy principles;
- Generic lessons for incorporating circular economy principles in structuring PPPs.

### 5.1. Origins of the Public–Private Partnership

In late 2004, RailCorp (now known as Sydney Trains)[1] called for expressions of interest for the delivery of new rolling stock that included both single-deck and double-deck car sets. In early 2005, RailCorp issued a request for proposals. Around March 2005, RailCorp decided, after more detailed analysis and consultations, that single-deck car sets could not be adequately justified on economic considerations and decided to only go for double-deck sets. In August 2005, a modified request for proposals specified the supply of 72 sets with eight cars each, another six sets of eight cars each as maintenance spares, and two spare carriages, or a total of 626 train carriages.

Bids were submitted to RailCorp by Reliance Rail and Star Transit in August 2005 and in December 2006. Reliance Rail was awarded the contract as a A$3.6-billion privately financed deal to finance, manufacture, and maintain 626 suburban passenger train carriages for

[1] From 1 January 2004 until 30 June 2013, RailCorp provided metropolitan passenger rail services via CityRail and long-distance services via CountryLink. RailCorp Rail Corporation New South Wales (RailCorp), as a statutory authority of the State of New South Wales, was responsible for providing metropolitan passenger rail services through its CityRail branded service and long-distance services through its CountryLink service during the period 1 January 2004–30 June 2013. During this period, RailCorp also provided access to freight operators in the metropolitan area. Subsequent to a restructure of RailCorp, SydneyTrains was established on 1 July 2013 to operate services in the Sydney metropolitan area whereas NSW TrainLink was to operate all other passenger services including those operated by CountryLink.

Sydney's rail network. This Rolling Stock Public Private Partnership between RailCorp (now Sydney Trains) and Reliance Rail is also referred to as the Waratah Trains Project. The government of the State of New South Wales (NSW) named the train 'Waratah' after the State of NSW's floral emblem.

In addition to building 78 car sets and two spare carriages, the contract also had two other important components (Reliance Rail 2015):

- Design, build, and commission the Auburn Maintenance Centre to provide maintenance services for the new Waratah fleet for 30 years. This would include the laying of 12 km of track and design and construction of training simulators to provide training to the crew. The total revenue from this was estimated to be A$240 million (fixed lump sum).

- Provide through-life-support (TLS) for all 78 eight-car sets over a period of 30 years. It was mandatory to provide 72 eight-car sets daily to Sydney Trains for its metropolitan services. The estimated total revenue over 30 years for providing TLS was estimated to be A$2.5 billion.

Essentially, Sydney Trains was to pay Reliance Rail based on the availability of the train sets over the life of the contract. Deductions/bonuses for TLS were to be based on performance.

### 5.2. Delivering the PPP Project

Reliance Rail is an SPV established to deliver the PPP project. It is owned by four entities (Reliance Rail, 2015):

- Downer EDI Limited (49 percent), one of Australasia's largest outsourcing engineering services companies. Downer EDI is an Australian Stock Exchange Top-100 company that operates across the Asia-Pacific region providing comprehensive engineering and infrastructure management services to the public and private transport, energy, communications, and resources sectors. It was founded as Downer & Co. in 1933 in New Zealand and merged with Evan's Deakin Industries in 2011 (Downer, 2015).

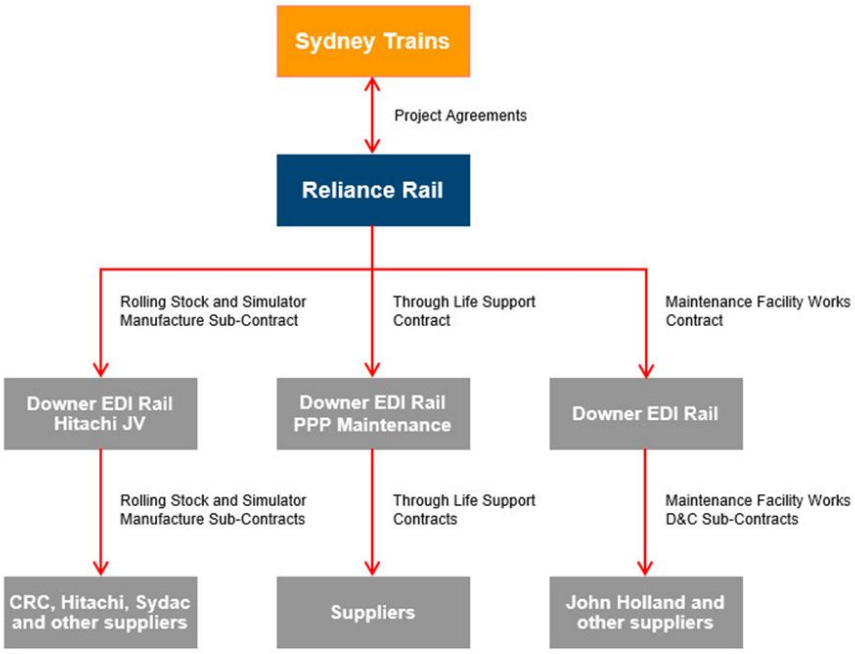
- Interests managed by AMP Capital Investors (25.5 percent), one of the leading specialist investment managers in Australia and New Zealand. It has experience in investing in Australian infrastructure asset class since 1988.

