MOVING PEOPLE

› From Workhorse to Thoroughbred

Review of bus rapid transit and branded bus service performance in Australia and future opportunities

Bus and Coach Industry

Policy Paper 12

BIC
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Review of bus rapid transit and branded bus service performance in Australia and future opportunities

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Executive Summary

Bus rapid transit (BRT) on dedicated right-of-way and branded bus services (BBS) with a distinct visual identity have been implemented in various forms around Australia over the past three decades. A major public policy debate has surrounded the relative success of these bus priority and branding measures as compared with generic route services in attracting patronage. In this report, we develop a metric known as a (gross) performance ratio to quantify the success for each of 7 BRT and 20 BBS systems as compared with regular route buses across six Australian capitals. We identify the distinctive locational characteristics of various bus priority and brand identity initiatives as a way of controlling for influences that are not under the control of the offered services, so that we can meaningfully compare the various systems, giving a net performance ratio. This allows an informed comparison between systems and cities, controlling for operating environment and other service characteristics.

The results reinforce the merits of upgraded bus services both as standalone initiatives and also as an alternative to expensive, rail-based infrastructure investment. Specifically, we point to four key findings of policy relevance:

- Australia has had some success with BRT and BBS, but in general, states and territories have not fully committed to nor funded in most instances these services to form the core of the transport network and thereby deliver the best patronage results.
- The analysis of different BRT and BBS systems show that service productivity is higher than standard route services and that this could be improved through a variety of hard and soft factors including greater bus priority, turn-up-and-go frequency, increased service span, and the provision of real time passenger information.
- Passenger boardings on BRT and BBS increases with the frequency of services and service kilometres (as quantity measures) and BRT/BRT boardings can be higher than light and heavy rail at a fraction of the cost for the equivalent service characteristics between rail and bus.
- Australian BBS have had varying success but there is real room for expansion through simple and long-term consistency in marketing, common livery, network simplicity and customer information.

We conclude this report with a discussion of future technologies which are fusing bus and rail characteristics (specifically the notion of ‘trackless trams’), as well as best practice from abroad in terms of network legibility and brand identity—all helping upgrade the image of the bus from workhorse to thoroughbred. We conclude with findings and recommendations.

Foreword

This research Policy Paper (12) is part of a policy series of publications aimed at decision and policy makers, academics and students. The Policy Series focuses on land transport, land use, integrated planning and urban development challenges in Australia.

The Bus Industry Confederation (BIC) has commissioned the Institute of Transport and Logistics Studies (ITLS) at the University of Sydney Business School to undertake a review of bus rapid transit (BRT) in Australia. Given the limited implementation of fully-fledged BRT schemes to date, our scope was extended to encompass a range of upgraded bus services, commonly referred to as BRT-lite, branded bus services (BBS) or buses with a higher level of service. Whilst BRT is typically defined by its right-of-way quality, BBS is distinguished by its brand identity within the broader network structure, often operated with a dedicated fleet, and usually complemented with some level of bus priority consistent with its premium brand. Both constitute high frequency, trunk services which serve primarily a mass transit (patronage) than a social service (coverage) function. We consider both BRT and BBS in this study.

ITLS presents this report with a view to inform industry and government on the merits of upgraded bus services. We begin by revisiting what is a common story around Australia (and indeed across developed economies) in terms of the difficulty in getting community and political traction for bus-based initiatives as compared with rail. We then review the operating characteristics of present BRT and BBS systems around Australia and evaluate their success by determining the performance proposition of these premium services in contrast to generic route services. A sophisticated methodology to test for and control relevant operating environment factors is described, to allow for an informed comparison between systems and cities. We conclude by exploring emerging bus technologies and branding experience from abroad in the context of future development opportunities for bus services in Australian cities, as well as summarising key findings and recommendations.

Acknowledgements

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1. The BRT debate: What happened?

The humble bus is often criticised. The underappreciated workhorse carries more people than trains even in cities with extensive rail systems (e.g., London), yet the age-old adage that buses are boring and trains are sexy holds stronger than ever. This belief resonates in Australian capitals despite buses accounting for the bulk of the passenger transport task from their sheer spatial availability, especially for shorter journeys in the inner city and as first/last mile services to rail in middle and outer suburbs (Wong and Hensher, 2019). As a result, the importance of bus dominates rail in passenger trip terms, and in the view of the authors, this is rarely appreciated by the community nor public policy makers. Despite this fundamental patronage/fact for buses as compared to rail, and the greater cost, rail has been the preferred modal choice for Australian governments at state and federal levels for decades. The well-documented saga that is **choice versus blind commitment** (Hensher, 1999, Hensher and Waters, 1994) continues to manifest itself around Australia, most recently in Canberra (Capital Metro), the Gold Coast (G:Link) and Sydney (CBD and South East Light Rail, and the proposed Parramatta LRT). It is often the case in the view of the authors, that these project decisions were based on questionable wider economic benefit calculations (Stanley and Wong 2016, Hensher et al. 2019) to justify these rail-based rapid transit projects in the absence of an agreed rapid transit project assessment tool such as the Australian Rapid Transit Assessment Guidelines (ARTAG) recommended in the Bus Industry Confederation's Rapid Transit report (BIC, 2014) prepared for Infrastructure Australia. In an ideal world, we as a community ought to consider a transport problem objectively and then select the most appropriate transport mode to meet that challenge. This is a rational but often unpopular approach given that bus rapid transit (BRT often being most cost effective) simply does not typically resonate with the community nor carry the same political benefits as rail. This is often the result of the public's existing experiences and biases on buses and trains (Hensher et al., 2019a). Indeed, bus services are conventionally perceived to be slow, polluting and unreliable (with poor service frequencies and ride quality) as there has been a constant failure to argue that service quality is a result of right-of-way (i.e., linked to congestion-induced travel time delay) and not traction technology (rubber versus steel wheels). It is therefore difficult for the public to imagine a bus-based service offering (BRT) which carries over many of the characteristics intrinsic to rail (although the recent interest in 'trackless trams' is encouraging). As we look around Australia on the BRT/LRT debate, it is an unfortunate reality that this battle might already be lost. Brisbane has traditionally been the sole exception, but time will tell if Perth joins this bandwagon. In the meantime, what are our alternatives?

Over the past two decades, BRT-lite or branded bus services (BBS) have emerged as a cost-effective reform to improve the bus network. There is growing interest around Australia in these schemes with a dedicated brand identity (fleet, stops, marketing, etc.), coupled with some level of bus priority and operating on estimated wait times (at least from the customer perspective) as opposed to traditional timetables and schedules. Often, they are developed and implemented together with wider network rationalisation, simplifying route structures and stopping patterns and consolidating services onto high frequency trunk corridors.

Interestingly, BBS is not usually delivered in the context of a bus versus rail debate, but rather in a politically-motivated environment to deliver better bus services at a fraction of the cost base—and to do so quickly.

In presenting the case for BBS, the authors are not condoning BRT creep.[1] Many other studies have confounded the BRT/BBS distinction which is problematic—e.g., Currie and Delbosc (2010) which includes Melbourne's BBS SmartBus amongst BRT initiatives, itself accounting for 174% of the 200% quantified increase in Australasian BRT route length (2006-10) to which the study refers. It is therefore important to note our use of terminology: **BBS is not BRT.** Whilst a distinct brand identity is an important element of quality BRT systems (ITDP, 2014), the essential characteristic of BRT remains its dedicated right-of-way and off-vehicle fare collection which delivers travel time benefits and operational efficiencies. The few BRT schemes in Australia (Brisbane being the sole system recognised by ITDP[2] and ranked silver—see Li and Hensher (2019)) rate poorly on brand identity, which together with service simplification constitute two of the most cost effective ways to grow bus patronage (Currie and Wallis, 2008). BBS (which by contrast usually enjoys more limited bus priority in Australia) enters the fray as a package of measures to change perceptions and the image of the bus (Devney, 2011). The rationale for BBS is that its distinct brand identity attracts patronage by making the bus network more legible and easier to navigate. Further, reforms usually follow best practices in network design, including a more appropriate mix of patronage versus coverage-oriented services (Walker, 2008, Nielsen et al., 2005), refined stop spacing and positioning, and adding cross-town orbitals to create a more 'gridded' network (thereby enhancing connectivity) as opposed to the traditional focus on radial routes in and out of the CBD. Our evaluation of BBS within this BRT/BBS review will encompass this broad suite of policy initiatives, whilst continuing to treat BBS separately to BRT.

1 BRT creep describes how the right-of-way requirements for strict BRT has gradually been disregarded (often with the intention to mislead), and results in misunderstanding within the community of what constitutes BRT.

2 The Institute for Transportation and Development Policy (ITDP) is a non-profit which has developed *The BRT Standard* to score systems around the world.

2. An overview of BRT and BBS in Australia

The aim of this report is to evaluate the performance of BRT and BBS schemes in Australia, relative to generic route services in their respective six capital cities. Studied systems are summarised in Table 1, and scored according to their BBS (fleet deployed and brand identity) and BRT bus priority characteristics. The authors have excluded services operating outside the standard contractual framework such as airport shuttles and tourist products. The first characteristic refers to whether a system is operated using a **dedicated fleet.** This allows for more specialised fleet characteristics including dedicated liveries and vehicle type (e.g., double-decker buses), but also reduces operational flexibility, resulting in increased vehicle and driver requirements. **Brand identity** refers to the prominence of a service against the broader network structure—*none*, where the service is unnamed (in contrast to the *infrastructure* name which often still exists); *weak* means that whilst the brand exists, it is not applied prominently nor consistently across customer-facing material; for *medium*, the brand is recognised consistently in timetables, network maps, bus stops and on the bus destination; and finally, *strong* signals a prominent branding applied across all mediums plus a fleet operated in dedicated livery. **Bus priority** can refer to a dedicated carriageway separated by a physical median or a dedicated lane with the potential for traffic conflicts (usually kerbside). The three levels refer to the proportion of the service granted each quality of bus priority. Signal priority in the form of induction-loop queue jumps and transponder-activated signals is captured within this characteristic.

As noted, premium bus services in Australia score highly either on brand identity or bus priority—but never both! This is peculiar and very much unlike implementation in other parts of the world, and certainly contravenes the BRT best practices espoused in ITDP (2014). However, we do note the tendency for branding elements not to accompany developed-world BRT implementation (especially in the US)—an example of BRT creep, but also the different institutional contexts at play.[3] As such, all upgraded bus services in Australia can be categorised as either BRT or BBS—and can be considered mutually exclusive. In the following sections, a comprehensive overview of the BRT and BBS systems in each of six Australian capitals is offered, with a particular focus on system-specific challenges and constraints.

Table 1: BRT (green) and BBS (blue) schemes evaluated, scored according to their service characteristics

City	Service	Fleet deployed	Brand identity	Bus priority
Sydney	T-way (Liverpool-Parramatta)	Mixed	None	Medium
	T-way (North-West)	Mixed	None	High
	M2 Busway	Mixed	None	Medium
	Metrobus (Phase 1)	Mixed/Dedicated	Medium	Low
	Metrobus (Phase 2)	Mixed/Dedicated	Medium	None
	B-Line	Dedicated	Strong	Low
Melbourne	SmartBus (Original)	Mixed/Dedicated	Strong	None
	SmartBus (DART)	Mixed/Dedicated	Strong	Low
Brisbane	Bus Upgrade Zone (BUZ)[4]	Mixed	Weak	High
	CityGlider	Dedicated	Strong	None
	Great Circle Line	Mixed	Weak	None
Perth	Central Area Transit (CAT)	Dedicated	Strong	None
	CircleRoute	Mixed	Weak	None
	Transperth 950	Mixed	Weak	Low
Adelaide	O-Bahn	Mixed[5]	Weak	High
Canberra	Rapid	Mixed	Weak	Low

3 In developing economies (Africa and South America), BRT often results from the formalisation of the informal minibus taxi sector, and hence is almost always set up as an independent company (and brand) from the outset. There are accompanying advantages and disadvantages to this model.

4 There is no system name for Brisbane's busway infrastructure, but the high-frequency BUZ network is closely aligned. All BUZ services use at least the CBD component of the busway (Cultural Centre to Roma St), and most use the majority of the entire busway corridor. TransLink routes 66 and 111 are dedicated busway-only trunk services which will be analysed separately as part of this research.

5 There is a dedicated O-Bahn fleet for maintenance and operational purposes, but no customer-facing brand elements.

3. Sydney

3.2 Liverpool-Parramatta transitway

Announced in 1998 and commencing service in February 2003, the Liverpool-Parramatta T-way was the first fully-fledged BRT in NSW and originally envisaged as the initial stage for a broader network of transitways across Western Sydney. The service links a series of intermediate destinations, including two TAFE colleges, a hospital, large shopping centres at Bonnyrigg and Prairiewood, Sydney's largest blue-collar employment zone at Smithfield/Wetherill Park, and the major hubs of Liverpool and Parramatta. Although the corridor itself was identified as early as 1975 in various Parramatta region transport plans, it was only in *Action for Transport 2010* (Department of Transport, 1998) that the entire transitway network was devised, and included an additional seven corridors (Parramatta to Rouse Hill, Blacktown to Castle Hill, Blacktown to Wetherill Park, Blacktown to Parramatta, Parramatta to Strathfield and Penrith to St Marys) to be constructed during the period 2003-10. Only the initial two (and the second, only partially) were ever constructed—as the North-West T-way. The remainder of the proposals have since been redesignated and incorporated within 40 strategic bus corridors. In the latest iteration, *Sydney's Bus Future* (Transport for NSW, 2013), these corridors have been divided between 13 Rapid bus routes and 20 major Suburban bus routes but little progress has been made (beyond the B-Line) to bring them into reality.

The transitway itself is 31 km long with 35 T-way stations, spaced on average 861 m apart. The system is unique by incorporating a mix of different bus priority qualities to take advantage of land availability along a former motorway reservation and a Sydney Water pipeline, whilst minimising cost on entry into the Liverpool and Parramatta CBDs. As such, there is 20 km of dedicated bus carriageway (both on dedicated alignments and as a carriageway in the road median such as on Hoxton Rd), plus 11 km of kerbside bus lanes (e.g., Parramatta Rd), accommodated either on the existing roadway or through road widening. Dedicated carriageway exists between Woodpark and Wetherill, and Horsley to Memorial stations, whilst dedicated lanes lie between Parramatta and Woodpark, Wetherill and Horsley, and Memorial to Liverpool stations (Figure 1). Signals in the carriageway sections are transponder-activated, requiring additional fleet infrastructure. The transitway operates as a closed system (the only in Australia) as route T80 although generic route services enter three T-way stations at Bonnyrigg, Prairiewood and Horsley. Between December 2017 and August 2018, Bonnyrigg station was also serviced by the Wetherill Park BRIDJ on demand service (the only such instance on a BRT in Australia) but this has subsequently been withdrawn due to low patronage.

Figure 1: Route map of the Liverpool-Parramatta T-way

Note: Map shows the 35 stations and how the corridor once crossed the operating areas of five incumbent operators.

Source: New South Wales Audit Office 2005: 16

The transitway infrastructure was built and owned by the NSW Government and an engineering reason for the excess cost related to a policy decision to have the dedicated carriageway sections of the system future-proofed for future conversion to LRT. The extra costs of 'over-engineering' to accommodate LRT is linked to the right-of-way geometry—LRT is limited to less than 6% gradient whilst BRT can handle 9% (Levinson et al., 2003). This constitutes an additional cost, but smoother bends and less steep climbs improve passenger comfort (a benefit difficult to quantify) by bringing additional rail characteristics to bus. The transitway is unique in how the procurement for an operator became a controversial process—for other BRT/BBS, it is simply allocated to the incumbent operator. The NSW Audit Office (2005) identified a number of factors for STA's competitive bid. Firstly, it was the sole bid which assumed no subsidy was required for the service. Forecasting patronage is difficult (especially in the two-month timeframe provided at the time), but the assumption made was 65% higher than STA's usual forecasts. The ambitious assumptions were not met initially, despite strong growth recorded—56% patronage growth, with 47% being new journeys (Currie, 2006)—as much of the variation depends on the rate of 'ramp-up'. A number of other assumptions were also optimistic—for instance, the bid was based on an expected 55 min peak running time.

This compares with up to 68 min peak (and 53 min off-peak) presently experienced. The outcome resulted in a number of dissatisfied bus operators who remained sceptical of how STA arrived at its near breakeven bid. The issue of fair competition and idea of building "trusting partnerships" (Stanley, 2010) between operator and regulator is an important issue, and would manifest itself in how well the system was able to integrate within the broader network structure.

At the time, five local bus companies operated services in the area traversed by the transitway—WestBus, Baxters, Hopkinson, Oliveri and Busabout (refer to Figure 1). Existing services were of a heavily east-west nature serving the heavy rail South/Cumberland Lines. The transitway constituted the first effective public transport north-south link across the region, enhancing connectivity and allowing travel to key destinations without circuitous routing or multiple interchanges. The interface of the transitway with existing route services is hence of enormous importance. The five incumbent operators had little incentive to cooperate with providing feeder services to the transitway, believing that the trunk operator would attract patronage away from them. Two operators estimated that they lost 30% of their patronage, as a result of the 400 m 'exclusion zone' on each side of the transitway (NSW Audit Office, 2005). Existing operators were not receptive to re-routing their services to feed the transitway and to provide integrated service, further compounded by the 'resentment' from the initial tender process. This issue was compounded by an interchange penalty in terms of a further fare payment for customers wishing to transfer, which existed before the MyZone system (introduced April 2010) brought together the fare structure across both STA and private bus operators (including TravelTen and other periodic tickets). The lack of integrated service has been identified repeatedly as a major limitation for the system reaching its full potential (NSW Audit Office, 2005, Currie, 2006, Currie and Delbosc, 2010).

The merits of closed and open BRT systems have been debated at length around the world, but the need to integrate feeder services has never been called into question. What is unique with the Liverpool-Parramatta case is the active resistance faced and how fragmentation of ownership and competition issues could prove an obstacle for achieving an integrated network so critical to the 'shuttle' operation. Many of the lessons would be incorporated in the development of the North-West transitway and remain topical to this day. The need for a sense of 'ownership' by other relevant operators is vital, and the issue of integration remains today especially at contract boundaries.[6] By virtue of the standalone service and independent operator, however, meant that for many years, the transitway operated as a BBS. A fleet of 17 T-way liveried buses were operated (Figure 2) until October 2013 when it was incorporated as part of SMBSC[7] Region 3 (won by Transit Systems). The full potential of this change in terms of better network design—including more through-routed services remains to be seen.

Recently, T80 was designated as Sydney's first Rapid route, following the hierarchy outlined in *Sydney's Bus Future* (Transport for NSW, 2013). This change is somewhat puzzling since there are no customer-facing brand elements and many other services already meet the level of service (frequency, hours of operation, etc.) required running on the identified strategic corridors but are not afforded the same designation. Further, there is an increasing fragmentation of the upgraded bus service brand in Sydney—T-ways, followed by the introduction of Metrobus and now B-Line. It would appear every new government is keen to make their stamp by launching their own branded initiative!

Figure 2: T-way liveried bus operated by Western Sydney Buses

6 This is especially true where multiple operators service the same corridor. There is little to no integration in timetables (despite Transport for NSW setting the standards), and smarter scheduling can deliver higher effective frequency for the customer at zero additional cost (concept explained in Section 8.2).