- Royal Bank of Scotland Group plc (12.75 percent), formerly known as ABN-AMRO, a market leader in developing and financing social infrastructure in Australia.

- International Public Partnerships Limited (12.75 percent), formerly known as Babcock & Brown, a United Kingdom–listed PPP/Private Finance Initiative global infrastructure fund and manager of social infrastructure assets. It is managed by Amber Infrastructure Limited which has global experience in the management of social infrastructure assets.

Reliance Rail raised approximately A$2.4 billion in debt and A$137 million in equity financing in December 2006 for the venture. The delivery structure is shown in Figure 12.1.

**Figure 12.1. Delivery Structure for the Rolling Stock PPP**




PPP = public–private partnership.
Source: http://www.reliancerail.com.au/Page/Home.aspx

Reliance Rail's funding model was the lowest cost financing of any PPP in Australia at the time. The funding structure was acknowledged with the PPP deal winning CFO Magazine's Annual Structured Finance Transaction of the Year Award (Reliance Rail, 2015). The cost of equivalent funding has now substantially increased post the global financial crisis of 2008 (Johnson, 2015).

To deliver the project within the given time frame and budget, Reliance Rail entered into subcontracts with many organisations in the Asia-Pacific region and Europe (Reliance Rail, 2015; Johnson, 2015).

The trains have been designed and manufactured under a contract Reliance Rail has with the joint venture between Downer EDI Rail (DEDIR) and Hitachi. Hitachi was responsible for traction and auxiliary power design and manufacture. DEDIR was responsible for the balance of the project scope including establishing and managing a major subcontract with Changchun Railway Vehicles Co in China for manufacturing the stainless-steel body shells and bogies as well as the partial fit-out of the train carriages using components supplied by other subcontractors separately engaged by DEDIR (Johnson, 2015).

The trains were designed in Australia by DEDIR in conjunction with Hitachi to conform to Australian and international standards. Many of the latest technological advances in rolling stock design were also incorporated. The designs were subject to review by Sydney Trains and many comments were generated, a matter that led to some considerable dispute and delay in the project (Johnson, 2015). Changchun Railway Vehicles Co was selected as the manufacturing subcontractor based on its manufacturing facility capacity and its considerable experience in building stainless steel cars for both domestic and international markets. Its manufacturing facilities incorporate advanced technology from France, Germany, and Japan. Changchun Railway Vehicles Co had built trains under joint venture agreements with Alstom, Hitachi, Bombardier, and Siemens.

To ensure that construction and testing were in conformance with the specified design, DEDIR-Hitachi and Sydney Trains had posted relevant personnel in Changchun to provide on-site quality, safety, and project management oversight in addition to audit and governance support.

Other Tier 2 subcontractors in the PPP supply chain responsible for specialist sub-system design and supply included the following (Reliance Rail, 2015; Johnson, 2015):

- Knorr Bremse (the Czech Republic, Austria, and China) for doors and brakes
- Thales (Australia) for train communication network, communications and surveillance, and systems integration designed in Australia and procured from a variety of international commercial off-the-shelf equipment suppliers
- EKE (Finland) for train information system
- Sigma Coach Air Group for heating, ventilation, and air-conditioning (HVAC), designed in Australia and manufactured in China
- Voith (Germany) for couplers
- Hubner (Germany), for gangways
- Fogtec (Germany) for fire detection system
- LPA Niphan (United Kingdom) for LED lighting and jumper cables
- Flachglas (Germany) for glass windows.

Tier 3 suppliers that manufactured components to DEDIR's designs and/or COTS products and commodities included the following:

- BNG/Miryung (Korea), stainless steel
- Huber and Suhner (Switzerland and China), cable and looms
- Smorgon (NSW, Australia), wheels and axles
- RPC (NSW, Australia), glass-fibre reinforced plastic cab structure
- Castech (China), ferrous castings
- BFG Philippines, GRP interior panels
- Luxembourg, composite floorings from composites.

Under the PPP contract, the NSW government had specified a minimum of 20 percent local industry participation. The project exceeded this by involving local partners (see some of the local partners listed above). Furthermore, the PPP supported training and skills development by taking on a fresh apprentice for every nine technical tradespersons.

The final manufacturing of the train, its assembly, and commissioning were carried out at DEDIR's Cardiff facility in Hunter Valley. This included crew cabs, air-conditioning, some traction equipment, and the train's computer and electrical systems. Prior to the final manufacturing and assembly of the Waratah fleet, Downer EDI Rail spent about A$22 million to upgrade its manufacturing, testing, and commissioning facilities at Cardiff.

The manufacturing and assembly activity at Cardiff led to significant economic and social benefits for the Hunter economy. An estimated A$200-million economic boost was delivered to the Hunter economy (Reliance Rail, 2015). Also, about 300 jobs (that included approximately 190 mechanical and electrical technicians and 30 apprentices) were created. In addition, there were peripheral business flow-on effects for the local economy.

As shown in Figure 12.1, Downer EDI Rail PPP Maintenance Pty Ltd, a wholly owned special-purpose subsidiary of Downer EDI Rail, has been established to provide TLS maintenance services for the Waratah train fleet from the Auburn Maintenance Centre, which was built at a cost of A$240 million and commissioned in 2010. The site area extends over nearly 2 kilometres and has the capacity to accommodate 1,000 cars. The facility has an automatic train-wash plant and a tandem underfloor wheel profiling lathe. TLS services provided at the maintenance centre include the stabling of the trains, washing, graffiti removal, vandalism rectification, carrying out scheduled and corrective maintenance, wheel turning, and presenting readiness certified trains in accordance with Sydney Train operation schedules.

### 5.3. Technological Aspects of the PPP

The technological aspects of the Waratah fleet may be divided into two parts: design and manufacture and operations related to TLS. Table 12.1 presents some of the key design and

manufacturing specifications of the train. Figure 12.2 shows the train set. Figure 12.3 shows the Auburn Maintenance Centre.

**Figure 12.2. The Waratah Train Set**

Source: http://www.reliancerail.com.au/Page/Home.aspx

**Figure 12.3. The Auburn Maintenance Centre**

Source: http://www.reliancerail.com.au/Page/Home.aspx

Some of the important design and manufacturing features that enhance the comfort and safety of passengers and the crew include the following (Transport for NSW, 2015; Reliance Rail, 2015):

Technological initiatives for improved comfort

- Smart air-conditioning that can adjust temperatures depending on passenger load and opening and closing of doors at stations.
- Use of durable woollen moquette fabric that provided greater comfort and is also vandal resistant.
- Electronic screens in all carriages to provide information and update passengers on train stopping patterns and arrival at stations.
- Use of LED lighting that saves energy while providing improved lighting.

**Table 12.1. Key Technical Specifications**

| Item | Description |
|---|---|
| Passenger capacity | 896 seats including 16 wheelchair spaces (eight-car set) |
| Train width | 3,035 mm |
| Ceiling height | 2,100 mm end saloons; 1,920 mm upper and lower saloons |
| Maximum speed (acceleration and deceleration) | 130 kph (1 m/sec²) |
| Traction system/motor | Two converters per motor car utilising spread spectrum modulation (four AC motors per car supplied by Hitachi, Japan) |
| Brake system | Regenerative brake with blended electro-pneumatic wheel mounted disc brakes (supplied by Knorr Bremse, Germany) |
| Heating, ventilation, and air-conditioning (HVAC) system | Two independent cooling units per car<br>38 kW cooling, 24 kW heat (supplied by Sigma Coach Air Group, Australia) |
| Body material | Stainless steel |

Source: Extracted from Reliance Rail, Transport for NSW.