7 Sydney Metropolitan Bus Service Contract.

3.2 North-West transitway

The North-West T-way was opened in two stages in March 2007 between Parramatta and Rouse Hill (along Old Windsor Rd) and in November 2017 between Blacktown and Parklea (along Sunnyholt Rd). Unlike the Liverpool-Parramatta T-way, the North-West T-way heavily emphasised running integrated services from its first day of operations. The transitway was linked to early plans for the large-scale Parklea Release Area, which from the outset aimed to have sufficient infrastructure in place early ahead of demand and development (Clifton et al., 2014). Construction was completed in time for the opening of a major regional and employment hub at Rouse Hill (the Rouse Hill Town Centre). Buses were a focus from the beginning, rather than using the 'off-centre' Richmond branch of the Western Line. Early projections in the strategic planning process aimed to have 60% of people using Sunnyholt Rd travelling in just 4% of vehicles—i.e., buses (Pund and Fleming, 1997).

The 24 km system is primarily a dedicated bus carriageway with at grade intersections,[8] except for 2 km between Old Windsor Rd at Briens station to Parramatta where it reverts to 3 km of on road bus lanes. The speed limit is 80 km/h on the carriageway and 40 km/h at stations. Originally proposed to incorporate signal priority, this was scrapped in favour of the Sydney-wide rollout of the Public Transport Information and Priority System (PTIPS)—then scheduled for 2009. There are a total of 58 stations, with average spacing 700 m on Sunnyholt Rd and 1 km on Old Windsor Rd (Currie and Delbosc, 2010). Stations are not equipped with real time passenger information (unlike with the Liverpool-Parramatta T-way) as a cost reduction exercise. There are two park and ride facilities at Riley and Burns stations offering a total of 400 car spaces.

Whilst a new trunk service was offered on the North-West T-way, the majority of routes comprised of existing services which had been re-routed to travel via the transitway for part or all of their journey. A T-prefix was added as the customer-facing 'brand' element for this network—including T6x series routes (ex-Parramatta and operated by ComfortDelGro as Hillsbus), T7x series routes (ex Blacktown and operated by Busways). There remained some non-T routes and X-sufficed routes on the transitway which join the M2 busway at Abbott station. Privately operated CBD express coach services have begun in recent years which use the transitway and offer travel time savings plus guaranteed seats, despite their higher fare.[9] In 2019, Sydney Metro Northwest will open and parallel the T-way between Bella Vista and Rouse Hill. How this might affect the existing network structure remains to be seen.

3.3 M2 busway

The M2 busway predates both the Liverpool-Parramatta and North-West T-ways, opening in May 1997 as part of the F2 freeway between North Ryde and Seven Hills. As part of the business case, high 'latent demand' was identified for express bus services to Epping, and so 16 km of median bus lanes were implemented between Windsor Rd to Beecroft Rd, earmarked for future conversion to LRT should there be sufficient demand. A dedicated, bus-only ramp was constructed to Epping station, presumably intended for busway customers to connect with existing Northern Line services to access the CBD.[10] Some criticised that the bus lanes were merely a device to justify the motorway, given the limited catchment surrounding the corridor (including large unpopulated areas), and the original single stop provided for at Pennant Hills Rd where there were no other public transport links (Goldberg, 1993). The approach appeared to contravene principles of land use and transport planning.

The *Passenger Transport Act 1990* was amended to permit private bus operators (who operated outside the STA-dominated inner suburbs) to apply to operate direct services into the Sydney CBD.[11] Westbus commenced its Hills-City Express from Castle Hill and Winston Hills to the CBD in mid-1996 via Victoria Rd and the new Glebe Island Bridge (Anzac Bridge today). When the M2 motorway opened, the travel time on these services reduced by up to 35% and patronage experienced significant growth. Additional routes were subsequently added from Bella Vista, Baulkham Hills, Blacktown, Seven Hills, and later from Rouse Hill to the City as well as the Macquarie Park precinct. It is the M2 busway that saw the reintroduction of articulated buses to Sydney streets after a more than 20 year absence.

The M2 busway is unique (as with the Adelaide O-Bahn) in that it caters for high-speed, line-haul travel between the CBD and outer suburbs with very few stops in between. Use of a motorway corridor is appropriate in this case since the focus is on speed and not on fostering a strong, development-oriented corridor. In terms of the merits of different motorway-based BRT alignments, Levinson et al. (2003) proposed that a separate right-of-way is most desirable (as in the case of the O-Bahn, given that the motorway was never built), followed by priority on one side of the motorway (eg., Brisbane's South East busway), and finally within the motorway medians (as is the case here with the M2 busway). One challenge with motorway medians is poor pedestrian access to stations and the difficulty of integrating them within the surrounding area to promote transit-oriented development. The two original, and median-situated stations at Oakes Rd and Barclay Rd indeed suffer from this issue, and poor land use/transport integration including a lack of connecting bus services, inadequate parking, and inappropriate densities/zoning for what is excellent accessibility (one-stop away from the CBD). Recently, ComfortDelGro's OurBus on demand trial in the North Rocks area focuses on alleviating this access/egress issue to the M2 busway. The median placement of the busway, and construction of an island platform necessitates a 'crossover' of the busway to align doors on the correct side. Two further kerbside stations were constructed beyond the median busway (to the west) at Cropley Dr and Gooden Reserve in Winston Hills.

8 Although five are grade separated at Cumberland Hwy, Prospect Hwy, Seven Hills Rd, Norwest Blvd and Old Windsor Rd.

9 Operated by North Sydney Bus and Coach and powered by the software platform Niftie. See https://www.niftiecommute.com

10 This access ramp was removed in 2012 as part of the M2 motorway widening, a connection used by Routes 611 and 740. As part of the works, the M2 busway was shortened by 450 m and a high occupancy vehicle (T2) lane added inbound between Terrys Creek and Lane Cove Rd.

11 Forest Coach Lines (now SMBSC region 14) took advantage of this and in 1992 became the first private bus operator in 40 years to operate bus services (from Terrey Hills) into the Sydney CBD. Originally, such services were not permitted to pick up or set down en route through other operator's territory, but this has been changed in recent years as government assumes greater patronage risk.

Kerbside bus lanes (of a minimum width and without a physical median separation) are provided only a few hundred metres before and after each station, so buses are required to quickly de/accelerate to leave/join high-speed 100 km/h (formerly 90 km/h) motorway traffic—with associated safety concerns. In all four stations, passenger amenity is a challenge as it is arguably a hostile environment for waiting passengers on a high-speed roadway.

After many years of proposals, the future Sydney Metro Northwest (opening early 2019) will largely duplicate the *function* of the M2 busway. Until the opening of the stage two Sydney Metro City and Southwest (projected for 2024), passengers will interchange at Chatswood for existing suburban services into the CBD. Buses in the Hills district will be rerouted as feeder services to Metro stations with the vast majority of direct services into the CBD discontinued—barring those directly on the M2 corridor. Based on available information and assumptions, analysis of different origin-destination pairs (Clifton et al., 2014) showed that most beneficiaries will be travellers to the Macquarie Park precinct and Chatswood—both important activity centres presently not well served by the M2 busway. Customers directly near Metro stations will also benefit, but in general, travel time to the CBD will increase, plus there will be the need to make two interchanges. Some of these realities are less well understood and demonstrates the often misunderstood benefits of open BRT systems in providing direct one-seat journeys, and even travel time savings, as compared to a hub-and-spoke model with rail.

3.4 Metrobus

We now turn to a series of BBS initiatives which have been launched in Sydney in recent years. Metrobus constituted Sydney's first instance of high frequency branding at a network level (as opposed to individual routes[12]), originally operated with a dedicated fleet of red buses, and was launched in two phases between 2008 and 2011. Phase 1 began as a trial with Routes 10, 20, 30 40 and 50 (later M-prefixed as Phase 2 launched), based on providing additional capacity (as a 'top-up' service overlaid on existing routes) along busy corridors to inner suburban centres 20-30 min from the CBD. These five Metrobus routes crossed the CBD, effectively merging what would otherwise be two separate routes terminating in the CBD. This negates the need to layover and use the scarce commodity that is road space, but the length of route can reduce service reliability. Buses ran every 10 min in peak, 15 min inter-peak and every 20 min evening and weekend, but service span was initially limited to around 8PM, linked to the periods supplementary service was thought to be required. Metrobus was unique in that there was no customer facing timetable (this was later reintroduced), effectively working on estimated wait times—a first for Sydney.

Phase 1 Metrobus were completely cashless, prepay-only services, following a successful trial on the City to Bondi Beach Route 333 service (Byatt et al., 2007). Metrobus utilised a dedicated fleet of high capacity (including articulated and three-axle rigid) and standard two-axle rigid buses. Five 'super' buses with different seating arrangements such as longitudinal seating were also tested (Figure 3). A bright red livery was applied (with the original design being route-specific, showing for example major locations M10 would call at) and each vehicle featured quality passenger information systems including next stop displays and audio announcements. No additional bus priority was forthcoming, as the services used existing bus lanes on the major arterials they served.

Figure 3: One of the original 'super' buses deployed on Metrobus, trialling high capacity longitudinal seating

Photo: Mark Bean

12 Route-specific branding has previously been implemented on Metro-Line (Routes 200/400), City-Link (Routes L23/L28/L38) and Ferry-Link—all have now been discontinued.

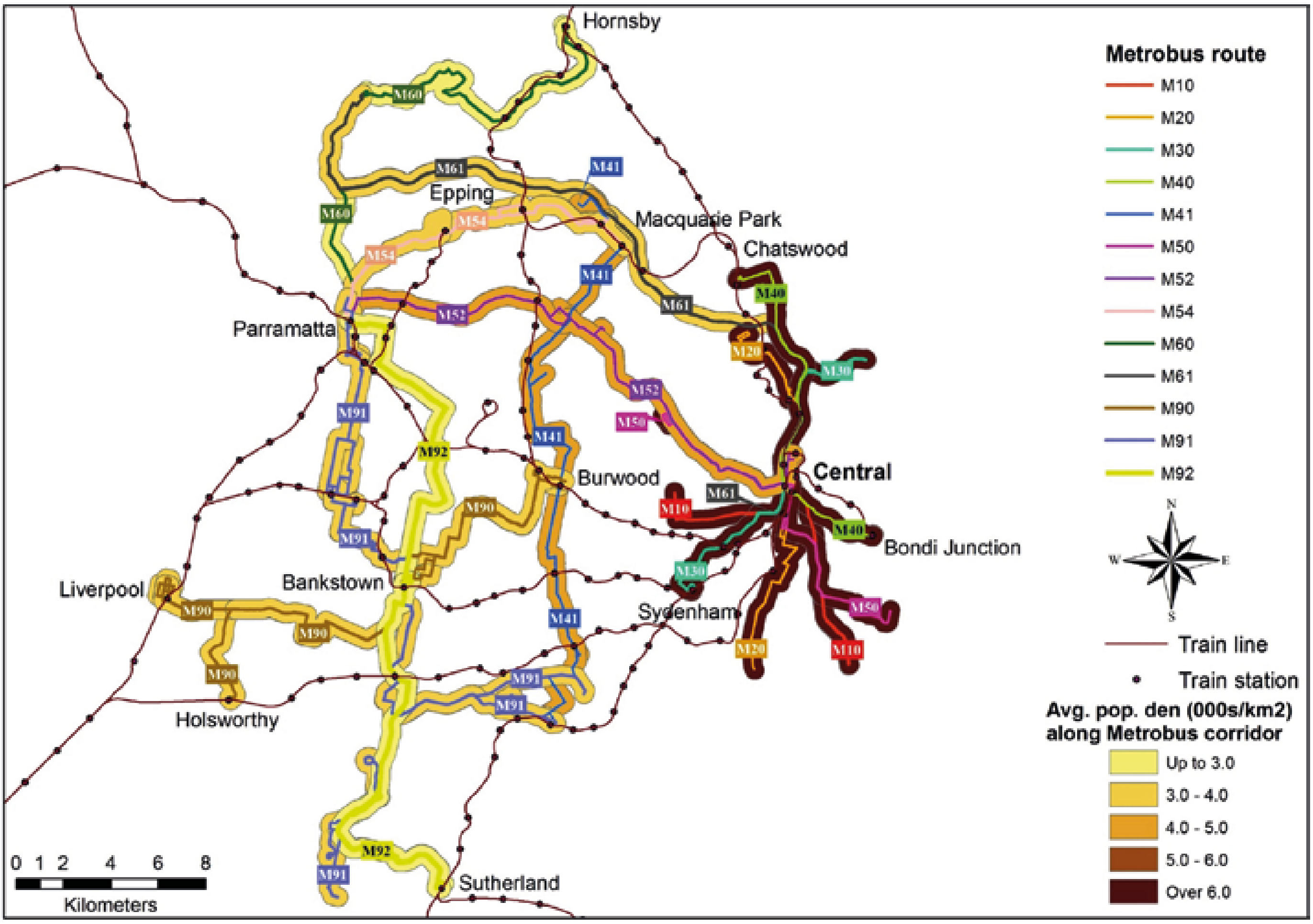
Metrobus Phase 2 significantly expanded the original network but also confounded the original philosophy behind the Metrobus concept. Phase 2 routes expanded the geographic reach of Metrobus, with six new routes as cross-town orbitals and two as radial trunks from CBD to Parramatta (via Victoria Rd) and Castle Hill (via M2 motorway)—all of which were corridors poorly serviced by rail. Barring one route, Metrobus Phase 2 was simply a redesignation of existing services now in branded form and operating with a dedicated new fleet (Table 2). For the first time, private operators (i.e., Transdev and ComfortDelGro) were brought in to operate some of these services. The entirety of the Metrobus network is shown in Figure 4. The expansion compromised original Metrobus ideals as Phase 2 routes all accepted cash fares with some (e.g., M52) even operating different stopping patterns (limited stops, short works and head offs). Customer-facing timetables were also offered unlike with Phase 1. Shortly after the entire network had been launched, a political decision was made to utilise mixed scheduling, thus deploying Metrobus-liveried fleet on regular route services and further confounding the BBS vision. This enabled fleet and driver savings as well as use of newer vehicles on the rest of the network (particularly weekends), but at the expense of branding and legibility for the customer. In the future, there are plans for Metrobus to be redesignated with the B-prefix, but nothing concrete has yet to be announced.

Extensive analysis on the performance of the Metrobus network was conducted by Ho and Mulley (2014). Phase 2 routes serving the metropolitan fringe were found to be far more successful in boosting patronage than on their Phase 1 equivalents serving inner suburbs where public transport networks were already denser. Boardings per kilometre for Phase 1 were lower than pre-existing (competing) routes on the same corridors with the reverse being true for Phase 2. This suggests that Metrobus and general bus services were viewed as substitutes in the inner areas, confirming much anecdotal research that passengers will board the first service to arrive. In the middle and outer suburbs, Metrobus services appear more as complements with evidence of a definite opt-in for the new services. Further, it was found that patronage appeared to take at least six months to ramp up to a 'steady state'. The configuration of Metrobus routes with respect to bus/rail complementarity/integration was also investigated and there exists enormous potential for better network presentation including frequent network multimodal branding (regardless of bus or rail) to better convey to the travelling public the spatial availability of high quality, turn-up-and-go services.

Table 2: Eight new Metrobus routes announced as part of Phase 2 expansion

Metrobus route	Original route	Date commenced
M41	*New*	19 December 2010
M52	L20/520	8 August 2010
M54	548	10 October 2010
M60	600	7 March 2011
M61	610X[13]	20 December 2010
M90	900	6 December 2010
M91	910	7 February 2011
M92	962	14 March 2011

Figure 4: Metrobus network, including both the original Phase 1 and subsequent expansion Phase 2 routes, overlayed on operating environment characteristics



Source: Ho and Mulley, 2014: 341

13 For a period of time, additional Route 610X ran the exact same corridor (City to Castle Hill via the M2 motorway) as a 'top-up' service—this fragmentation of service identity confused customers. Presently, Route 610X constitute extensions of the M61 service beyond Castle Hill to Rouse Hill.

3.5 B-Line

The Northern Beaches is an extremely challenging region of Sydney with only three roads leading in and out of a population of more than 250,000—Spit Bridge, A38 Warringah Rd and A3 Mona Vale Rd (for a total of 14 traffic lanes counting both directions). Both rail and road-based initiatives to improve public transport along the A8 corridor from the CBD to Mona Vale have been studied extensively over past years (Hensher et al., 2019b). The corridor has been a particular priority for the NSW Liberal National government over its present term (2015-19), given the prominence of ministers (and leaders) representing electorates at both state and federal levels on the Northern Beaches. What began as BRT became a BBS scheme named B-Line which was finally launched in November 2017 after a period of planning and works. This express service features just 9 stops along a 27 km route from Wynyard to Mona Vale, via major load points at Neutral Bay Junction, Spit Junction, Brookvale and Narrabeen.

B-Line is operated by the State Transit Authority with a dedicated new fleet of 38 bright yellow Gemilang-bodied double-decker MAN A95s[14] (34 peak requirement plus 4 spares) plying the route delivering service every 5-15 minutes (Figure 5). A key part of the program is its strong visual identify reflected through stop upgrades with real time passenger information, coupled with new commuter car parks and minor bus priority infrastructure improvements. These involve lengthening a few bus lane pinch points and relocating bus stops to the departure side of traffic signals, to take advantage of the Public Transport Information and Priority System (PTIPS). Land acquisition was also made to construct several indented bus bays. Whilst we do not promote this in general due to the delays incurred by buses returning back to general traffic lanes (despite the yield-to-bus requirement), it is sensible in the case where the nearside is a bus lane, and with the various stopping patterns on this corridor it enables buses to pass one another.

Accompanying B-Line are network changes across the Northern Beaches region based on route rationalisation, and increased frequencies at the expense of additional connections. Whilst Metrobus already had a focus on marketing its high service frequency, B-Line is the first where the key performance indicator for the operator is not on time running but headway regularity. The authors recommend taking the customer perspective since there is evidence to show customers arriving at their stop/station randomly once headways drop below 12 min (Clifton et al., 2018). There was also no compromise in timetable construction, with regular departures at clock face intervals (despite leading to longer layovers than required, and hence more resources). The original intention was for B-Line to be extended to Newport, but due to concerns from local residents about large vehicles and infrastructure changes this is no longer on the agenda. However, an innovative new, on demand service named Keoride[15] has been launched providing bookable, shared first/last mile connections to the B-Line terminus. There are plans for further B-Line type services along other Sydney corridors in the future.

Figure 5: A double-decker B-Line bus

14 Note axle weight limits were increased on the corridor to permit these vehicles to operate on NSW roads
15 Operated by Keolis Downer in partnership with GoGet (who supplied the vehicles) and technology provider Via (formerly Routematch).

3.6 Other initiatives

Whilst the T-way and M2 busway represent the major BRT schemes and Metrobus and B-Line the major BBS schemes present in Sydney, a number of other bus priority and branding initiatives also exist, but being limited in scale and as isolated examples are beyond the scope of the present study. Indeed, bus lanes on the Sydney Harbour Bridge[16] and M1 Warringah Freeway approach (southbound) were game changing when first initiated. The Moore Park busway which was converted from an old tram reservation was also an important initiative. The Inner West T-way or bus-only Bennelong Bridge which connects new developments at Wentworth Point to the Rhodes peninsular is a bold new undertaking. The project's geometry is very similar to the immensely successful Eleanor Schonell 'Green' Bridge in Brisbane which promoted public and active modes of transport to the 'isolated' peninsular that is the University of Queensland's St Lucia campus (Charles-Edwards et al., 2015). Bennelong Bridge is unique in that Wentworth Point developers contributed to the cost of construction in exchange for government approval to build greater densities in their developments. In the future, there are proposals to convert the bridge into LRT connecting Parramatta and Strathfield via Olympic Park, Wentworth Point and Rhodes.

A number of BBS initiatives have also been launched over the years, with many still active and selected services illustrated in Figure 6. Forest Coach Lines launched **Route 197** in 2008 as a quasi-BBS with a dedicated fleet of liveried buses plying the A3 between Mona Vale and Macquarie University (with a dog-leg into Gordon station). Mixed scheduling was soon implemented after the initial phase although it helped to garner recognition and publicity in the region. The route has seen service levels increase considerably over the years and has since grown to become a major trunk corridor in the region. Also in 2008, the free Sydney **CBD shuttle** commenced with a fleet of green liveried buses. The shuttle concept was extended into ten suburban and regional CBDs (including Parramatta, Liverpool, Bankstown) approaching the 2011 NSW election. The shuttles were quickly implementable and as a BBS showcased effectively action on public transport. Most of these shuttles were subsequently discontinued upon the change of government.

In September 2018, two BBS were launched in Sydney. Route 333 **Bondi Link** was 'upgraded' to a (government-proclaimed) B-Line style service and included a fresh livery for many vehicles plying the routes (although the fleet is not dedicated) to effectively 'sell' the service upgrade (headways as short as 3 min in the peak). **Station Link**, a joint venture between Transdev and ComfortDelGro, was introduced on seven routes to replace trains for the temporary shutdown of the Epping to Chatswood Rail Link (for conversion to Sydney Metro Northwest). A prominent pink front and branded sides (consistent with the colour of passenger information used for other service disruptions including bus route changes in the CBD to accommodate light rail construction) on a fleet of 60 new buses were procured (and housed in a temporary depot in Camellia). The temporary branding 'wrap' can be removed quickly and easily for future incorporation as part of the generic route fleet.

A number of BBS schemes have also been proposed by bus operators, state and local governments. SMBSC region 14 operator Forest Coach Lines (now a member of ComfortDelGro Australia since October 2018) in association with SHOROC, a partnership of councils in Sydney's North East, has been lobbying heavily for a B-Line style service along the A38 Warringah Rd, between Dee Why and Chatswood, complementing/replacing the existing heavily patronised Routes 280 and 136. The rapid corridor (designated route B2) has been touted to cost AUD 7 million in capital for 13 buses, with operating costs at AUD 6 million per annum (AUD 2.5 million of which would be recouped from ticket sales). It would feature seven stops at Dee Why Beach, Skyline Shops, Northern Beaches Hospital, Forestway Shops, Jamison Square, Crown of the Hill and Chatswood Interchange. The main attraction is its quick deployment potential, able to be up and running in just 6 months. Elsewhere in Sydney, attention has turned to the Parramatta Rd corridor with the opening of WestConnex M4 East, which will offer major opportunities for urban renewal and the revitalisation of the corridor, shifting away from a roadway prioritising throughput to one with an emphasis on place. Again, various technologies have been considered including traditional LRT, 'trackless trams', BRT and BBS. Media attention and speculation is high, but it remains to be seen what will materialise. Again, these proposals exist outside the scope of this study but are ripe topic areas for future research into their potential, performance, and success.

Figure 6: Other BBS initiatives

16 The bus lane and Cahill Expressway general traffic lane replaced two tram tracks which formerly ran on the eastern side of the Sydney Harbour Bridge (mirroring heavy rail tracks on the western side).

4. Melbourne

4.1 SmartBus

Bus transport in Melbourne has never garnered the same political attention as Sydney, partly because of the extensive tram network available throughout the inner (and some middle) suburbs. A recent departure from this has been the BBS initiative SmartBus, which following a period of trial from 2002 was formally launched in 2005 and progressively expanded growing to nine routes by 2010 (Figure 8). Although originally a policy initiative of the Kennett Liberals (to be called MetLink[17]), they were only implemented in the Bracks and Brumby Labor era. Of the nine routes, three provide a circumferential link with the many radial rail and tram corridors into the CBD, two connect key destinations in the middle suburbs, whilst the remaining four are radial Doncaster Area Rapid Transit routes which connect Manningham Shire via the M3 Eastern Freeway to the Melbourne CBD. SmartBus as BBS uses dedicated vehicles with a distinctive livery, branded bollards at all stops plus real time passenger information at interchanges (Figure 7). There is a high level of service with long hours of operation and higher service frequencies (10-15 min daytime headways and 30 min in the evenings and weekends). As BBS, SmartBus mainly operates in mixed traffic but enjoys limited bus priority treatment including queue jumps (signal priority) and bus lanes. Present operators of SmartBus routes include Ventura Bus Lines, ComfortDelGro and Transdev.

The three cross-town orbitals (Table 3) are unique in that they realise the principles of a gridded public transport network allowing anyway-to-anyway travel (not just CBD-centric), long promulgated by experts (and now even more advanced with the Suburban Rail Loop proposal). SmartBus routes 901, 902 and 903 combined several shorter services and provide a premium, branded offering with a higher level of service span and frequency. As evident, considerable travel time savings are realised from the upgrades, and the relative growth in patronage has exceeded the growth in service kilometres, implying a service elasticity exceeding unity (Loader and Stanley, 2009). Some of these passengers may be attributable to existing users, but others reflect a modal switch from car to bus. It is worth nothing that Route 901 has become the longest metropolitan bus route in Australia, at 115 km in length, connecting nine railway stations and over 100 bus routes, and taking 4.5 hours to traverse.[18] Because of this, the route offers tremendous connectivity, but also leads to great operational difficulties—including the need for hotseating and extended dwells at major timing points to maintain reliability. There has been a push to split up the route for some time now.

The absence of quality public transport priority has continued to limit the full potential of SmartBus. In many cases, bus lanes are non-existent or too short, but recently there has been greater focus on increasing and trialling the use of intermittent bus lanes as a compromise in congested road networks (Currie and Lai, 2008, Currie and Sarvi, 2012). The SmartBus network has not been extended since 2010, though this is not due to an absence of activism from the bus industry. Bus Association Victoria has continued to push heavily for its proposed BRT and high capacity bus network, featuring 23 routes across greater Melbourne (BusVic, 2018). A core component of the plan is to connect the six national employment and innovation clusters in East Werribee, Sunshine, La Trobe, Parkville, Monash and Dandenong.

Figure 7: Distinctive SmartBus vehicles and real-time stop infrastructure

Table 3: Original three SmartBus routes and measures of their success (Currie and Sarvi, 2012: 65)

SmartBus route	SmartBus 901	SmartBus 902	SmartBus 903
Previous route(s)	Route 665/830	Routes 888/889	Route 700
Previous travel time (min)	57	87	98
New travel time (min)	43	68	74
Travel time reduction (%)	14	37	24
Patronage growth (%)	42	47	21
Passengers previously driving (%)	34	29	21

Source: Currie and Sarvi, 2012: 65

17 This later became an umbrella brand for all government-contracted tram, train and bus services (succeeding The Met and later replaced by PTV).
18 Sydney's L90/190 from Palm Beach to Wynyard (formerly, Railway Square), Brisbane's Great Circle Line (Routes 598/599) and Perth's CircleRoute (Routes 998/999) are also unusually long for urban bus routes.

4.2 Doncaster Area Rapid Transit

Manningham shire, comprising the major centres of Doncaster and Templestowe, houses a population of 120,000 but remains the only local government area in Melbourne without access to heavy rail. As part of the Brumby government's The Victorian Transport Plan (Victorian Government, 2008), AUD 360 million was allocated to implement SmartBus in Manningham shire, offering a premium service into the CBD (Lonsdale St) via the M3 Eastern Freeway and Hoodle St (see Figure 8). Doncaster Area Rapid Transit (DART) is the policy name for this initiative. Some element of bus priority was implemented including dedicated bus lanes on Hoddle St in the AM peak in the peak direction, and the ability for buses to use the hard shoulder to bypass heavy traffic on the motorway. A high-quality park and ride facility with 400 spaces and indoor waiting rooms was constructed at Doncaster, also facilitating interchange between SmartBus and regular route services. Despite these investments, SmartBus was deemed to be an interim solution and more permanent infrastructure (either bus or rail) has continued to be proposed for construction along the Eastern Freeway median to service Doncaster and Templestowe.

In 2017, and as part of Victoria's market-led proposal program, the incumbent bus operator Transdev proposed an AUD 550 million BRT concept based on the construction of a dedicated bus-only carriageway in the Eastern Freeway median. This would have been just 10-16% of the estimated AUD 3-5 billion cost of constructing heavy rail to Doncaster. A dedicated bi-articulated fleet (similar to the present proposal for Brisbane Metro) would be procured and off-vehicle fare collection arranged so as not to delay station dwells. This proposal was not successful, however, as part of the North East Link, BRT is again on the agenda, but built on one side of the Eastern Freeway (similar to the South East Busway in Brisbane), with stations constructed at the overpasses with Chandler Highway, Burke Rd and Bulleen Rd.

Figure 8: SmartBus network, showing cross-town orbitals, plus radial DART services to the Manningham shire

Source: Public Transport Victoria

5.2 Busway

Brisbane has enjoyed the greatest bus-based investment out of any Australian city. This investment has been infrastructure-heavy, and Brisbane's busway network (the South East, Northern and Eastern corridors) is world class, and perhaps the best implementation at scale of BRT in any developed economy, supported initially by a champion in government. One of the primary reasons bus has been able to get such high political traction is due to the division of responsibilities between bus and rail modes in Brisbane. With a population of 1.1 million, Brisbane City Council covers roughly half of the population in the Brisbane metropolitan area—unlike other Australian capitals where the central local government area covers only the CBD and some surrounding inner suburbs. The Council has the responsibility for running its own bus service (Brisbane Transport, now Transport for Brisbane)—the only such instance in Australia—whilst the state government continues to oversee the commuter rail network as Queensland Rail's CityTrain. As such, there has always existed an element of disconnect between bus and train networks. Buses rarely fed into the railways, but rather competed with the train directly. One reason is that the level of service on the trains is poor, although it is equally the case that the lack of a hub-and-spoke system hinders the development of a quality railway.

A McCormick Rankin (now MRCagney) report for Brisbane City Council in the 1990s proposed that four to five major busways be constructed in Brisbane. Each of these were to parallel an existing train line, with the explicit intention being to shift demand from rail to bus. The idea was for railways to serve longer distance commuting, whilst shorter trips were transferred onto the busway system, following the model set up in Ottawa, Canada. During the period post-2000, the first busway (**South East**) was opened to service, extending in the following decade to reach 27 km by 2014. The entire system exists as open BRT, with all services through-routed extending beyond the busway trunk on-street into residential suburbs, although there is some push to turn this into a closed system (see Brisbane Metro). All stations are high quality and feature disabled access and real time passenger information, though not off-vehicle fare collection. Management of the busway infrastructure is by TransLink but services are operated (primarily) by Transport for Brisbane, but also (in the South East) by Clarks Logan City Bus Service, Mt Gravatt Bus Service and Transdev Queensland.

The South East busway is hailed as best practice in BRT design by several commentators (Levinson et al., 2003, Mees, 2010). The majority of this busway was built beside the M1 Pacific Motorway, and was not based on the principles of transit-oriented design, but rather as a response to future growth in suburbs further south east. As such, many of the stations exist as commuter car parks, with only a couple on South Bank being true activity nodes. The South East busway offered a staggering 70% saving in travel time upon launch, reducing journeys from 60 to a mere 18 min for the length of the route (Levinson et al., 2003). Initially, the system saw 56% patronage growth, with 26% of all passengers having shifted from their cars (Currie, 2006).

New Zealand's first BRT, Auckland's Northern Busway, shares many of the features of Brisbane's South East busway (including running beside a motorway), but this is beyond the scope of the present study.

In 2006, a 1.9 km extension that is the **Northern busway** was completed. Whilst short, this was an important addition since it included a CBD bus tunnel (connecting with Roma Street railway station) and a new underground bus station at King George Square, complementing the existing underground Queen Street Mall terminal which was fast becoming cramped. Further stages of the Northern busway opened in 2009 and 2012, being built on viaducts to the Royal Brisbane and Women's Hospital and Kedron. The **Eastern busway** opened in 2009 with the Eleanor Schonell 'Green' Bridge and connected the University of Queensland's St Lucia campus to the South East busway at Buranda station and subsequently (from 2011) onto Langlands Park. The Eastern busway is significant in linking the university (which previously existed effectively as an isolated peninsular) onto the busway network and was crucial in increasing public transport and active mode share for those travelling from east of the Brisbane River, as well as redistributing where students and staff chose to reside (Charles-Edwards et al., 2015). Whilst Brisbane's busways operate as an open system with all services through-routed, there exists two services (Routes 66 and 111) which run the trunk alignment only. We will assess these routes independently in the subsequent analysis as a point of comparison between closed and open systems, to test how traffic congestion when operating outside the BRT dedicated corridor might impact on service performance.

Despite the busways' success in exceeding patronage targets, there exists a number of limitations arising from how the busway was designed. Queuing is particularly prevalent at key bottlenecks, the most significant of which being at Cultural Centre station and across Victoria Bridge. Peak movements at this point increased from 150 per hour in 2006 to 259 in 2010 (Currie and Delbosc, 2010)—and remains at an average headway of just 14 seconds in the peak. Two problems exist relating to platform design and also system throughput. Firstly, buses generally arrive in a random sequence in a platoon of three to five vehicles (from the previous green signal phase). The platforms are up to 80 m long and there is no information for passengers in terms of which bus will arrive where. Time is hence lost in the station as passengers cross each other's paths to find their bus. This delay has been estimated to cost 10% of the theoretical capacity of the station (Jaiswal et al., 2010). Longer platforms which can be split into route groups (but necessitating wider right-of-way to enable overtaking and turning manoeuvrers) can alleviate this problem but space is at a premium at this station. A staggered platform design is one solution which can increase bus throughput per hour per direction from 20-60 in a conventional design to 60-90 movements, though this has already been well exceeded (Levinson et al., 2003). Because of constraints at Cultural Centre station, buses are banked up waiting to pick up/drop off and these can extend hundreds of metres across Victoria Bridge (southbound) and also to the South East busway tunnel portal (northbound) where there are two sets of traffic signals. The result is that during the green phase, buses are not able to proceed and thereby further delaying the system. A big impetus for developing Brisbane Metro is to alleviate this bottleneck.

5.2 Bus Upgrade Zone

The Bus Upgrade Zone (BUZ) was introduced in 2003 as a frequent network branding scheme, where services run at least every 15 min in the daytime and evenings (everyday) and every 10 min or better in peak periods. The BUZ brand acronym is featured on bus destination displays and the BUZ logo can be found at stops (Figure 9), although far less prominent than other BBS brands. The BUZ network is more or less synonymous with bus services running on the three busways so can be deemed equivalent in this analysis. The frequent BUZ network has seen proven success, accounting for more than half the growth in overall bus patronage with significant off-peak and weekend growth.

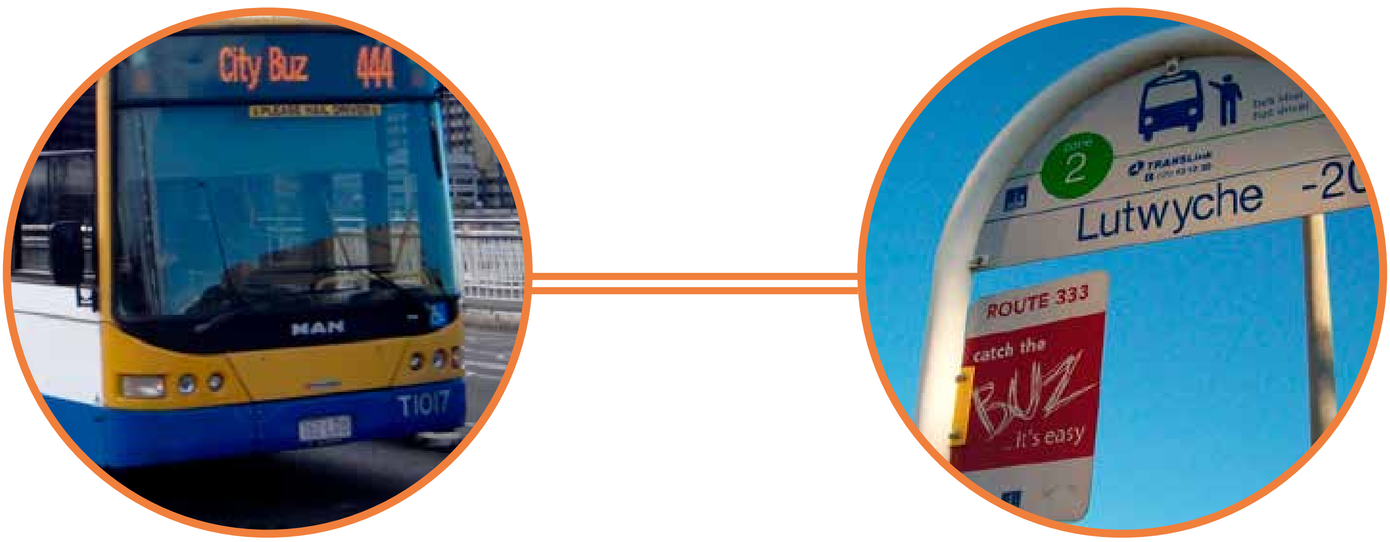
An exception to the BUZ network running on the busways are the downtown circulators known as **CityGlider**. These use a dedicated fleet and there are two routes in operation—Blue (Route 60) and Maroon (Route 61). These were launched in 2009 and 2013 respectively. Whilst not free, the services are popular and the branding prominent on both vehicles and at stops. The **Great Circle Line** (Routes 598/599 depending on direction) is another BBS although on timetables only and without a dedicated fleet. The service connects major centres in the middle suburbs including Chermside, Cannon Hill, Sunnybank, Indooroopilly, Toowong and Mitchelton. The service is not particularly frequent, running every half hour on weekdays (no ramp up in peaks) and hourly on Saturdays, with no service on Sunday. An end-to-end trip takes around 4 hours though it does play a crucial role in connecting key centres. Transport lobbyists have suggested that that Great Circle Line be scrapped, and the resources deployed onto 16 cross-city bus services instead, better aligning with people's travel patterns. Both CityGiders and the Great Circle Line will be benchmarked as part of this analysis.

5.3 Brisbane Metro

Brisbane's busways are largely dedicated carriageway and grade-separated, although it interacts with the general road network at key bottlenecks including both ends of Victoria Bridge, leading to the queuing of buses and significant delays of up to 50% longer journey times than scheduled. The core rationale for Brisbane Metro is to reduce vehicle movements by moving from an open to a closed BRT, using larger vehicles and streaming passenger movements at stations. The project was originally conceived as a guided, rubber-tyred metro operating two metro trunk routes. Metro 1 would operate between Eight Mile Plains and Roma St, whilst Metro 2 would run between the Royal Brisbane and Women's Hospital and the University of Queensland at St Lucia. A rail-based system although higher cost does provide greater capacity—25,000 as compared with 22,000 people per hour per direction (Infrastructure Australia, 2018b). It was subsequently determined that a bus-based solution would provide greater value for money.