Layout for improved accessibility

- Provision of additional handrails, more priority seats, and more wheelchair spaces (16 per eight-carriage train) to facilitate greater disability access.
- Facilitating faster boarding and alighting by having wider entrance areas in the train vestibule so that waiting time at stations can be reduced to enable on-time arrivals and departures.

Safety and security

- Provision of additional passenger emergency help points on the train with direct communication access to the guard
- Provision of internal closed-circuit TV monitoring all areas of the train carriage
- Strengthened carriage design and use of fire resistant materials
- Advanced fire-detection technology
- Use of a walk-through carriage configuration to enable passengers to move away to another carriage in case of an adverse incident in their carriage. This walk-through design permits passengers to walk through the entire train if needed so that faster evacuation is possible.

### 5.4. Circular Economy-Based Innovations in the Reliance Rail Project

As evident from the earlier discussion on the rationale for PPPs, governments enter into a PPP contract based on the tacit assumption that the private sector is capable of providing the service more efficiently than a public sector entity. Innovations in design and operations can lead to greater efficiency. However, based on studies of PPPs, it is pointed out by Rangel and Galende (2010) that innovation is not an intrinsic characteristic of PPP projects although it is an important feature to have. The focus of the public sector client is on KPIs and the private sector partners are free to innovate in the design, construction, technical, and commercial elements provided they are within the context of the performance requirements (KPIs) specified by the contract. However, while KPIs tend to focus heavily on aspects such as time, operations, delivery, safety, and security, they are not explicitly linked to circular economy principles. A review of the contract documents (Transport for NSW, 2015) shows that this is the case for the Waratah Train PPP.

It is of interest that Waratah trains have incorporated several innovations relevant to the promotion of a circular economy. These are described briefly below. The information has been obtained through interviews with Mr Brad Johnson (2015), Mr P. Jaishankar (2015), and information from Reliance Rail (2015) and Transport for NSW (2015).

a) Mass reduction and reusable materials

   Reducing the mass (weight) of the train without compromising safety and critical performance parameters can lead to substantial reductions in the use of energy and simplification in the design of other components of the train. The contract included substantial abatement of revenue to Reliance Rail, and ultimately to the DEDIR–Hitachi joint venture, for exceeding the agreed maximum train mass (Johnson, 2015). During the design stage, Reliance Rail explicitly looked for safe and secure opportunities for weight reduction. For instance, while the body of the train was made of stainless steel for reasons of safety and maintenance, the thickness of the exterior stainless steel was optimised to a thinner panel than on equivalent trains. Many of the panels of the interior were also made of aluminium rather than GRP that provides lightness, durability, and ease of maintenance. Furthermore, the axles of the train were of a hollow design to achieve substantial reduction in weight without compromising safety or performance. Thus, the train was engineered to use less material and the key materials used, while intended to last for the life of the train, are all recyclable.

b) Energy consumption

   The traction system of a train consumes the greatest amount of energy. The Waratah train fleet uses a regenerative (energy recovery) braking system that has the ability to recover energy even at single-digit slow speeds. These considerations were incorporated explicitly into the design and involved the use of advanced simulation systems to study traction and braking patterns across the train network before

finalising the design parameters. The traction system was designed and manufactured by Hitachi of Japan (see Figure 12.1).

The second largest, and almost equivalent to the traction system, area of energy consumption is climate control (heating, ventilation, and air-conditioning) (Johnson, 2015). The Waratah fleet incorporates a three-stage control system that can adjust the load on the HVAC system depending on the number of passengers in the car, opening and closing of doors, and temperature optimisation across zones in the car. The design of the climate control system was done in partnership with Sigma Coach Air Group in Australia.

The third largest area of energy consumption is the lighting system on the train. The Waratah train fleet uses energy-efficient LED lighting (except for headlights) for all internal saloon and cab lights. It is interesting to note that while the initial specifications in the contract did not specify the use of LED lights, Reliance Rail proactively promoted this to save energy and costs of operations as a trade-off against other areas of increased mass and thereby reduce any revenue abatement associated with exceeding the agreed maximum train mass (Johnson, 2015). Thus, the Waratah fleet has the distinction of being the first in the world to use 100-percent LED lighting. All these energy-saving measures while promoting the adoption of circular economy principles also contribute to costs savings especially by reducing power demand and by reducing peak load demand.

c) Improved train allocation and maintenance

The timely arrival of a train and avoidance of breakdowns are all resource saving and lead to conservation of resources (especially energy) and their efficient usage. The Waratah fleet uses a fleet allocation recording system that uses information received from planning, asset management, timetabling, and train tracking systems and delivers information in real time on train movements, allocations, and maintenance alerts thereby enabling better fleet allocation and enabling fleet planning up to a fortnight in advance. This system was designed by Quintiq.

Reliance Rail also explicitly incorporated maintenance aspects at the design stage (design for maintainability) to ensure that the maintenance footprint is as low as possible. Wheels, brakes, and doors are the main areas for regular maintenance while other components and parts are replaced on a predetermined schedule during planned routine and preventive maintenance checks. Maintenance alerts are transmitted to the Auburn Maintenance Centre by the diagnostic software integrated with the various major components of the train such as the traction, braking, HVAC, and doors sub-systems. DEDIR established the specifications for the communications protocols to be used by all sub-systems suppliers in providing fault data in the design stage to enable the integration of the diagnostic software of the major components

to be interrogated by the maintenance management information system established at the Auburn Maintenance Centre (Johnson, 2015).

The proprietary intelligent scheduled maintenance system used by EDI Rail PPP Maintenance Pty Ltd was developed by DEDIR during the design phase (Johnson, 2015). This system has the capacity to program and schedule maintenance services to maximise fleet reliability. The performance data generated by the diagnostic software in the trains are analysed to assess any corrective maintenance that may be needed before a train returns to the Auburn Maintenance Centre. The centre also has state-of-the-art equipment such as an advanced wheel conditioning monitoring system that can monitor and assess the wheels of the train from safety and operational performance perspectives as it enters the wash plant for exterior cleaning. To minimise the time for exterior cleaning, the wash plant has been designed to simultaneously wash the sides and ends of the train.

Thales was responsible for designing the train's extensive system of 98 CCTV cameras, digital video recorders, guard video display units, passenger information displays, emergency intercoms, audio servers, and PA systems and hearing loops, all of which are linked together with power over Ethernet. The various sub-system suppliers were responsible for implementing the agreed software communications protocols within their equipment to enable seamless transmission of maintenance data and fault alarms to the Auburn Maintenance Centre. These information technology-based measures to improve allocation and maintenance have long-term implications not just from operational and revenue perspective but also from an environmental perspective. Improved scheduling and maintenance reduce energy usage and thereby contribute towards environmental protection by generating a lower carbon footprint per passenger-km.

d) Use of long-lasting, ease-of-maintenance, and low smoke-toxicity materials

The flooring of the Waratah fleet uses a polymer-based material (Treadmaster TM8) which is durable and resistant to vandalism and graffiti. Woollen moquette fabric is used to cover the seats of the train. This, too, has been chosen for durability and vandal/graffiti-resistant properties. These materials had to go through many tests to ensure that while they are individually highly fire resistant, with low smoke-toxicity output, they have the same attributes when used in conjunction with adhesives used to affix them to the floor and seats. The seats were designed by DEDIR (for which DEDIR owns the intellectual property rights) to ensure safety in case of a crash by incorporating an inertia-locking mechanism into the roll-over seat. The design of the interior, seats, doors, etc. incorporated the safety measures recommended by the Justice McInerney's Report into the Waterfall rail accident[2].

[2] The Waterfall rail accident occurred on 31 January 2003 near Waterfall, NSW, Australia, where the train derailed as a result of travelling at a speed in excess of 117 km/h as it approached a curve where

### 5.5. Commissioning the Waratah Fleet

The global financial crisis in 2008 slowed down the project's progress. The target dates for the introduction of the first train were set for late 2010. Due to a series of delays, this did not eventuate and the first train was delivered to the operator towards the end of April 2011. RailCorp, as the operator, did not accept the train due to several concerns. Henderson (2011) lists the quality and occupational, health, and safety issues for the rejection of the train as follows:

- Windscreens that turn milky when sunlight strikes them at certain angles
- No padding at the ceiling-mounted guide rope pulleys for the passenger emergency ramp at either end of the train
- Cable shrouding that partly obscures the peripheral vision of the driver
- Train-monitoring computer screen glare and reflection
- Poor quality stainless steel welding seen in the indents of some areas of the carriage exterior
- Gaps in the plastic moulding
- Hand rails not lining up with the stairs
- Software issues.