The present proposal is to procure a dedicated fleet of 60 bi-articulated, branded ('metro') buses to ply two routes. Vehicles will feature less seating and carry 150 people. For the first time, off-vehicle fare collection would be implemented, and all-door boarding and alighting permitted with up to four sets of doors per vehicle. Metro services would run every 3 min in peak and 5 min off-peak. Most existing through-routed services would be truncated at their nearest busway station, requiring passengers to interchange, although a limited number of express services would continue to run into the CBD at peak periods. The program is coupled with infrastructure improvements including grade separation and a new underground station at the Cultural Centre, a new Adelaide St tunnel, changes to North Quay, existing busway station upgrades, and changes to remove cars from Victoria Bridge. For customers, Brisbane Metro should save 30% travel time in the AM peak and 50% travel time in the PM peak. In peak times, there would be 340 fewer buses at street level at the Cultural Centre station. Infrastructure Australia (2018b) states the project's benefit-cost ratio at 2.4, with a net present value of AUD 1.2 billion (at a 7% real discount rate).

Figure 9: BUZ branding as seen at bus stops and identified on the bus destination



6. Perth

6.1 Central Area Transit

Perth is the original home of free downtown circulators in Australia (older than Melbourne's City Circle Tram and later the Free Tram Zone, for instance). The free Central Area Transit (CAT) features four bus routes in the Perth CBD, two in Freemantle and three in Joondalup. Only the Perth CATs (Red, Blue, Yellow and Green) will form the focus in this study. The Red and Blue CAT were launched by MetroBus in 1996, replacing the City Clipper services which had operated since 1973. The fleet of 16 vehicles were very technologically advanced for their time, being fully air-conditioned and having the ability to kneel for those with disabilities (Figure 10). The vehicles were radio antenna equipped to enable tracking, and real time information was presented at stops in both visible and audible formats. In 2002, Yellow CAT was introduced and in 2013 following a review, Green CAT joined the network. The high-frequency CAT services are unique in being fare-free, but this leads to the issue of data logging and so patronage counts have been conducted manually until automatic passenger counters (which are notorious for their unreliability) are installed. Passenger surveys show the CAT routes to be the most successful and well-regarded on the Perth metropolitan network, with customer satisfaction routinely reaching 94% or more (Department of Transport, 2011). Presently, the CATs are jointly funded by the Western Australian state government and the City of Perth (through a city-wide parking levy). A proposal is underway to offer a night-time 'black' CAT service to provide service round the clock.

Figure 10: A CAT bus in its iconic silver livery

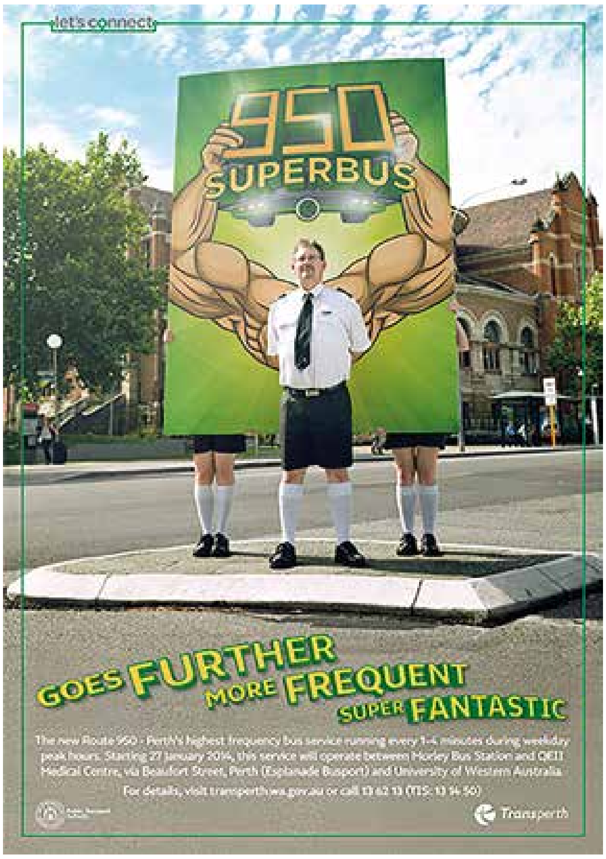
6.2 CircleRoute

Similar to Brisbane's Great Circle Line, Perth also has an orbital BBS called CircleRoute (Routes 998/999), which opened in stages from 1998. The CircleRoute was designed to provide the first rapid cross-suburban service linking important suburban centres and train lines in an otherwise strongly radial network. Key destinations include Morley, Bayswater, Belmont, Carlisle, Bentley, Willetton, Murdoch, Fremantle, Cottesloe, Claremont, Shenton Park, Wembley, Churchlands, Innaloo and Stirling. The limited stops service takes 3.5 hours to traverse the entire 78 km route. Services operate every 15 min on weekdays and every 30 min in evenings and weekends. As part of the launch, every household within 500 m of the route received a CircleRoute brochure and timetables. Currently there is a focus in Perth of developing on-road rapid transit (i.e., LRT or BRT), and one proposal is for a future inner 'CircleRoute' to link Glendalough on the Joondalup Line with Canning Bridge on the Mandurah Line, as well as Subiaco and the University of Western Australia before entering the CBD from the east via Victoria Park (Department of Transport, 2011).

6.3 Transperth 950

Route 950 was introduced in January 2014 and quickly became the highest frequency bus service in Perth. Also known as Superbus (Figure 11), the route replaced Routes 21 and 22 from Morley to Perth CBD and Routes 78 and 79 from Perth CBD to Nedlands—similar to the Metrobus Phase 1 concept in Sydney to through-route services through the CBD. The route has been identified as a potential BRT corridor in the Public Transport Plan for Perth in 2031 (Department of Transport, 2011). Services operate every 3-4 min to Morley and every 1-2 min to the University of Western Australia. The route capitalises on existing bus lanes from Morley through Inglewood to the CBD. Although there is no Superbus-specific branding onboard buses, the 9XX series have now been earmarked as high frequency routes in Perth (as the CircleRoute 998/999 are), so can be thought of a rudimentary form of BBS. Transperth is looking to consolidate other strategic routes into through-routed services and implementing greater bus priority as a result of Route 950's success.

Figure 11: Promotional material for Superbus route 950



Source: Public Transport Authority Annual Report 2013-2014)

7. Adelaide

7.1 O-Bahn

Adelaide's O-Bahn is one of the world's longest and fastest guided busways, but its inception bore typical resemblance to technology being selected for technology's sake. These political circumstances may be traced back to the launch of the *North East Area Public Transport* Review (Department of Transport, 1978) which determined BRT and LRT to be most appropriate to serve the new growth area of Tea Tree Gully, out of an option set which included heavy rail and freeways up the River Torrens valley. The incumbent Labor government opted to pursue LRT technology by means of extending and modernising the Glenelg tram line. Whilst there was bipartisan agreement on the need for new transport infrastructure to service the north east, their political rivals opposed the LRT technology as a matter of policy difference and so this became the central issue in the 1979 South Australian election. One of the first acts of the Liberal government subsequently elected was to scrap plans to extend the tram, so they were left to construct a transport corridor with a number of technologies already having been 'ruled out'.

A worldwide search thus began for alternative technologies and the government quickly looked to Germany and their kerb-guided bus then being experimented in the city of Essen. Coined the O-Bahn[19], the system was conceived by Daimler-Benz to enable dual-mode buses to safely share tram tunnels, thereby avoiding traffic congestion on the surface. The guidance system is essential so that buses would travel along a controlled, fixed path, minimising the lateral width required both on straight stretches and when manoeuvring on curves (Levinson et al., 2003), important within the limited confines of the tunnel diameter (which specifies the loading gauge or maximum vehicle cross-section). Whilst the ability to operate on a narrow right-of-way is especially important in constricted environments such as road medians, at elevation and within tunnels, this was not a driving factor in Adelaide since there already existed a corridor of sufficient width (then earmarked for a motorway) along the River Torrens linear park, though minor infrastructure savings could be attributable to a narrower guideway structure—2.7 m as compared with 3.6 m for traditional BRT (Rogers, 2002). Another advantage of kerb-guided bus is its ability to offer precision docking at stations not unlike that provided for in a rail system (Phillips, 2006). However, this was not the case in Adelaide as buses exit the guideway to access stations, so the roadway can widen to allow for overtaking.

The 11.8 km Adelaide North East Busway (ANEB) or O-Bahn opened in two stages in 1986 and 1989. The busway begins at Hackney Rd in the inner north suburb of Gilberton and follows the River Torrens to the north east. There are a total of just three stations on the O-Bahn at Klemzig, Paradise and Tea Tree Plaza (originally named Modbury), each built with significant park and ride facilities, bicycle access, storage and parking. At 4-5 km, these are some of the longest station spacings in the world for BRT, followed in second place by the average 1.8 km spacing in Hangzhou, China (Hensher and Golob, 2008). O-Bahn's alignment caters for longer distance service than shorter trips by contiguous residents. The bus network is designed around a high frequency trunk along the full length of the busway with services through-routed beyond Tea Tree Plaza on-street into outer residential suburbs. Feeder buses provide interchange opportunities with the 'line-haul' O-Bahn at the two intermediate stations.

Because of active guidance control, a higher service speed can be operated safely on the system. The O-Bahn was designed for a maximum speed limit of 100 km/h, and with only two intermediate stops saw an end-to-end average speed (including stops) as high as 80 km/h (9 min to cover the entire length of route). Together with its dedicated alignment (unlike where BRT is built on a median or parallels a roadway where the travel time differential with private car can be far more marginal), the O-Bahn offers a staggering 38% in journey time savings, reducing a 40 min trip into the Adelaide CBD to just 25 min (Levinson et al., 2003). As such, O-Bahn has been immensely successful in attracting patronage, with 24% initial growth and some 40% of passengers shifting from cars (Currie, 2006). This is against a backdrop of subdued growth and even patronage decline on other radial routes out of Adelaide CBD. Most customers (around 80%) were found to be travelling from the outer suburbs with just 20% of passengers originating from one of the three busway stops. Customers have also commended O-Bahn's impressive ride quality, in part because of the high-quality engineering of the trackway components which are superior to normal street pavements. O-Bahn buses are equipped with guide wheels which engage with the vertical kerbs of the busway. Adelaide is unique in that it pioneered an innovative safety feature where a metal inner tyre is fitted to prevent full deflation in the event of a puncture, thus allowing a loaded bus to be driven off the busway at speeds of up to 50 km/h. Hence, there is a dedicated O-Bahn fleet for operational and maintenance purposed, but to date there exists no customer-facing brand elements.[20] Upon opening, the initial fleet comprised of 41 rigid and 51 articulated Mercedes-Benz buses. To comply with the maximum fleet age of 25 years, these were renewed with a total of 160 new buses delivered between 2007-2012 (Figure 12). Modern buses are far more advanced and lightweight, but with a heavier chassis no longer available, are more prone to vibrations and have hence had to be speed limited to 85 km/h on the busway (Currie and Delbosc, 2010). This issue showcases the long-term risks associated with selecting new BRT technologies—particularly proprietary technologies tied to one manufacturer. O-Bahn's working life has been estimated at 30 years so there are continual issues with renewal and replacement as the infrastructure ages.

19 The 'O' is short for omnibus (for all people), whilst 'bahn' is German for railway.

20 O-Bahn is presently incorporated as part of the Go Zone frequent network, but the brand exists at stops and stations only (not as vehicle liveries). Go Zone is beyond the scope of the present study.

That said, kerb-guided buses remain the most successful of all guidance technologies on buses (mechanical, optical or magnetic—see Section 12.2). Kerb-guided busways have (apart from Essen and Adelaide) also been implemented in Ipswich (UK), Leeds (UK), Nagoya (Japan), Bradford (UK), Sussex (UK), Edinburgh (UK), Cambridge (UK), Euclid (US) and Sao Paulo (Brazil). Whilst some implementations are sensible, with the same benefits not able to be accrued from other modal technologies,[21] most systems were built as a compromise solution replacing an earlier LRT proposal, and driven by a fixation on showcasing an innovative transport technology. The O-Bahn story in Adelaide is a case in point, as a pure political decision arising from government and the opposition taking rigid positions on policy and hardware far removed from the advice of technocrats (Rogers, 2002). Although the O-Bahn has grown to become the most heavily patronised public transport corridor in South Australia, its success cannot be attributed to the choice of kerb-guided bus technology. Whilst there have been proposals to extend the O-Bahn further north east to Golden Grove and even to southern suburbs via the Seaford railway line, none has progressed beyond consultation and so the system remains a standalone showcase of technology driven by modal ideology.

7.2 O-Bahn City Access Project

One of the greatest limitations of the O-Bahn is that its dedicated infrastructure and right-of-way ends at Gilberton and so buses are caught in congested mixed traffic as it traverses the final 4.4 km along the Inner Ring Route into the CBD. The AUD 160 million O-Bahn City Access Project was announced in 2015 and opened in December 2017, with a claimed 7 min in travel time savings per user per day. It provides for dedicated bus lanes along the median of Hackney Rd (whilst maintaining at-grade intersections with cross streets), plus a 670 m bus-only tunnel under the Adelaide Botanic Garden and into the CBD at Grenfell St / East Terrace. One criticism of the project is a concentration of services onto Grenfell/Currie St leading to increasing bus movements and greater passenger loads at bus stops, as well as longer access/egress for some customers as services are withdrawn from North Terrace and King William Road.

Figure 12: The latest Custom-bodied Scania articulated buses operating on the O-Bahn

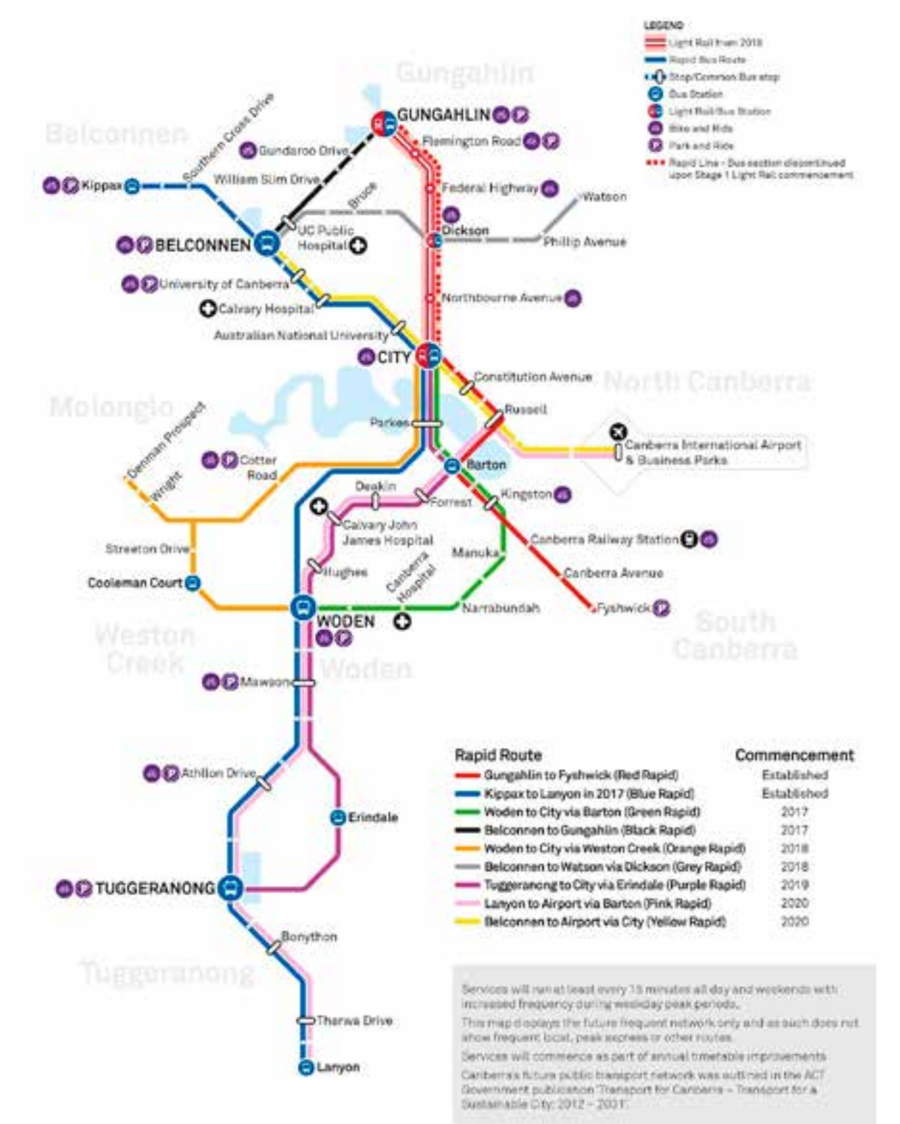
21 For example, where space is constrained such as on a former railway alignment.

8. Canberra

8.1 Rapids

Canberra's Rapid routes serve as the city's frequent trunk network. They represent a limited application of BBS ideals with excellent branding at stops and stations, as well as on marketing material, but generally no branded vehicles. Services operate every 15 min or better from first to last service but remain strongly weekday-centric as Canberra (unique amongst Australian capitals) operates a separate network of different routes (numbers and structure) on weekends. For many years, there existed only two Rapid routes—the Blue Rapid (300 series) and Red Rapid (200 series) services—which connect Canberra CBD with its four town centres[22] of Belconnen, Woden (Phillip), Tuggeranong (Greenway) and Gungahlin. In recent policy developments, an expanded strategic transport corridor network was envisaged in the 2012 masterplan *Transport for Canberra* (ACT Government, 2012). In subsequent years there was no progress on these additional Rapid corridors (despite clear progress targets set) but coming into the 2016 territory election, the Canberra Liberals released their bus-based alternative to ACT Labor's light rail proposal, and so the government was caught 'on the backfoot' and quickly set out their own plans for an expanded Rapid network integrating with LRT, operating seven days a week (Figure 13). Two routes have subsequently been added (for a total of four), with five more on the way to be implemented in April 2019 and coinciding with the light rail's opening.

Figure 13: Transport Canberra's Rapid network (2017).



22 Canberra's spatial structure consists of five independent 'towns' (built around a town centre and multiple group centres), each of which were meant to be self-sufficient to reduce cross-regional commuting. In reality, this exacerbated journey distances since very few centres had the necessary scale to house the workplaces, schools, facilities and other opportunities required to meet people's day-to-day livelihoods.