These issues were traced both to China and Cardiff and after these problems were rectified, the first train set was allowed to commence its run in July 2011 under carefully controlled conditions. In October 2011, this set was allowed to operate during peak hours. More Waratah train sets were then rolled out progressively and in June 2014, the final set was delivered.

On 2 February 2014, the Community of Metros (2014) stated:

> In just over 14 months, 14 eight-car double deck trains (which include 1 spare set) have been introduced into passenger service and accumulated more than a million kilometres in service. Feedback and internal surveys indicate customers rate the Waratah train as the best train for performance and comfort amongst all existing fleet, including other recent fleet acquisitions. Similarly feedback from crew about the Waratah trains has been positive with train performance in line with expectations.

### 5.6. Challenges Faced in Delivering the PPP Project and the Scope for Incorporating Circular Economy Principles

The Waratah PPP project had its share of difficulties during implementation. Redesign and rework to meet the technical requirements of the public sector partner was one area which caused delays in the implementation. Issues with some suppliers in terms of meeting contract

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the safe speed was 60 km/h. The driver of the train had apparently lost consciousness due to heart attack. Seven people aboard, including the train driver, died. The inquiry identified several shortcomings – systemic, technical, design, staff training, etc. The Waratah PPP has incorporated all the recommended measures to promote safety.

specifications also led to delays. Sending DEDIR experts to the various sub-system suppliers helped to expedite some of the work and expeditiously resolve difficulties. With the benefit of hindsight, it was felt that some of these problems and delays could have been minimised or avoided. However, a major challenge is how to explicitly introduce circular economy principles within a PPP framework. A discussion with Johnson (2015), who was extensively involved in this project, brought out some insights that are not commonly found in the literature.

Firstly, the term 'mutual benefit' itself, in respect of partnerships in PPPs, could be open to debate. What is beneficial for one entity (say the private sector) may not necessarily be seen as beneficial by the other entity (the public sector) and vice-versa. This mismatch could come about due to differences in objectives and the different planning horizons of the two entities. For instance, the private partner may want more time to undertake focused efforts to work with its supply chain partners to explicitly introduce circular economy principles and introduce innovations in design and manufacture. However, this may not be acceptable to the public sector partner who may be under pressure to ensure quick delivery due to political compulsions.

Secondly, the priority for private sector investors in the SPV is return on investment and generating a steady revenue stream as quickly as possible. Johnson (2015) refers to this as 'a hard-dollar approach.' The preference is, therefore, for the use of tested and proven approaches in terms of design, manufacture, and maintenance so that the risk of compromising financial returns is minimised. The adoption of circular economy principles, as of now, is still not widespread and thus their incorporation requires innovation across the supply chain. This is seen as inherently risky. Thus, no overt support is extended by the investors for incorporating circular economy principles unless it can be clearly demonstrated that it can lead to cost reduction and enhanced revenue streams or it is specified at the outset as contract deliverables and any perceived risk profile is appropriately priced by the debt and equity investors in the SPV (Johnson, 2015).

In the case of the Waratah PPP project, the SPV created two main entities to implement the project: the delivery structure and the maintenance structure. The delivery structure team was responsible for the design, manufacture, and final delivery of the 78 sets to RailCorp (Sydney Trains). The maintenance structure team is responsible for providing life-cycle maintenance and support to the fleet through the Auburn Maintenance Centre. While both entities operated as core contractors to the SPV, misalignment of the overall objectives of the two entities led to difficulties. The performance assessment of the delivery structure team was based on timely delivery and on keeping design and manufacturing costs as low as possible. This led to differences of opinion with the maintenance structure team who wanted the design and manufacturing to be such that operating costs would be as low as possible since they would be assessed on how much surplus they generate during the provision of life-time support. For instance, wheels, brakes, and doors are the main areas for regular maintenance and thus the maintenance structure team exerted pressure on the delivery structure team to design and manufacture these sub-systems so that life-time support costs would be low. In

some instances, this led to increases in design and manufacturing costs thereby creating anxiety within the delivery structure team with respect to their performance assessment. While the creation of two such entities by the SPV for the implementation of the project would seem rational in terms of meeting project objectives, unless performance assessment of the managers and staff of the staff are based on a life-time and holistic view, such internal conflicts can delay and disrupt project delivery.