The present **Blue Rapid** brand evolved from the *Intertown 333* operating non-stop between Belconnen, City, Woden and Tuggeranong town centres. The importance of this trunk corridor has been established for decades with the NCDC (1976) even considering modes such as rail for its development. The hub-and-spoke model worked well for a number of years, as staff at interchanges held connecting buses to allow transfers between the Intertown trunk and local suburban routes. A variety of factors including funding cutbacks led to a deterioration of this model, and in a *Review of ACTION's Services* (Graham, 1997), a 'direct service' model (implemented in 1998) was proposed where trunk services would be through-routed as multiple local services to suburbs in Belconnen, Woden and Tuggeranong—similar to an open BRT system as routes overlayed on the trunk provide frequent service. Stops were also added to the Intertown route (including diversions to major hospitals and a group centre), thereby changing the non-stop service into one serving multiple en route trip generators. Apart from offering one-seat rides and allowing a reduction in the size of interchanges redeveloped (e.g., at Belconnen), the scheme was not without its detractors (Mees, 2012, Mees, 2011), who criticised the inability to operate more specialised fleet (e.g., articulated buses on the trunk and minibuses in the suburbs). MRCagney (2015) also observed very poor loading on the suburban component of through-routes and thus suggested truncation for operational savings. Increasing route length also reduced reliability and despite a very high combined frequency, there continues to be severe platooning in the absence of active headway management. One improvement has accompanied new bus priority constructed including the Belconnen to City transitway (inbound bus lanes and signal priority), adding to existing high occupancy vehicle lanes on Adelaide Ave.

The **Red Rapid** is a relatively more recent addition to Canberra's network. The service was born out of a recommendation in the *ACT Strategic Public Transport Network Plan* (MRCagney, 2009) for a limited stop service between the new town of Gungahlin and Kingston via the City and Parliamentary Triangle. A trial service began in late 2009 as the 727 REDEX (Rapid Express Direct) running from 7AM to 7PM (hence the name 727) every 15 min. These launched with a liveried fleet which was soon discontinued as the service formed a permanent fixture in late 2010 (renamed as Red Rapid 200) but operating as a trunk-only service until through-routing into Gungahlin suburbs was introduced in 2014 (becoming the 200 series). The Red Rapid corridor features a very successful inbound bus lane on Flemington Rd but at the same time suffers from severe congestion along Northbourne Ave. It is this section between Gungahlin and the City which has been the constant focus of BRT/LRT proposals over past years and will form stage one of Canberra's light rail system. The **Black Rapid** (Route 250) between Gungahlin and Belconnen town centres replaced a suburban route in 2014 and has grown in service frequency in the years since, concentrating service resources from other parallel (and circuitous routes) in surrounding suburbs onto the main corridor. The **Green Rapid** was launched in 2017 and brought together two individual routes (combined as part of the Green Line) to form a high(er) frequency and more direct service connecting Inner South suburbs with the City and Woden.

Beyond the Rapids, Canberra also operates a peak period, peak direction express bus service branded **Xpresso** (700 series). The idea behind these services is to provide a quicker journey from residential suburbs in Belconnen, Woden and Tuggeranong into the City and Parliamentary Triangle, by offering a one-seat ride and bypassing local town centres.[23] Alternative travel will necessitate a connection between a suburban route and their respective Rapid trunk (for most suburbs which do not enjoy a through-routed Rapid). Originally, Xpressos existed as an independent network with limited overlap with suburban routes, but in 2014 these were better aligned (including more intuitive route numbers) to operate as a variant of existing route services. A number of Xpressos also operate from Woden bus station to the Parliamentary Triangle and business parks at Campbell Park, Majura Park and Fairbairn. The Xpresso product as a peak-first offering is notoriously resource intensive and responsible for Canberra's high operational peak-to-base ratio (Wong, 2014). Split shifts (which are limited to 30% of all shifts as per their enterprise bargaining agreement) could well involve one or two inbound Xpresso trips in revenue service with the rest of the time spent dead running. The Xpresso product in providing such a direct (but time-limited) service offering also encourages people to travel within peak periods, hindering efforts to smooth peak demand. The recommended approach is to alter variables such as service frequency and perhaps stopping patterns in response to demand, but never entire route structures (Walker, 2012). For these reasons, the Xpresso network will be discontinued and kilometres redistributed including on upgrading and extending the Rapid network as part of the next network launching April 2019.[24] There is one other BBS in Canberra—the Free City Loop—using a dedicated fleet of liveried midibuses, but these are beyond the scope of the present study.

23 There are no Xpressos operating from Gungahlin since direct services are provided by the through-routed Red Rapid (200 series).

24 Under current proposals, the only Xpresso-type services (though no longer branded as such) which will remain are Routes 180, 181 and 182 operating from southern Tuggeranong (Gordon, Condor and Banks) to the City via Tuggeranong Parkway and Monaro Highway, bypassing both Tuggeranong and Woden town centres.

8.2 Lines

Canberra's frequent network has also included the Green and Gold Lines, although the former has been upgraded to the Green Rapid and the latter will be replaced by Rapid route R5 in April 2019. Despite its eventual phasing out, the concept of branding frequent corridors where routes overlapped is sound and offers great potential for broader application. On the advice of Jarrett Walker, a public transport consultant, the ACT Government took a tangle of infrequent routes which individually offered scattered frequency due to poor scheduling (including bunching),[25] but after a clever revision of timetables built up effective frequency on corridors where the routes overlapped for zero additional cost (Wong, 2014).

Routes 2 and 3 were branded to form the Gold Line and Routes 4 and 5 the Green Line, and both combined the 20-30 min headways of individual routes to offer a 10-15 min service where they overlapped. Importantly with the branded signage at stops and marketing material, this combined frequency is legible, and together with the Blue and Red Rapids, offer extensive service coverage around the City and Parliamentary Triangle (Figure 14). One of the authors in this present report (in his previous role) extended this concept of improving effective frequency by better scheduling routes on other corridors including Athllon Dr, and also between key origins and destinations including at the group centres Erindale, Chisholm, Calwell and Weston.

Figure 14: Canberra's City and Parliamentary Triangle frequent network

Source: Walker 2010

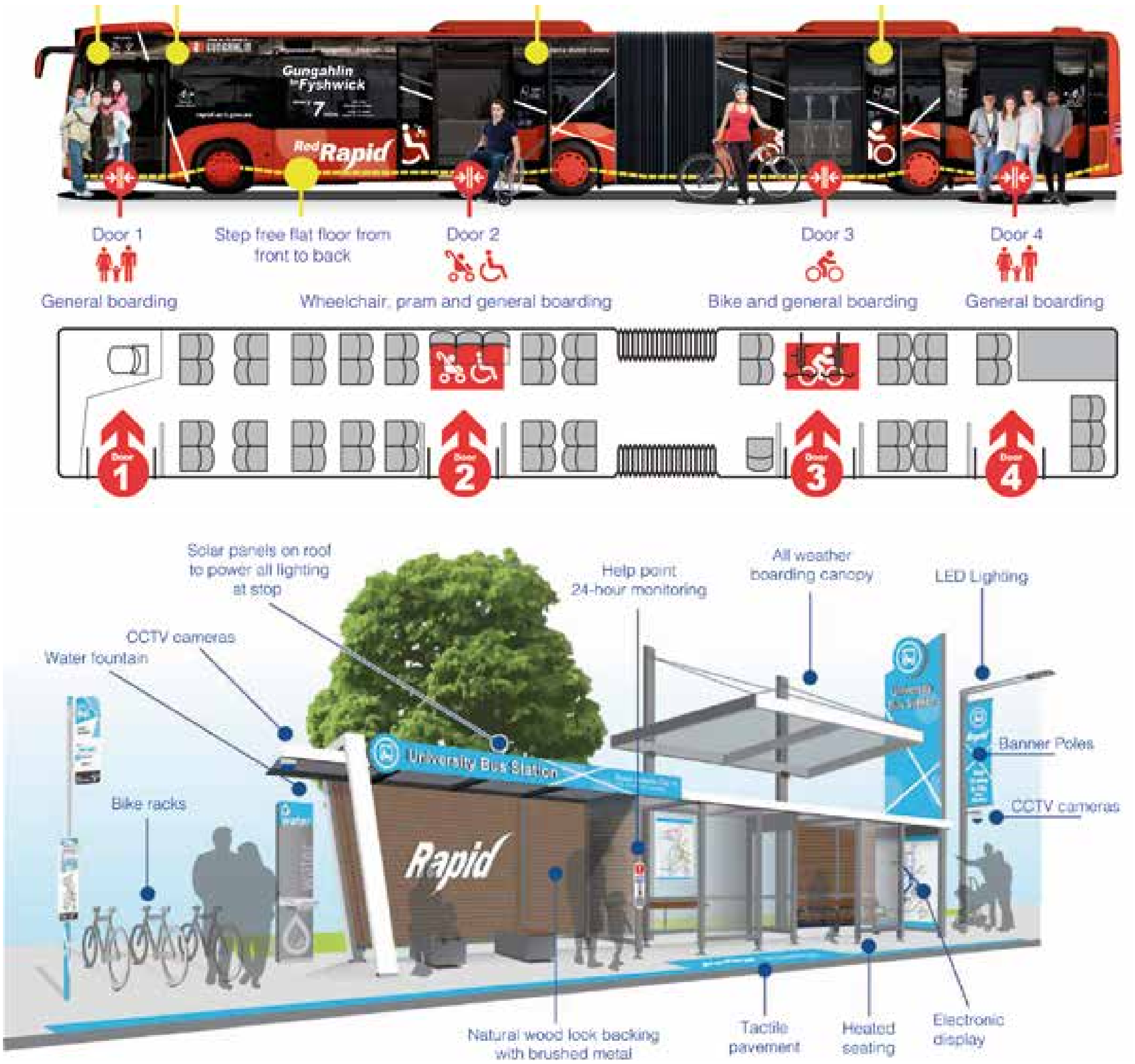
25 Such issues are very severe in Sydney at SMBSC contract boundaries, including on the A3 Ryde Rd and A38 Warringah Rd, and even within a single operator (e.g., Richmond Rd).

8.3 Alternative proposals

Walter Burley Griffin designed Canberra with wide avenues and medians which were earmarked for streetcars over 100 years ago. In the time since, LRT proposals have emerged time and time again, and been the subject of countless studies. This bus versus rail debate has again ensured in recent years surrounding the Gungahlin to City light rail corridor. The ACT Labor government undertook in the 2012 election to conduct another study, but when forced into minority government with the Greens promised to construct LRT in their coalition agreement. Contracts were signed just prior to the 2016 election, and as part of their election platform the Canberra Liberals undertook to terminate contracts should they win government—akin to the Andrews Labor government in Victoria who threatened to cancel the East-West Link contract which they followed through upon winning in 2014. Led by Alistair Coe, the opposition offered their alternative vision *Canberra's Transport Future* (Canberra Liberals, 2016), based on a significant expansion of the Rapid network, including upgrading to true BBS standards. This prompted the Labor government to hastily release their own Rapid expansion plans which (despite some delays) are being carried out having been re-elected (Figure 13).

Canberra's Transport Future included an AUD 20 million boost to ACTION's annual operating budget, six new Rapid services, free travel after eight paid journeys (adapted from Brisbane and Sydney), a seven-day network and services running until 1AM on Thursday, Friday and Saturday nights. Of particular interest is a new Rapid bus fleet, each colour-coded and significant upgrades to Rapid bus stops and stations (Figure 15). The fleet of Mercedes Citaro articulated buses[26] would have offered comprehensive passenger information systems, four double-doors plus all-door boarding. Customer features on the proposed stops would rival even the best BRT systems in the developed world. Some bus priority would also have been delivered including bus lanes on Northbourne Ave. The entire package of proposals if implemented (although unlikely given their allocated budget) would have become Australia's best BBS.

Figure 15: Route-specific branding for buses and stations on an expanded Rapid network proposed by the Canberra Liberals for the 2016 ACT election



Source: Canberra Liberals 2016

26 Incidentally, these proposed vehicles are not permissible on Australian roads, being the European standard 2.55 m wide. The maximum allowable width (excluding mirrors) on Australian roads is 2.5 m.

9. Gross performance comparison

Having showcased each BRT and BBS in Australia with a focus on system-specific challenges and constraints, we now evaluate their relative success according to our devised index of performance (see below). A number of characteristics have been selected, segmented by individual BRT, BBS and generic route services as inputs into our criteria for comparing and assessing the performance of each system:[27]

- Total vehicle service kilometres
- Average service headway (every x min) in weekday AM and PM peak (directional), weekday inter-peak, and weekends. The weekday time of day segments are: AM peak (7:00-9:00AM; 2 hours), inter-peak (9:00AM-4:00PM; 7 hours), and PM peak (4:00-6:30PM; 2.5 hours)
- Percentage of route distance that is in priority lanes or carriageway in each of the weekday AM and PM peak (directional), weekday inter-peak, and weekend periods[28]
- Average speed (km/h) in weekday AM and PM peak (directional), weekday inter-peak, and weekend periods
- Total passenger boardings per annum
- Average number of passenger boardings per vehicle service kilometre.

Whilst more detail has been provided for Sydney (appended as a report companion), to be able to compare the six cities in Australia (Sydney, Melbourne, Brisbane, Perth, Adelaide and Canberra) where there exists varying quantum of BRT and BBS, the data set is limited to the items summarised above. In addition, it must be recognised that some comparisons make more sense within the one metropolitan area given differences in the scale of services and the characteristics of the service delivery areas with respect to population density, road quality and the overall supply of public transport (including the presence of competing modes). For example, the overall vehicle service kilometres in Sydney are ten times greater than Canberra and cover a much greater catchment area and population with much greater traffic congestion in peak periods. We do, however, define a number of features of the various systems that represent either a service-specific feature or a context-specific setting potential influence to capture these effects as summarised in Table 4 in Section 11.

The authors have developed a performance indicator to capture the relationship between patronage, service kilometres and service frequency. This indicator, which we call the **gross performance ratio (GPR)**, is defined as the ratio of passenger boardings per service kilometre to the frequency of provided services. This measure enables us to comment on the success of each service offering in attracting passengers, consequent on the amount of service kilometres delivered and its embedded service frequency. This aligns well with two important drivers of patronage growth—connectivity (correlated with service kilometres) and frequency.

It is important to add some clarity on why headway is included to adjust the patronage per service kilometres in the GPR index. In arriving at an average headway (the inverse of service frequency), we accounted for headways during three times of day; namely (i) peak period peak direction (as the peak), (ii) inter-peak (measured at 12PM as the trough), and (iii) weekend (usually flat). We then defined average headway as (peak + trough + flat)/3. This approach allows us to capture peaks and troughs and overcomes concerns such as the performance metric being heavily impacted by the span of hours of service. A service with shorter span of hours (e.g., Perth CAT buses) will score highly because the average headway is higher. If we had defined headway as a straight up average, this would have been conflated with service kilometres. Under our formula, headway has a partial correlation of -0.32 with passengers per service kilometre.

In assessing each BRT and BBS system, it is necessary to define a suitable level or scale of analysis. Importantly, there exists an inverse relationship between greater aggregation and the inherent level of variance in each characteristic which is essential for explaining the causes of variability in performance. For this reason, some of the studied BRT and BBS systems of interest are considered in totality (as one unit), whilst for others particular routes (or series of routes) are assessed and compared independently. The rationale is explained below.

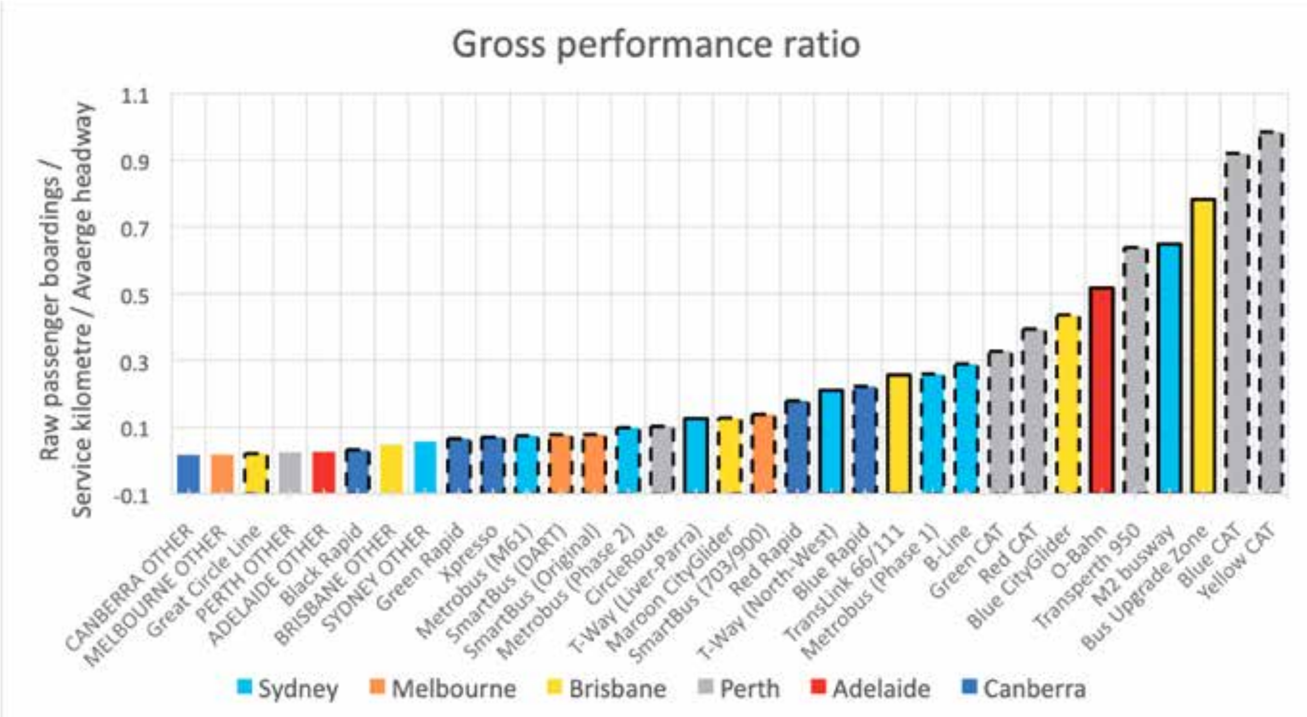
- Sydney's Metrobus Phase 1 and 2 serve different functions ('top-up' versus cross-town orbital) so are segmented for analysis. Metrobus M61 is also assessed separately since it is unique in running express (and at high speed) along the M2 motorway unlike other frequent stopping trunk services which ply major arterials.
- Melbourne's SmartBus is segmented into Original (Routes 901, 902 and 903), Doncaster Area Rapid Transit (DART), and Routes 703/900. These are (respectively) cross-town orbitals, radial express routes via the M3 Eastern Freeway, and shorter connections in the middle suburbs.
- Brisbane's TransLink routes 66 and 111 operate on the busway trunk only and are assessed separately to Bus Upgrade Zone (BUZ) services which capture all busway services including through-routes into residential suburbs in mixed traffic. This tests for differences between closed and open BRT operations and how it might impact on performance statistics.
- Brisbane's CityGliders are assessed independently (Blue and Maroon) since they face different operating environments (and by extension, traffic levels). The Maroon CityGlider operates on significant parts of the South East busway.
- Perth's Central Area Transit or CAT (Red, Blue, Yellow and Green routes) are separated for analysis to capture greater detail in their relative performance.
- Canberra's four Rapid services (Blue, Red, Black and Green) are analysed independently given different operating environments and serving different patronage functions.

27 The authors thank state and territory agencies for the provision of data.
28 This accounts for time-limited priority such as peak-only bus lanes.

What interests us is the relationship between patronage, service kilometres and service frequency. Figure 16[29] compares the patronage per service kilometre against the service frequency over a seven-day period (weekdays and weekend), which we refer to as the gross performance ratio index. It shows the relationship between the number of bus passengers, the amount of provided service kilometres and service frequency (average headway). We would want to see growing patronage when we increase vehicle service kilometres and introduce more frequent services (shorter headways). A high patronage per service kilometre (a larger value) and a higher service frequency (a lower value) will increase the performance ratio. Conversely, a smaller number for the ratio suggests a lower relative level of performance. As examples, the M2 busway in Sydney (rank 4) has a relatively high patronage per service kilometre and a relatively high service frequency, resulting in a higher performance ratio. In contrast, the Liverpool-Parramatta T-way (rank 18) has a relatively lower service frequency and passengers per service kilometre, resulting in a lower performance ratio. Another way of viewing this is to consider how effective the provided service kilometres and associated service frequency are in attracting patronage.

Figure 16: Rank of gross performance ratio defined as raw passenger boardings per service kilometre divided by average headway.

Note: Column outlines represent service type: BRT in solid outline, BBS in perforated outline, and generic services without outline



It is important to clarify how the assessment of the performance of each of the services being compared within and between the six capital cities is justified. Specifically, we fully understand that the locations in which specific services are operating vary greatly between geographical jurisdictions. Influences such as alternative public transport on offer (notably rail), levels of traffic congestion on the roads, population density and other land use factors, all can influence the success of a specific bus-based service.

In this study, the authors acknowledge all of these potential influences (see Table 4 in Section 11). We propose a normalisation process (to be introduced) to obtain what we call a **net performance ratio (NPR)** (in contrast to a gross or unadjusted performance ratio), enabling us to make comparative assessments of what is actually provided by focussing on how well bus services appear to be performing at present, controlling for the role of other effects.

At a very broad strategic level, this provides encouraging evidence on the performance of particular services, and is very useful in messaging the value of BRT and BBS. The focus is on the demand side and not on the cost of providing the service where additional costs are required when there is investment in bus priority infrastructure and dedicated branding of vehicles and stops.

29 Column colours correspond with the (primary) bus livery colour in each city.

10. Rationale for normalisation

Whenever any form of transport service is compared there is always the risk that we end up making comments that amount to comparing 'apples and oranges' and hence relative performance assessment is questionable and of limited value. When there is an interest in comparing the performance of bus systems, it is essential that this is undertaken in such a way that clear and valid statements can be made about how one system performs relative to one or more other services. It is often the case that individuals make comments on how efficient one system is compared to another. The authors are often asked how such individuals can make such comments! A common concern is that "surely they are not comparing like with like?"

While one can never be sure what a specific study actually does to form a view (factual or otherwise) as to how well one system compares with another (or indeed an entire sector), there are nevertheless some good practical and meaningful principles to adhere to so that sensible debate can occur. The great majority of commentary appears to be based on a simple comparison of key performance indicators (KPIs) measured in terms of what we call the gross level (e.g., passengers per service kilometre as observed). The failure to recognise sources of influence on such KPIs that are not under the control of the system (such as location) and which vary by contextual setting is very poor analysis, resulting in nothing more than a comparison of 'apples with oranges'.

So what should be done? As a start, identify those features of service provision that incur a disproportionate performance impact across the systems being compared—that the system has effectively no control over—and are a recognition of the reality of operating in a specific jurisdiction. To make a valid comparison, these differences must be recognised and accounted. We call this **'normalisation'**, although some people often talk of 'standardisation'.

In the context of metropolitan bus operations in Australia, with a focus on performance related to passengers accommodated by the provision of service kilometres and service frequency, the main influences that are outside the control of most systems are likely to be associated with the location of the services. If there are circumstances that give a particular service an advantage over another simply because of external contextual influences, then these must be controlled for; examples would include location such as city and intra-city geographical service areas (e.g., the CBD or inner suburbs). Such spatial contextual influences are proxies for population density, the availability of competing modes and other considerations.

How does normalisation work? The most popular method involves replacing the impact of a specific influence not under the control of the system (but essentially under the control of the operating environment), with an average (or median) level (across all sampled systems) of a factor that may influence performance. The same rule would apply to all selected influences that need to be 'normalised' as a way of removing the influence of these factors on the comparison of system performance. However, the story does not stop there.

Before we can normalise the KPI of interest, we need to find out what role these normalisation criteria play in explaining differences in the level of the KPI of interest, so that we can then ensure that this role is used as a weight to allow for the replacement of the system-specific level of (as an example) direct competition with other services of the sample of all operations being compared. These weights are obtained using a regression model that assures that all influences on differences in a KPI are accounted for (which includes those influences under the control of the system).

A final comment is a question for all analysts—are valid methods being used to undertake a comparative assessment of performance? As an example, a gross KPI cannot be used to make statements about whether one operation is more or less efficient or has a higher level of performance than another operation (in situations that are potentially so different). A real fear and concern of the authors, is that this is exactly what is happening in many sectors, including the bus transport sector.

11. Net performance comparison

While the gross performance measure presented in Figure 16 (section 9) is interesting, it is also potentially misleading and requires appropriate adjustment to obtain a strictly 'apples with apples' comparison.

To achieve this, we estimated a series of linear regression models designed to identify contextual characteristics that, together with system descriptors, can explain systematic variations in the gross performance ratio index. Table 4 summarises these service-specific and context-specific effects and identifies those which emerged as statistically significant used in the normalisation of the performance ratio.

Table 4: Service-specific and context-specific effects tested for how they influence passenger boardings.

Note: Asterisked (*) attributes are statistically significant and form part of the normalisation model

Category	Attribute (1/0)	Description
Bus priority	Dedicated carriageway*	Substantial section of route (>30%) on dedicated bus-only carriageway separated by a physical median
	Dedicated lane*	Substantial section of route (>30%) on dedicated bus-only lane with the potential for traffic conflicts
	Signal priority	Substantial amount of grade separation or signal priority either as induction loop-queue jumps or transponder-activated signals
	Premium stations	Substantial number of premium stations featuring better customer amenities
Brand identity	Soft branding	Distinct service branding in marketing material, stops and bus destination display
	Hard branding	Exclusive use of branded fleet reducing operational flexibility
Service type	Downtown circulator	CBD loop service
	Radial inner	CBD to inner suburbs route
	Radial outer*	CBD to inner plus outer suburbs route
	Cross-town/Orbital*	Route connecting suburban CBD locations
	Feeder/Coverage	All other services connecting to the high frequency network
Other	Direct competition*	En route competition for a significant section of the corridor (>60%)
	Free service	Service is fare-free
	System-specific dummies*	Controls for all other system-specific effects not otherwise captured
	City-specific dummies*	Controls for all other city-specific effects not otherwise captured

The final model identified 17 influences plus a constant. The model included six city-specific dummy (1,0) variables for Sydney (Syd), Brisbane (Brs), Canberra (Can), Melbourne (Mel), and Perth (Per) (Adelaide being the base); and seven system-specific dummy (1,0) variables for Perth's CAT services (PCat), Brisbane's busways (BBWay), Brisbane's CityGlider services (BCGlid), Canberra's Rapid services (CRapid), Melbourne's SmartBus (SMetB), Sydney's B-Line (SBLine), and Sydney's M2 busway (SM2Bw). Three variables represented location effects—radial/outer (Outer), cross-town/orbital (Orbital) and the presence of competition on the corridor (Comp). Finally, we found both dedicated carriageway (PricWay) and dedicated lane (PriLane) to be statistically significant influences on gross performance. Branding attributes (both hard and soft) did not emerge as statistically significant despite evidence from the literature to the contrary (Currie and Wallis, 2008), perhaps because of unique ways in which branding affects travel choice and behaviour. It has been found that 'hard' factors such as service span and frequency drive modal shift, but once people become regular users it is the 'soft' factors which retain patronage (Hensher et al., 2010). Therefore, the importance of distinct branding should not be dismissed.

Equation 1 is the final formula used to obtain the NPR, using the normalisation procedure explained in the previous section. First we estimate this model using GPR as the dependent variable in order to obtain the parameter estimates. This is a linear regression model with all parameter estimates having t values greater than 1.96 which means that all parameter estimates are significantly different from zero at the 95% confidence level. The overall explanatory power of the model (R-squared) is 0.729 which tells us that 72.9% of the variation in the dependent variable (i.e., GPR) is explained by the variation in the levels of the explanatory variables. To obtain the NPR we use this equation but replace the levels of specific variables (excluding ones that refer to a service dummy variable) by the average of the sample of services. These include PricWay, PriLane, Outer, Orbital and Comp.

Figure 17 summarises the net performance ratio evidence and Figure 18 compares the gross and net performance ratios for the 27 BRT and BBS systems relative to generic route services in the six Australian capitals. As can be seen, there are a number of changes after normalisation that are important to recognise and comment on. The most notable adjustment is the elevation of Brisbane's BRT Routes 66 and 111 (running trunk-only), which exhibited the greatest absolute difference between net and gross performance (moving up from rank 12 to rank 6). However, it does not perform as well as its BUZ cousin despite the latter including suburban running in mixed traffic. This may be attributed to a lower level of service on individual routes relative to a combined service offering. Perth's four CAT services and Route 950 show consistently high performance, despite a slight drop in absolute performance (though its relative rankings remain relatively unchanged) upon normalisation, accounting for the impact of free fares (in the case of CAT) and high service frequency. Adelaide's O-Bahn exhibits the greatest negative adjustment post-normalisation (moving down from rank 6 to rank 13), which means that much of its performance may be linked to system-specific characteristics such as its high operating speed and right-of-way. It means that the O-Bahn ought to perform better than it presently does for its given level of infrastructure and geographic setting. The best normalised performance ratio for Sydney is associated with the M2 busway (rank 5)—and this is considering the impact that NorthConnex construction had on service performance during the period of data collection. Melbourne's SmartBus (Original) perform similarly to Sydney's Metrobus (Phase 2), with both being cross-town orbitals serving the metropolitan fringe. Finally, Canberra's Blue and Red Rapids perform well, though they remain mid-range in the context of all Australian systems.

Of special interest is the performance ratio for all services that are not classified as BRT or BBS. The regular services in each city under the gross performance ratio were ranked 26th (Sydney), 27th (Brisbane), 29th (Adelaide), 30th (Perth), 32nd (Melbourne) and 33rd (Canberra). After normalisation, their rankings changed to 21st (Sydney), 23rd (Perth), 25th (Adelaide), 26th (Brisbane), 27th (Melbourne) and 28th (Canberra). The improvement of Perth and Adelaide is noticeable. What we find is that the performance ratio for generic routes is (relatively) low and supports the proposition that the services provided on regular route services have a worse performance ratio than the majority of BRT and BBS. The exceptions are a number of BBS with performance close to generic route level being Brisbane's Great Circle Line, and Canberra's Green Rapid, Black Rapid and Xpresso services. Poor performance in Canberra is consistent with Australia-wide benchmarks of farebox recovery and other performance indicators (MRCagney, 2015).

To gain a better appreciation of how normalisation has influenced the ranking of systems, Figure 18 compares the gross and net performance ratios. Reading from left to right, the larger negative values indicate that performance has deteriorated after normalisation, in contrast to the right-hand side where performance has improved. Clearly, normalisation has had a noticeable impact on the relative performance of the 33 systems and services, but a large majority have changed only slightly (between -0.5 and +0.5). The top three rankings (Perth's Yellow and Blue CATs, and Brisbane's BUZ) have remained unchanged post-normalisation.

What is very noticeable is the presence of high performing services that are not privileged to have a significant amount of bus priority, and indeed the Perth services stand out as having virtually no bus priority and compete in mixed traffic. One has to be careful in inferring anything about the influence or not of bus priority since the traffic streams in many situations where BBS exists may not justify a dedicated lane given achievable average speeds in mixed traffic (including consideration of stop distances and traffic type—e.g., circulation versus through-traffic). Our regression model of the proportion of a route that is afforded bus priority (either dedicated carriageway or lane) is poorly correlated with average speed, and the reason is largely due to the high incidence of mixed traffic distances in the overall route operation where any gains on a dedicated corridor are dissipated by the performance when off the corridor, resulting in a lower average speed. Sydney's M2 busway and Brisbane's BUZ services (the two top performing BRT) are a case in point where significant sections of route are in mixed traffic off-corridor (both being open BRT systems). Despite limitations, our robust methodology has identified the important attributes driving the system performance of BRT and BBS in Australia. Through a normalisation process, we have benchmarked and ranked the 27 service offerings in Australia, and found a very strong endorsement of the relative performance benefits associated with both BRT and BBS.

Equation 1

The equation used to undertake the normalisation:

$$NPR = 0.1068-0.772*Syd+0.0199*Brs-0.0189*Can+0.1396*Per+0.0293*Mel +0.3065*PCat+0.3678*BBWay +0.0509*BCGlid+0.0763*CRapid +0.0726*SMetB+0.1486*SBLine+0.0244*SM2Bw+0.1252*PricWay +0.0977*PriLane-0.1048*\text{Average Outer}-0.0879*\text{Average Orbital} +0.1038*\text{Average Comp}$$

Figure 17: Rank of net performance ratio defined as normalised passenger boardings per service kilometre divided by average headway.

Note: Column outlines represent service type: BRT in solid outline, BBS in perforated outline, and generic services without outline

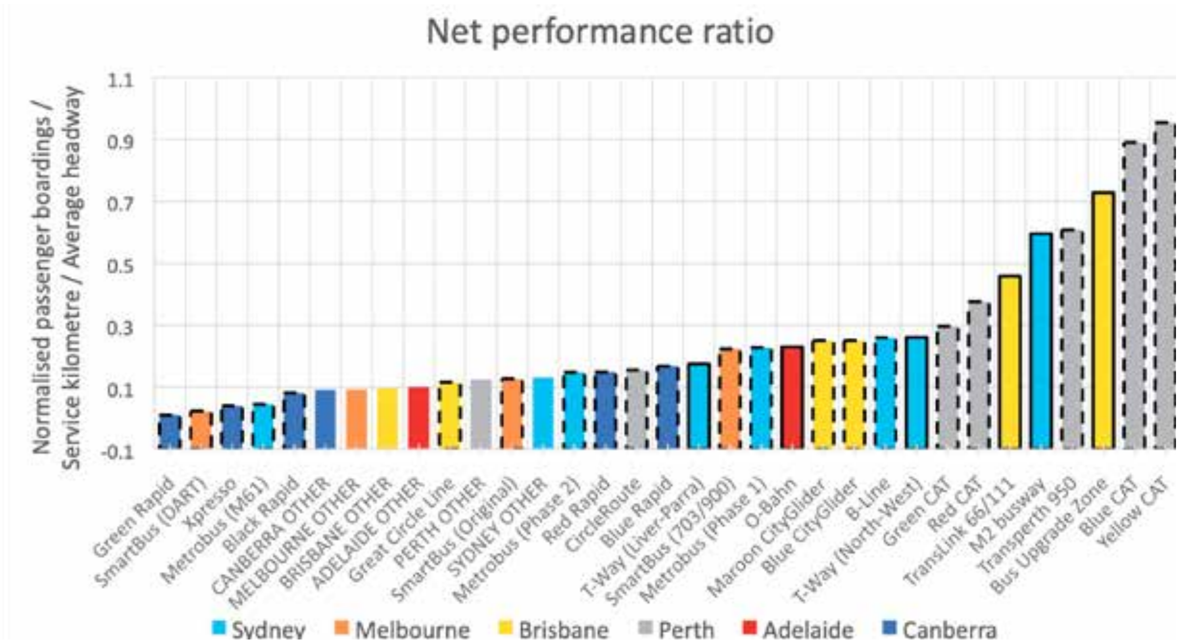
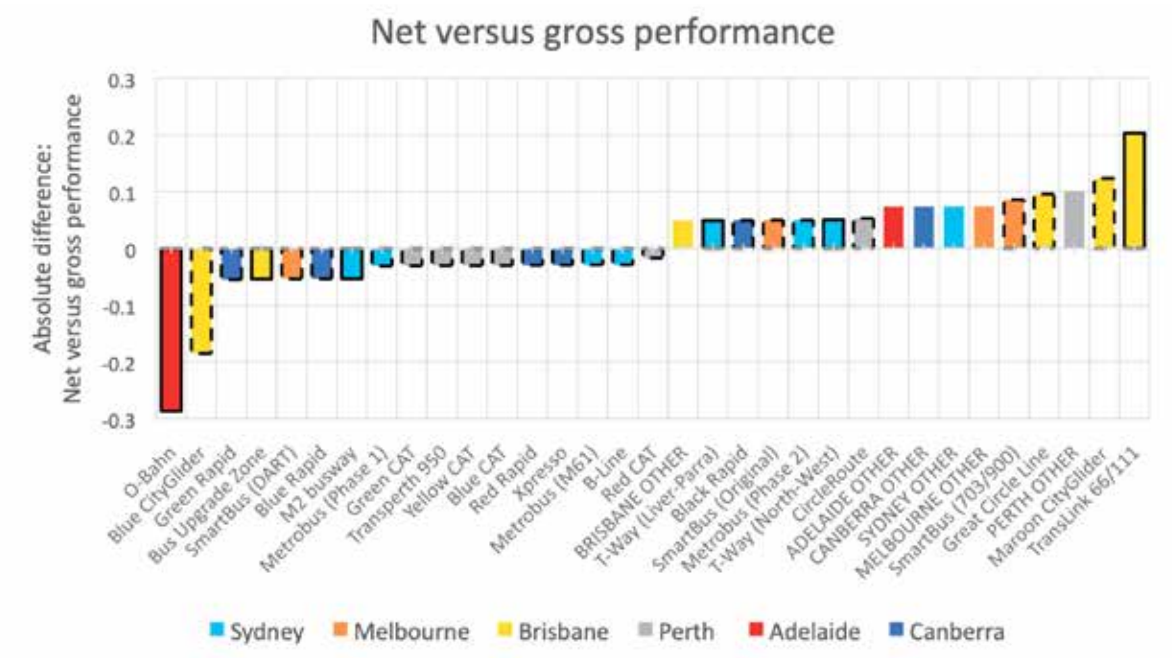


Figure 18: Difference (net minus gross) in the performance ratio of systems under net and gross performance calculations.

Note: Column outlines represent service type: BRT in solid outline, BBS in perforated outline, and generic services without outline



12. Best practice from abroad

12.1 Route and service-specific branding

Two examples from Seoul, South Korea and Auckland, New Zealand have been used to showcase the extremes of service-specific versus route-specific branding. Seoul has implemented a simple citywide colour scheme which makes the structure of the bus network obvious at a glance (Figure 19). The four distinct service types include:

- trunk (blue)—mostly radial corridors on dedicated right-of-way
- branch (green)—feeder buses connecting suburbs to local centres
- rapid (red)—express buses operating from Seoul CBD to across the metropolitan area
- circulation (yellow)—orbital services, which tend to be perpendicular to blue and red routes.

Whilst most bus networks are hierarchical to some extent (e.g., patronage versus coverage functions), this is rarely communicated well to the customer—vehicles look the same, but occasionally route numbers will have some pattern to them so as to hint at the importance of each route. However, most customers will see all routes as generic. There is value in a system similar to that in Seoul so customers can observe at a glance which service type they should board. It also helps in orienting people when the route structure is visible in its most potent form.