Fourthly, a project of this magnitude would inevitably involve many suppliers. While the delivery structure of the project could incorporate circular economy principles in the designs developed by DEDIR, it would be difficult to ensure this when its suppliers are responsible for designing and manufacturing specific modules and systems at which they are regarded as the most capable. It would, of course, be advantageous if these suppliers are already incorporating circular economy principles in their design or that these principles were incorporated into the subcontract requirements. Today, many leading engineering and manufacturing firms in the world have adopted 'green approaches' such as waste reduction (through lean approaches), the 3R (reduce–reuse–recycle), design for manufacturability, design for maintenance, reverse logistics, etc. However, it is not evident whether all of them explicitly incorporate circular economy principles although the adoption of green approaches could be regarded as an early stage of incorporating circular economy principles. Thus, in a PPP project such as the Waratah project, unless compliance with circular economy principles is regarded as an essential criterion for supplier selection, it would be difficult to align it with circular economy principles.

Lastly, while the term 'PPP' is used quite extensively, the term 'partnership' itself is quite ambiguous. One would expect the term to refer to a collaborative and cooperative approach. However, Johnson (2015) refers to it as a master–servant relationship where the public sector partner derives tremendous power due to government backing and uses this to demand and obtain what they see as important and reasonable outcome whether explicitly specified or not. The public sector entity places great emphasis on contract compliance and timely completion and becomes wary if innovative approaches are proposed. While it appreciates the value that can result due to successful innovations, it also sees innovation as inherently risky which can lead to delays in delivery. There is thus a tendency to reject suggestions that it does not regard as tested and proven. Since the use of circular economy principles is of recent origin, the private sector partner may lack the leverage to convince the public sector partner of the need to be given an opportunity to be innovative through the adoption of these principles.

## 6. Discussion

The paper is based on the premise that an economic system that is regenerative by design and is based on circular economy principles that conserve and restore materials and energy and protects environmental health is a pragmatic way forward in today's complex global setting. There is evidence that individual firms across the world, especially in more advanced

economies, have already adopted 'green approaches' to accelerate the move towards a circular economy.

Over the past 2 decades, the use of PPPs to implement economic infrastructure and social infrastructure projects has increased quite dramatically across the world and many claims are made as to the inherent benefits of PPPs. Common benefits as discussed earlier include lower project costs, faster delivery, development of innovative solutions by the private sector, and higher quality of the delivered end product. The main objective of this paper was to carry out a preliminary examination of whether PPPs have the potential to incorporate circular economy principles into the project structure.

A preliminary study of the literature suggests that, in Australia, applying circular economy principles seems to be an exception rather than the norm with the focus being on cost, time, and delivery. This emphasis could act as a barrier for developing innovative solutions based on circular economy principles. A further barrier is that if variations to the contract are proposed after financial close, there could be substantial cost and time implications due to renegotiating the myriad of agreements required to support the PPP framework. To explore this issue in more detail, the Waratah Train PPP project in NSW, Australia, was examined as a case study. The case study is described in detail in section 5 of this paper. Some useful insights based on both published literature and the Waratah PPP case study, discussed in section 5, are summarised below.

***Contributions towards a circular economy***

The Waratah PPP, through the initiatives of the private sector partner in seeking to minimise whole-of-life costs, has taken measures to control the use of materials, reduce energy consumption, and protect the environment. These are explained in more detail in section 5.4. The major contributions are:

- Mass reduction and the use of reusable materials in the design and manufacture of the train sets

- Explicit incorporation of energy-saving designs and innovations to reduce the energy consumed in traction (through the use of a regenerative braking system); heating, ventilation, and air-conditioning (through the use of a three-stage control system); and lighting (through the use of LED lighting)

- Improved train allocation and maintenance through the use of information technology-based interventions (FARS, sub-system diagnostic software, intelligent scheduled maintenance system), an innovative advanced wheel conditioning monitoring system

- Use of long-lasting, easily maintained, and low smoke-toxicity materials.

***Challenges faced in explicitly incorporating innovations based on circular economy principles***

- A mismatch in the objectives of the public sector client and private sector partners due to differences in objectives and the different planning horizons of the two entities can act as a barrier. Suggestions made by the private sector partner to introduce circular economy principles–based innovations in the design and manufacture may not be acceptable to the public sector partner who may fear that 'uncertain' outcomes due to such innovative work may jeopardise compliance, delivery, and cost targets. The power asymmetry between the public sector client and the private sector partner, with the government-backed public sector partner having more leverage, aggravates the situation unless circular economy principles are incorporated into the initial fabric of the procurement for the project by the public sector.