The alternative to the Seoul approach is route-specific branding which has been implemented in many cities but particularly prominently (in our region) in Auckland, New Zealand. Over the past few years, Auckland has been undergoing a period of network reform which has finally concluded and now sees the number of people living within 500 m of the frequent network (defined as where services run every 15 min or better) doubled from 215,000 to 530,000. On the frequent network, many of the core routes are branded—including three circulators in the CBD and inner suburbs, Northern suburbs BRT and other specialised services (Figure 20). Northern Express services utilise headway gap displays in the driver's cab so they may see how they are tracking to schedule. Movable off-vehicle ticket validators are also used in peak periods so passengers can use the rear door to board and alight. The 380 Airporter even competes with the commercially-operated SkyBus and provides a frequent and inexpensive connection to Manukau and Onehunga town centres / train stations. Amongst many New Zealand cities, BBS schemes are quite a common fixture—as is the case in the United Kingdom outside London. We believe the economically deregulated environments in these countries has raised the level of competitiveness in the bus industry and so private operators leverage branding to expand the patronage base. The important role of competition in fostering cost efficiency, cost effectiveness and innovation is well known but it is how they are operationalised, for example, through branding and product distinction which is of real interest (Wong and Hensher, 2018).

Quality bus partnerships in the United Kingdom also showcase how public and private enterprise can work together to deliver BRT and BBS and other cooperative intervention initiatives (Hensher et al., 2010). In Leeds, articulated Wright Streetcars (Figure 21) have been operating as Route 72 Hyperlink (formerly *ftr*) to Bradford, based on commitments from the Passenger Transport Executive (in West Yorkshire) to deliver bus priority and from FirstGroup to purchase new fleet and deliver a reliable service. The selection of vehicles mimics light rail in design and appeal to the emotional and biological elements within us. Drawing on this comparison, we will now consider various proposals for optically-guided bus (trackless trams) which has garnered immense interest recently in Australia.

Figure 19: Service-specific liveried buses in Seoul, South Korea.

Note: Red is rapid, green is branch, blue is trunk and yellow is circulation

Photo by Minseong Kim

Figure 20: Route-specific liveried buses in Auckland, New Zealand.

Figure 21: Route 72 Hyperlink connecting Leeds and Bradford, operated by the distinctive Wright StreetCar

Photo by Calum Cape

12.2 Optically-guided bus (trackless trams)

Optically-guided bus is the latest in a long line of initiatives to repackage existing bus as premium rail-based technology. The name 'trackless trams', design of the vehicles and modest deployment cost has appealed to many, and the concept has gained traction in Australia, led by prominent individuals including Professor Peter Newman of Curtin University (a well-known critique of bus-based systems). In *The West Australian* on 28 December 2017,[30] the headline read "Trackless trams could be the answer to Perth's traffic woes", citing that the "Experts say the new technology could be a game changer for Perth". It is 'trackless' because the vehicles are guided by on-board optical systems that follow painted stripes on the road. The news story goes on to quote Professor Newman:

> *….The trackless tram has a number of unique features that makes it particularly attractive, especially the price […] It is estimated to cost between $10-$17 million per kilometre—about four times less the cost of a standard light rail like the MAX system proposed by the previous Barnett government. It could also be made locally […] We have been working on light rail for Perth for several decades—we now believe technology like the trackless tram will be a game-changer for Perth and cities like it […] It is cheap, involves little disruption, can be rapidly brought to market and has all the passenger comfort and ride-quality attributes of light rail—yet it is a new kind of bus on the road.…*

As a result, it does not require the digging up of streets and disruption to businesses, houses or traffic while it is being built. The trackless tram would be electric and powered by lithium-ion batteries that are recharged at each station in 30 seconds. Planning has begun on this 'new' concept of public transport that experts believe will be a game changer for Perth.

Despite the clever use of the phrase 'trackless trams' to give some continuing emotional attachment to light rail (Hensher, 1999), what we are referring to is a high quality BRT system that ticks all the boxes of the Gold Standard (ITDP, 2014)—something that currently does not exist in Australia. Such a BRT system also recognises the value for money proposition where the same level of service can be provided for a cost considerably lower than LRT. As suggested by Hensher et al. (2019b) in evaluating options for the Northern Beaches of Sydney (where the B-Line was introduced in 2017), if we were to spend the same amount on BRT Full as on LRT at the LRT cost level, then BRT Full would deliver a significantly higher benefit-cost ratio, travel benefits and economy wide impacts making it undeniably a much more attractive investment (and value for taxpayers' money) than LRT. The resulting service coverage, frequency, connectivity and visibility would mean that the Northern Beaches (together with the Lower North Shore) of Sydney would see improved accessibility that only BRT and not LRT can provide for the same dollar outlay of investment. This is a very important finding and recognises that the served catchment area can change substantially for a given budget in a way that supports many more 'corridors' of service frequency that is typically not identified in an overly constrained corridor interpretation of project appraisal. Maybe it is time to rethink the context within which benefit-cost analyses are undertaken?[31]

Hensher et al. (2019a) present evidence from a survey of public transport preferences undertaken in five countries (Australia, UK, Portugal, USA and France) by ITLS and the Volvo Research and Educational Foundations Bus Rapid Transit (BRT+) Centre of Excellence on the key drivers of community preferences for BRT and LRT. Service levels can be used effectively to deliver value for money BRT over LRT in the exact same corridor (and indeed many more corridors of BRT) for the same dollar sum as LRT, as clearly noted by Newman for Perth. We hope that the Perth view of a future bus-based system that delivers exactly what the light rail supporters want will send a signal that BRT has great merit and should not be discarded simply because of some emotional attachment to light rail and a misguided view that light rail can carry more passengers than a bus-based system. What matters is not vehicle capacity but service capacity and BRT definitely delivers on this metric. If we have to make our buses look like light rail to win the debate then so be it!

Whilst we applaud the recognition for the role of upgraded bus and BRT (and 'trackless trams'), a certain level of dogma fuelled by more wilder claims about the technology and its potential has taken hold. Many misconceptions have been promulgated which prompts us to set out the facts and debunk the myths.

Myth 1: Optically-guided bus is a revolutionary new technology.[32]

Optical guidance systems date back to the late 1980s[33] and have been deployed with limited commercial success since the early 2000s—we count just three applications in Rouen (Normandy, France), Castellón (Castelló, Spain) and Las Vegas (Nevada, United States).

30 See https://thewest.com.au/news/wa/trackless-trams-could-be-the-answer-to-perths-traffic-woes-ng-b88698244z

31 See http://sydney.edu.au/business/itls/thinking/2018/refocussing-benefit-cost-analysis-start-with-a-budget

32 An abridged fact check of these three myths has been published in The Conversation: https://theconversation.com/looking-past-the-hype-about-trackless-trams-107092

33 See pioneering work on vision-based vehicle guidance systems by Dickmanns et al. and Pomerleau

Whilst mechanically-guided bus remains the most popular—including [Adelaide O-Bahn styled] kerb-guided bus and to a more limited extent rail guidance systems—magnetic[34] and wire guidance technologies have also been trialled to deliver the same benefits including precision docking, lane assist, reduced road footprint and a better ride quality, but doing so for lower cost due to the absence of continuous physical infrastructure.

The three systems in Rouen, Castellón and Las Vegas are all based on the optical 'self-steering' guidance system developed in France by Matra under the trade name Visée, later rebranded as Optiguide upon acquisition by Siemens. The technology utilises a roof-mounted, forward-facing camera to detect a 'virtual rail' in the form of twin, white dashed lines painted on a darker road surface. The image is transmitted to an on-board computer which combined with the speed, yaw and wheel angle of the bus determines the correct path to be followed and in turn adjusts the vehicle's steering mechanism as required. In partnership with Renault, the Civis[35] concept was developed into a transport system based on Irisbus Agora articulated buses fitted with the optical guidance system.

The most extensive deployment has been on the Rouen BRT called TEOR (Transport Est-Ouest Rouennais), inaugurated in February 2001 (Figure 22). The system has subsequently grown to three lines totalling 32 km all using the same guidance technology. The second deployment has been in Las Vegas along Las Vegas Boulevard North on the Metropolitan Area Express (MAX) BRT, which launched in 2004 but was discontinued in 2016. This system was unique in that optical guidance was used for station docking only and not general lane assist. For many years, the technology was deactivated due to poor reliability arising from the desert sun, dirt, grease and oil build-up on the road diminishing the pavement marking's contrast, despite the system stated to work even if just one-third of the stripes are visible. The third implementation (before Zhuzhou) has been in Castellón (Transporte Metropolitano de la Plana), which is an 8 km trolleybus route launched in 2008.

Figure 22: The TEOR optically-guided bus which has operated since 2001 in Rouen (Normandy, France)

Photo by Florian Fèvre, Mobilys, https://www.mobilys.net

34 Most prominent being the Phileas bus, using guidance technology from FROG (Free Ranging On Grid) Navigation Systems.

35 A derivative called Cristallis was also offered which featured a different driver seating configuration to allow driver-operated fare collection.

So what is different this time round?

The present incarnation doing the rounds is admittedly a more advanced deployment of previous optical-guidance technologies. Led by Dr Feng Jianghua, the research arm of Chinese manufacturer CRRC[36] has used high speed rail technology (in particular, relating to the latest Fuxing series) to independently develop what it calls autonomous rail rapid transit or ART (智轨列车). The system is more akin to light rail than any of its predecessors. The vehicle dimensions are larger (2.65 m wide[37] by 3.4 m high), and can be lengthened or shortened by adding/removing sections from each consist. The vehicles (Figure 23) are electric, using supercapacitor batteries which are mounted on the roof and charged via a collector at stations only (which feature an electric 'umbrella'). This allows the vehicles to be 100% low floor (330 mm floor height), as opposed to low entry for most diesel fleets in Australia. Note that the supercapacitor technology is not new, and has been launched in Shanghai (buses), Nanjing (light rail), Guangzhou (light rail) and Ningbo (buses) over the past decade. Despite this, 'new energy buses' in China (including Shenzhen's 16,400 strong electric fleet—the largest in the world) has not taken up this technology, relying instead on traditional lithium-ion batteries.[38]

A major advantage of the CRRC system is its multi-axle hydraulic steering technology and bogie-type wheel arrangement which is designed with less overhang thus requiring less clearance in turns. On the Zhuzhou test track (and as an example for comparison), the vehicles require just 3.83 m of swept path clearance, as compared with 5.74 m for a standard rigid bus. Each section of the 32 m vehicle is around 10.5 m long, and a minimum turning radius of 15 m is required. The cost of deployment is said to be USD 7-15 million per kilometre, as compared with USD 20-30 million for light rail and USD 70-150 million for metro. Capital costs for each vehicle is USD 2.2 million.

Figure 23: CRRC's optically-guided bus (trackless tram) now operating in Zhuzhou (Hebei, China)

36 CRRC is the world's largest rolling stock manufacturer, formed by the merger of CNR and CSR in 2015

37 Hence does not meet Australian 2.5 m width limit as specified by the NHVR.

38 Supercapacitor (or ultracapacitor) buses recharge rapidly, but store just 5% of the energy that lithium-ion batteries can, and are thus limited to around 5 km per charge plus suited only for very predictable routes with frequent stops.

Myth 2: Optically-guided bus offers improved ride quality.

This is true but to an extent only, and has as much to do with traction technology, route alignment and driver behaviour as it has with the optical-guidance variable. Ride quality is a direct result of rubber versus steel traction—think rubber-tyred metros compared with their steel counterparts. The track gauge (narrow, standard or broad) and axle loads (light or heavy) also determine the quality of ride on a railway. Another important factor is the alignment geometry. Light rail can handle only 4-6% gradients whilst rubber-tyred traction can reach 9%. A higher quality bus corridor with smoother gradients and curves will hence offer better ride quality. Pavement quality is another important factor which makes a marked difference to the ride experience.[39]

Optically-guided bus offers a much smoother ride, but this is primarily due to its advanced automation. It is true that the existing bus can be 'jerky', and this has a lot to do with buses getting more powerful (and lighter) over the years. An average bus engine generated 230 horsepower 20 years ago but today this can be up to 330 hp—important for uphill climbs but also allowing the driver (the opportunity) to accelerate quicker. One suggestion is to apply an acceleration limiter (perhaps more accurately the first derivative of acceleration or jerk limiter) in buses so as to limit the potential g-force experienced by passengers. The need for harsh braking is also an issue but linked to the level of bus priority afforded (i.e., traffic signals and traffic congestion) as well as driver training.

Myth 3: Optically-guided bus will be game changing for the provision of transport services and infrastructure.

Two issues with optical guidance technologies have not been considered in the present debate such as the Civis. These remain proprietary technologies so there are always huge risks when locked into a single supplier. Secondly, the technology remains unproven for snow, heavy rain and fog conditions—and environmental constraints can be quite problematic as proven in the Las Vegas case. The potential success of the technology, however, is not related to whether the buses are optically-guided or not (nor linked to any of the above described characteristics, for that matter).

The modern, sleek, rail-type appearance of these vehicles certainly appeals to the cultural and biological elements within us. There is the potential for optically-guided bus to challenge the age-old adage that "buses are boring, and trains are sexy" and what we term at ITLS as choice versus blind commitment in the bus and rail debate. The challenge always is to avoid being emotionally fixated on technology, but rather choosing the appropriate mode to meet a particular transport requirement. However, the core characteristics of transport service are 'invisible' to the customer—frequency, service span, travel time and connectivity. Running on the road, right-of-way quality remains the critical defining factor. What good is a 'trackless tram' if it continues to be stuck in traffic?

In car-dominated Australia, governments have struggled to reallocate road space away from inefficient private cars (averaging just 1.1 people per vehicle for journey-to-work) to spatially-efficient mass transit. Whenever bus priority is built, it usually arises from the widening of a road rather than any redesignation of existing road space.[40] As long as this mentality holds, we will struggle to improve the relativity of bus as compared with car—and this is the most important element for attracting users onto public transport.

That said, if 'trackless trams' can radically alter the political paradigm and garner the necessary support amongst the community for the sensible reallocation of road space including the provision of at-grade signal priority, then there exists a huge opportunity for the cost-effective deployment of high quality mass transit. After all, priority is the key to efficiency and urban amenity. ITLS research has shown there to be huge latent demand for public transport in the middle and outer suburbs of Australian capitals. We believe this to be where the technology holds its greatest potential, and can readily be deployed along cross-town and orbital strategic corridors presently serviced by (for example) Metrobus in Sydney and SmartBus in Melbourne. Time will tell whether 'trackless trams' can shift the conversation including altering the idea of permanence and fixed infrastructure from one synonymous with rail to the pressing issues of right-of-way quality and public transport priority.

39 A prominent example of how pavement quality affects the ride may be found in Melbourne's Albert Park where roads are built with high specification concrete to accommodate the Australian Grand Prix.

40 Historically, the (incorrect) argument made for LRT has been that it does not take away from road capacity, but rather adds to public transport capacity.

13. Discussions

It is an unfortunate reality that bus-based investment has at times struggled to gain political traction in Australia. An example is Infrastructure Australia's national priority list (Infrastructure Australia, 2018a), which is dominated by road projects and urban rail (Brisbane Metro perhaps being the sole exception). Economic analysis has shown time and time again that BRT investment offers far greater value for money than LRT schemes, yet the notion of 'bus stigma' holds truer than ever. In popular media and culture, the bus is painted as a grimy last resort, not a first choice for the travelling public. It is up to academics and Industry to debunk the myths and advocate for sensible policymaking—to showcase the importance of bus as an underappreciated workhorse of our cities. The purpose of this report is to showcase the many BRT and BBS schemes (27 in total) in Australia and to perform some benchmarking (through a sophisticated normalisation process) so as to demonstrate their productivity as compared with regular route services in Australian capitals. The authors have established an evidence base with which to prosecute the value of investing to upgrade bus-based services in Australia.

BRT is not a revolutionary new technology, but a timeless geometric reality. Indeed, the origins of the BRT concept can be traced back to 1939 when the world's first exclusive bus lane was opened in Chicago (Deng and Nelson, 2011). Not being a 'technology', it has struggled to gain the same attention as emerging concepts such as autonomous vehicles, on demand buses and even shared electric scooters. NSW's *Future Transport 2056* strategy is a case in point where there is little recognition of how geometric realities such as right-of-way and transport corridors might limit the potential operation of future technologies (Transport for NSW, 2016). The philosophy of allocating public transport priority continues to be problematic. The conversation is always around building additional road space (through land acquisition or otherwise) to accommodate a bus lane rather than reallocating existing road space for the bus. What is important is the travel time relativity between private car and public transport that can attract users onto more sustainable, spatially-efficient modes. Government mentality continues to be on 'growing the pie' (with links to the concept of Pareto efficiency) and improving both roads and public transport—and so the **relativity** between modes remains unchanged and thus it is little wonder governments struggle to improve public transport mode share (which is almost a universally stated aim). What this does is buy a few more years of accommodation for growth. Not only must there be a far more optimal allocation of road space (with success breeding success), but also the need to incorporate a road pricing mechanism with inputs by time of day, geography and modal efficiency (including passengers per vehicle and proportion of time on the road network). The authors believe future developments such as mobility as a service (MaaS) offers immense opportunities to bring the entire transport system into equilibrium (Wong et al., 2017).

On the topic of relativity, railways with their usually dedicated alignment performs well because there exists not the same corridor competition. BRT even with dedicated carriageway often parallels an existing roadway and therefore relies solely on congestion to increase this relativity. Adelaide O-Bahn, Brisbane's busway (especially the Eastern busway to the University of Queensland's St Lucia campus) and to a lesser extent Sydney's Liverpool-Parramatta T-way are excellent examples of where this is not the case and so perform extremely well in terms of attracting modal shift. Another issue with BRT is the confusion between vehicle capacity and corridor capacity. It is well known that when implemented well BRT routinely offers throughput above 20,000 (and even up to 45,000) passengers per hour per direction—as is the case in many Latin American cities such as São Paulo, Porto Alegre, Bogotá and Curitiba (Hensher and Golob, 2008).

In terms of modal ideology, the preference for rail is driven by both cultural and biological factors. Ride quality is invariably better on a guided system where there is less lateral movement, although we have also explained how pavement quality and corridor geometry might also contribute to passenger experience. It is very much the case that public perception depends very much on their experience of bus and rail systems (Hensher et al., 2019a). ITLS research has shown that people with greater exposure to quality BRT systems (eg., residents in BRT-extensive cities) are more likely to support bus-based investment as compared with rail. Their preferences are conditioned based on experiences of vehicle amenity, network legibility and susceptibility to delays (see previous commentary on bus priority). It is also the case that rail networks are marketed better (simpler) whilst buses remain unnecessarily complicated. BBS and initiatives such as 'trackless trams' are a deliberate effort to make bus and tram feel as similar as possible, although some commentators argue that 'trackless trams' are not BRT—something we dispute if delivered at the Gold Standard (ITDP, 2014). Despite the additional cost and sacrificing operational flexibility (and this is a trade-off policymakers will have to evaluate), the authors have shown there to be great benefit to BBS which in many cases even outperforms BRT. This is despite many being marred in controversy from the outset and introduced only as a quick political fix.

Whilst our modelling has shown branding factors to rate marginally in terms of affecting travel choice, the authors believe there is still value, especially around frequent network branding and network simplification (Currie and Wallis, 2008). It is usually the case that 'hard' factors such as service span and frequency drive modal shift but once people become regular users it is the 'soft' factors which add value to retain patronage (Hensher et al., 2010). It remains a curiosity why BRT systems in Australia lack quality branding or BBS elements. The importance of branding cannot be understated given the complexity of many bus networks. In the same way that street directories (and online maps today) show a hierarchy of roads for different purposes (motorway, arterial, collector and local), frequency mapping can help communicate where all-day, turn-up-and-go services may be accessed. Especially in Sydney, there is a severe fragmentation of frequent network brands (and linked to different political persuasions when implemented) and so we call for a coordinated multimodal (bus and rail) approach for showing the spatial availability of frequent services across the metropolitan area. There are also enormous opportunities to extend this frequent network through clever scheduling (especially on corridors at contract boundaries) to improve effective frequency for zero additional cost (Wong, 2014)—easily implementable 'low-hanging fruit'.

Whilst this constitutes a comprehensive review and benchmark of all BRT and BBS systems in Australian capitals, there remains a number of opportunities for further empirical research. Supply-side constraints such as the costs of construction and ex-post cost-benefit analyses have not been considered, but these are difficult to do at scale and as a comparison. It is more readily conducted at the margin and so we suggest two key areas for future focus. The first revolves around understanding the secondary benefits of public transport priority (Currie and Sarvi, 2012). Whilst passenger travel time savings are well known and usually a key metric for road authorities implementing bus lanes and signal priority, what is less researched is its impact on operating costs, fleet resources, modal shift and even changes in land use. A better understanding has practical implications for future project appraisal. Secondly, it is important to understand the value uplift potential of bus-based projects. Rail is often hailed as transformative and there has been work done investigating the impact of BRT (Mulley and Tsai, 2017), but none so far for BBS incorporating the best branding elements of rail. This is an important research gap considering the potential of BBS to upgrade the image of the bus and as an ever more attractive alternative to fully-fledged BRT or rail-based schemes in an increasingly financially-constrained environment.

14. Recommendations

There are many findings in this report that we summarise as a set of recommendations for a progressive commitment to positioning bus-based services within the broader remit of government to provide value for money investment in public transport in our cities but also throughout Australia.

Fundamentally, the focus should be on the customer and giving them improved access to public transport, and this requires a recognition of the need to service all of metropolitan areas and not to focus on a few corridors that may deliver high patronage. Rail, in particular, is expensive, albeit popular, but typically is radial and directionally focussed on the central areas of cities (lacking circumferential service support). Changing land use is showing up significant gaps in public transport service levels that require cross-regional travel which is commonly serviced by the car due to the paucity of sufficiently attractive travel times provided by public transport. Greater frequency in localised corridors often carries the high risk of poor coverage and connectivity throughout an urban area creating disparities in equitable levels of public transport service provision. The great appeal of the bus is its flexibility in adjusting to changing demands for improved public transport and this is especially true where the opportunity exists to provide a dedicated corridor solution.

The need to find ways to make public transport more attractive in such settings suggests a greater role for bus, especially where it can be offered with significant bus priority. There is often a high amount of bus capacity in a metropolitan area but the great majority of that capacity has to compete every day with the car and other traffic in congested road settings. The call to 'solve' this by investing in more heavy rail (including metros) is a positive move but it is a very expensive one, and often ignores the possibility of a BRT or even BBS treatment as an initial first investment which may even have sufficient merit in time to continue as the preferred solution. The opportunity to deliver value for money for the taxpayers' dollar has never been so real, as the call for greater investment in transport infrastructure comes at a time of increasingly scarce funding, given demands on the budget from other sectors such as health and education.

This report has provided evidence of the patronage appeal of BRT and BBS in contrast to regular road-based public transport services. There are a number of key recommendations, reinforcing those made in the Bus Industry Confederation's Rapid Transit report (BIC, 2014), which we present as a synthesis from both reports.

Recommendation 1

In any assessment of future investment in public transport, the full range of public transport options should be assessed on a level playing field including the prospect of improving the service levels of existing services (which includes moving some existing regular bus services to BBS). This should be recognised through Infrastructure Australia and equivalent state organisations.

Recommendation 2

Greater visibility of bus services, approaching that of rail, should be a priority. While the patronage benefits have to be weighed up against the costs of upgrading public transport, the need for greater visibility of bus-based transport is clear and shown in this report as a significant contributor to potential patronage growth, after controlling for the environment within which the comparison of services are made.

Recommendation 3

Road-based rapid transit be delivered in small-scale forms and incrementally ramped up so as not to require a massive initial investment. These require minimal expenditure on physical and network infrastructure and include change of service measures, branded buses and priority measures for existing routes through to dedicated right-of-way, where practical, by reallocating existing road capacity.

Recommendation 4

There should be greater government and community support in recognition of roadbased rapid transit due to its wider range of service types and flexibility of operation that can uplift the community and social inclusion value of an entire public transport network.

Recommendation 5

Given that road-based rapid transit provides the flexibility to operate on a closed and/or open system, including the provision of similar operation and customer service characteristics of rail-based rapid transit, then it should always be assessed as an possible alternative to a rail solution, especially light rail, and the recent interest in 'trackless trams' offers an appealing setting within which to promote this initiative.

Recommendation 6

The secondary impacts (network effects) of public transport priority on congestion, infrastructure savings, mode choice, social inclusion and land use are not well understood and has been identified as a research gap requiring further study. There is also a need for a coordinated multimodal approach in the assessment of frequent (trunk) services across Australia through the development of a consistent national benchmarking methodology so as to place different modes, cities and operational paradigms on a level playing field in service assessment and project appraisal.

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Appendix: Included routes in each service cluster

City	Service cluster (Table 1)	Service cluster (Figures 1, 2 and 3)	Included routes
Sydney	T-way (Liverpool-Parramatta)		T80
	T-way (North-West)		S8, T60, T61, T62, T63, T64, T65, T66, T70, T71, T72, T74, T75, 602X, 607X, 613X, 616X, 617X, 619, 705, 706, 708, 711, 715, 740, 744, 745
	M2 Busway		M61, 602X, 607X, 610, 610X, 611, 612X, 613X, 614X, 615X, 616X, 617X, 618X, 619, 620N, 620X, 621, 622, 627, 628, 642, 642X, 650, 650X, 652X, 653, 740
	Metrobus (Phase 1)		M10, M20, M30, M40, M50
	Metrobus (Phase 2)	Metrobus (Phase 2)	M41, M52, M54, M60, M61, M90, M91, M92
		Metrobus (M61)	M61
	B-Line		B1
Melbourne	SmartBus (Original)	SmartBus (Original)	901, 902, 903
		SmartBus 703/900	703, 900
	SmartBus (Doncaster Area Rapid Transit)		905, 906, 907, 908
Brisbane	Bus Upgrade Zone (BUZ)	Bus Upgrade Zone (BUZ)	66, 100, 111, 120, 130, 140, 150, 180, 196, 199, 200, 222, 330, 333, 340, 345, 385, 412, 444, 555
		TransLink 66/111	66, 111
	CityGlider	Blue CityGlider	60
		Maroon CityGlider	61
	Great Circle Line		598/599
Perth	Central Area Transit (CAT)	Red CAT	1
		Blue CAT	2
		Yellow CAT	3
		Green CAT	5
	CircleRoute		998/999
	Transperth 950		950
Adelaide	O-Bahn		500, 501, 502, 502X, 503, 506, 507, 528, 530, 540, 541, 541X, 542X, 543X, 544, 544X, 545X, 546X, 548, 556, 557, 559, 578, C1, C1X, C2, C2X, J1, J2, M44, N502, N541, N542
Canberra	Rapid	Blue Rapid	300, 313, 314, 315, 316, 318, 319, 343 (weekend 300 trunk-only)
		Red Rapid	200, 251, 252, 254, 255, 259 (weekend 200 part-only)
		Black Rapid	250 (weekday-only)
		Green Rapid	6 (weekend 938)
		Xpresso	705, 712, 714, 717, 718, 719, 720, 725, 726, 732, 743, 744, 749, 765, 767, 783, 775, 791, 792 (weekday-only, peak-period peak-direction)

Solutions for Policy Thinkers Series

EXECUTIVE SUMMARY

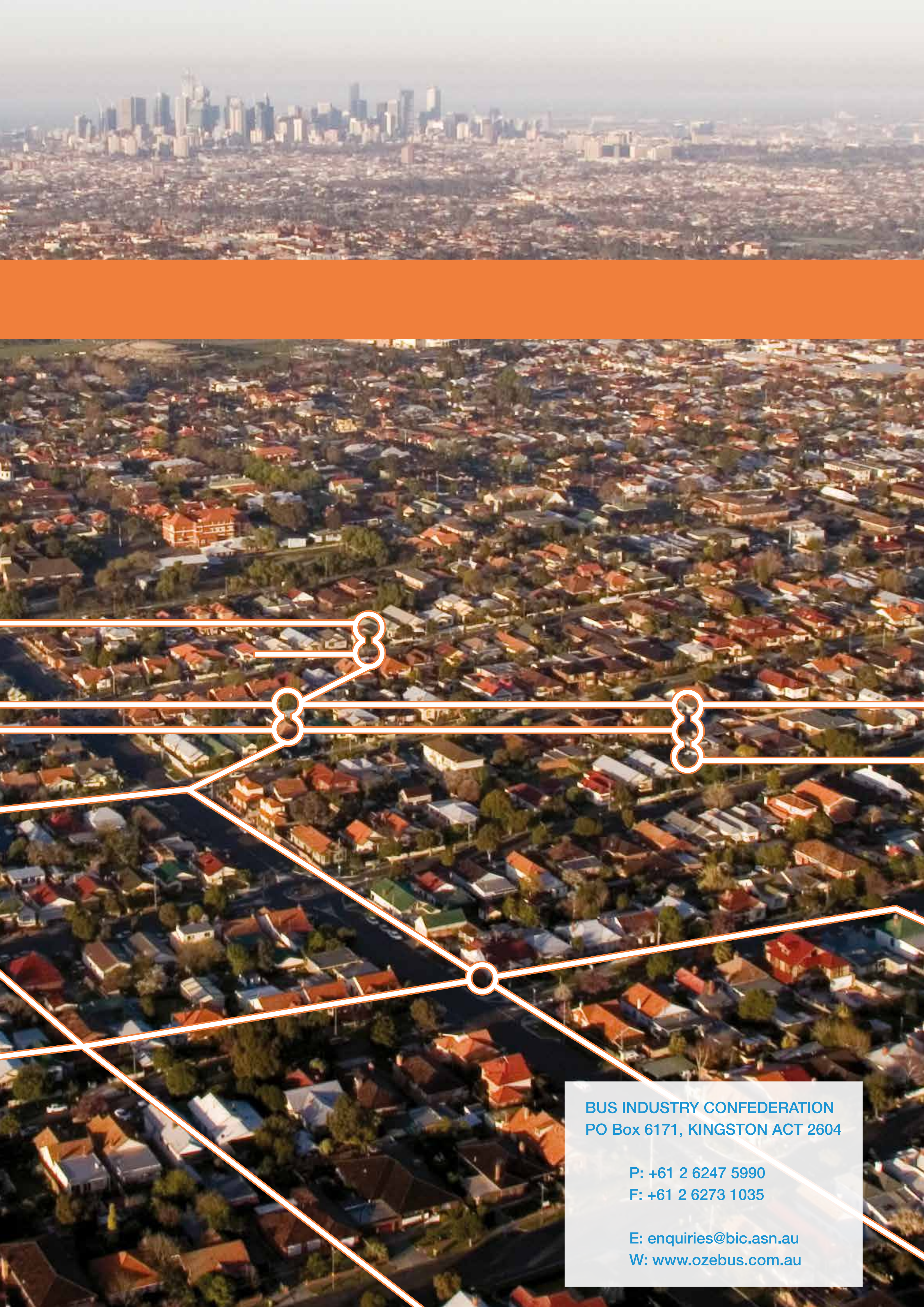
TITLE	SUMMARY DESCRIPTION
Policy Thinkers Series - 11 Published June 2019 **Moving People in the Future: Land passenger transport and "new" mobility technology**	This Paper explores socio-economic trends and their interaction with new technologies, largely by developing optimistic and pessimistic scenarios about how the future of land passenger transport might emerge in coming years. Policy measures to help ensure that emerging transport technologies are net contributors to social welfare are outlined, including transport pricing reform, urban land use/transport planning to promote more compact towns and cities and to slow urban sprawl, together with shared mobility contracts to support social inclusion from local transport.
Policy Thinkers Series - 10 Published - May 2018 **The value of getting there: mobility for stronger Australian regions**	Mobility is a fundamental requirement for well-functioning regions and for the wellbeing of their residents (and visitors). This Paper first examines the potential for agglomeration economies from mobility improvements in Australian regions, concluding that this prospect is most likely to be relevant for those regions with the largest urban centres (e.g. 200,000 population).
Policy Thinkers Series - 9 Published - June 2017 **Improved public transport services supporting city productivity growth: *an Australian city case study***	Australian cities are increasingly pursuing compact settlement. This paper explores the opportunities to use urban structure to promote productivity growth. It examines the contribution of population and employment density and travel times.
Policy Thinkers Series - 8 Published - August 2016 **Local government roles in C21 integrated land use transport planning**	This Policy Paper examines ways in which local government can support the major development directions and, based on the conclusions from the governance Policy Paper 6, be recognised as a vital partner in so doing. In this Paper we examine desirable development directions for our cities and regions, then explore local government roles in these directions, at both the strategic and local levels.
Policy Thinkers Series - 7 Published - April 2016 **National Guidelines: Bus Services Procurement and Bus Service Contracts**	The bus and coach industry has, for a long time, fostered relationships with academics, industry experts and government, to grow public transport services and patronage and to help develop contractual frameworks that support this growth. These connections and experience have been utilised in preparing the enclosed guidelines. These guidelines have been framed with public value uppermost in mind, while recognising the importance of a financially viable bus industry if quality bus services are to be provided on a sustainable basis for our communities.
Policy Thinkers Series - 6 Published - October 2015 **Governance for integrated urban land use transport policy and planning**	Australia is relatively unusual in having state governments responsible for (speaking for) capital cities. This role is more commonly associated with local government in some format. The difficulties Australian cities have in establishing and pursuing integrated strategic land use transport policy directions over time is partly a function of our adversarial political environment. This Paper looks at governance, with a particular focus on integrated governance in land use transport policy and planning and how it might be improved in Australian cities, to enable them to deliver better economic, social and environmental outcomes.
Policy Thinkers Series - 5 Published - October 2015 **Urban land use transport integration and the vital role for Australia's forgotten inner/middle suburbs**	Australia's capital cities are all seeking to achieve more compact settlement patterns, as an essential element for improving their long term sustainability. The inner/middle suburbs are vital to successful outcomes. This is where most urban Australians live and work. This paper examines how strategic land use transport policy in our major cities can be shaped to promote productivity growth and better share the benefits from this productivity growth more widely among city residents.
Policy Thinkers Series - 4 Published - March 2015 **Connecting Neighbourhoods: The 20 minute city**	A '20 minute city' is one in which most people are able to undertake most activities needed for a good life within a 20 minute walk, cycle or public transport trip from where they live. This Policy Paper puts forward that a neighbourhood structure embedded in a 20 minute city, with good local and regional transport choices, is likely to promote many positive outcomes in terms of personal and societal wellbeing, enhance liveability (which is already a strong international brand for our cities), as well as being cost effective to service and supportive of increased economic productivity. Flowon effects will include lower traffic congestion levels, improved health outcomes, lower accident costs, reduced emissions (greenhouse gases and air pollutants) and greater social inclusion.

TITLE	SUMMARY DESCRIPTION
Policy Thinkers Series - 3 Published - October 2014 **Public transport: funding growth in urban route services**	BIC's various *Moving People* publications have made the case for increasing the provision of public transport services in Australia's cities, both because of the benefits these deliver for service users but also, and perhaps more importantly, for the wider nationally significant economic, social and environmental benefits they deliver. A current Australian infrastructure backlog of about $150b had been estimated. Public transport forms an important part of this backlog.
Policy Thinkers Series - 2 Published - June 2014 **Sustainable transport in Australian cities: targeting vehicle kilometres of travel**	Overall urban densities in our cities need to increase by 50-100 per cent over the next 30-40 or so years, with allowance for local circumstances. This will enable greater availability of local services, including local public transport. Minimum density targets of about 35 people plus jobs per hectare should be adopted in land use/transport strategies/plans for our cities, to both support development of 20 minute neighbourhoods and provide an effective market for local and trunk public transport. This Paper takes a unique approach to understanding the challenges of Australian cities and the interrelationship between land use strategies and reducing vehicle kilometres travelled.
Policy Thinkers Series - 1 Published - March 2014 **Pricing opportunities for Australia: Paying our way in land transport**	Pricing is the hot button issue in the infrastructure and transport policy space. Paying our way for the use of our roads is the key to ensuring that infrastructure gets built when and where it is needed. The BIC supports the development of a comprehensive user pays system for all road users that is based on the costs of maintaining and building roads and externalities related to driving that will generate future revenue to fund infrastructure and pay for better public transport services.

Special Edition Policy Papers

EXECUTIVE SUMMARY

TITLE	SUMMARY DESCRIPTION
Published - April 2019 **Coach solutions for driving land transport tourism**	This Paper outlines a 10 year strategy policy for driving land transport tourism. There are 9 key areas that all levels of government and industry should adopt to increase travel by coach to generate dispersal of tourists from major cities and attractions to regional Australia and grow Australia's tourism economy.
Published - May 2018 **Australian Government's role in the development of cities**	Cities are becoming more complex and this poses challenges for policy and planning. Links between land use, transport, economic productivity, housing markets and social exclusion illustrate this complexity. Integrated governance is central to tackling such cross-cutting issues. Awareness of the importance and urgency of taking more integrated approaches to city strategic land use transport policy and planning is widespread and practice is generally improving. However, the rate of improvement in land use transport planning capability in Australia, and more broadly, is running ahead of improvements in governance (and funding arrangements).
Published - July 2016 **Improving public transport service: Hobart – A corridors case study**	Hobart faces more traffic congestion problems and slower public transport unless city planners make sensible land-use and transport decisions going forward. This report finds that Hobart is very low density and car dependent, and that structural changes in the economy were leading to the highest productivity jobs being located in central or inner parts of the city. The study also found that jobs were moving in at the same time as people were moving out for cheaper housing, and Hobart's fringe densities were as low as they went in Australian cities.
Published - March 2014 **Rapid Transit: investing in Australia's Transport Future**	This report has been developed as a result of the Bus Industry Confederation undertaking a two week Rapid Transit Study Visit of North America in August and September of 2012 and information collected by the BIC's internal research program. The report analyses the advantages of building Rapid Transit against benefits which can be achieved by simply improving existing transport networks, modal considerations notwithstanding.
Published - December 2012 **Moving People Solutions for a Liveable Australia**	This policy statement sees the BIC taking the lead in the national discussion on how we fund *moving people* infrastructure and services in the future. The aim of the report is to generate discussion about how Australia should shape its future land transport policy, to promote national goals for productivity, sustainability, liveability and social inclusion.



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