- The private sector investors in the SPV whose priority is a good return on investment and the generation of a steady revenue stream may adopt a 'hard-dollar approach' and may not extend overt support for design and manufacturing innovations unless it can be clearly demonstrated that it can lead to cost reduction and enhanced revenue streams or is a matter of absolute contract compliance.

- Conflicting objectives and non-alignment within the entities of the SPV can also act a barrier to the introduction of circular economy principle-based innovations. In the case of the Waratah PPP project, the delivery structure and the maintenance structure within the SPV had conflicting objectives due to performance assessment approaches that were based more on short-term measures in case of the delivery structure and on life-time and holistic view perspectives in the case of the maintenance structure.

- The involvement of multiple suppliers of components and systems and the use of manufacturing subcontractors can make it difficult to incorporate circular economy principle-based innovations unless many of them incorporate circular economy principles in their own organisations. Thus, in a PPP project such as the Waratah project, unless the use of circular economy principles is regarded as an essential criterion for supplier selection and compliance, it would be difficult to align it with circular economy principles.

Thus, the question of whether circular economy principles can be incorporated into a PPP needs to be linked with the scope that exists for innovation within a PPP framework. Rangel and Galende (2010) and Leringer (2006) examined this aspect in their study of economic infrastructure PPPs. Two aspects based on their studies are relevant. These are design freedom (Leringer, 2006) and penalties and bonuses (Rangel and Galende, 2010).

***Design freedom (Leringer, 2006)***

One of the arguments used to justify PPPs is that while the public sector client may specify requirements through outputs specifications and service-level agreements, the private sector partner has the freedom to interpret the technical specifications without being guided and impeded by past practices, standards, and norms, thereby facilitating the development of innovative approaches to deliver the project. If this is the case, then the private sector partner could have the 'design freedom' to incorporate circular economy principles in the design and delivery of the project.

However, Leringer (2006) and Johnson (2015) point out that, in general, confusion arises because the private sector partner may assume a degree of freedom that may not be seen as acceptable by the public sector partner and other regulatory bodies. The major issue here is that the output delivered through a PPP has to match the public sector expectations which may not have been comprehensively specified and also converge with other related existing infrastructure of the public sector client, and has to be approved by national regulating bodies. Thus, even though design freedom is spoken of as an advantage of a PPP, in reality, the uncertainty that can arise as a result of exercising design freedom acts as a deterrent to the private sector partner to engage in innovation.

***Penalties and bonuses (Rangel and Galende, 2010)***

Penalties and bonuses in a PPP are linked to the private sector partner meeting specified performance and quality requirements. A high level of delivery, in accordance with the established KPIs, leads to improvements which can be transferred to users and some of the benefits can be shared with the private sector partner as a bonus. On the other hand, failure to fulfil specified performance and quality requirements can lead to penalties and even cancellation of the contract.

Rangel and Galende (2010) state that to avoid penalties and take advantage of bonuses, a private sector partner is likely to engage in some research and development (R&D) to ensure that they are able to meet the specified performance and quality requirements. The innovations generated through such R&D are likely to be incremental and not radical (major) since the latter could, in the case of failure, lead to the non-achievement of expected outcomes thereby attracting a penalty.

Johnson (2015) also states that the private sector is often ill-equipped or under-prepared to deal with commercial implications that may arise in these large and complex PPP transactions where relatively small margins are achieved through competitive process but the risks of failure to perform adequately are heavily penalised.

The Waratah case illustrates fairly well the behaviour of the private sector partner in the context of design freedom and penalties and bonuses. The design freedom aspect presented by Leringer (2006) provides a possible explanation as to why the adoption of circular economy

principles in the design and manufacture was restrictive. Many of the innovations introduced in the Waratah PPP project were either based on well-understood and known technologies or were incremental in nature. Radical innovations that incorporate circular economy principles were not evident. This is supported by the explanation of Rangel and Galende (2010) in the context of penalties and bonuses.

It may, therefore, not be incorrect to state that at the current stage of practice with respect to PPPs, incorporating circular economy principles into the project framework while desirable will not be easy because of the various challenges that have been elaborated in this paper. Unless circular economy principles are specified at the request-for-bid stage and included explicitly in the KPIs, it may be difficult to get the private sector partners to engage in circular thinking and propose innovative solutions.

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