TITLE: Density and LRT: the case of Canberra, Australia

ABSTRACT: Canberra, the capital of Australia, is a city with two modes of mechanised passenger travel: traditional bus and automobile. While Canberra is the capital of the country, it is a relatively small city, with a current population of approximately 340,000, and relatively spread out with a low overall average population density. The City has grown rapidly over the past 40 years (its 1960 population was approximately 40,000). There are increasing pockets of traffic congestion as a result, and projected slow but steady growth in coming years will make these pockets worse.

The city is a completely planned entity and the original designer, Walter Burley Griffin, incorporated two elements into his urban plan: a series of ‘shops’ to serve each community, allowing for walkability to basic services; and a tram system to link communities. The shops element of the original plan has largely been followed and is roughly incorporated into current development plans which densify the urban core and lay out increased economic and population density in existing communities. However the light rail element was never implemented.

Recently the local government (the government of the Australian Capital Territory) submitted a bid to the Australian federal government to fund a light-rail system for the city. This paper examines the issues of serving low and medium density communities with light rail, using Canberra as a case study. The study sets the scene by qualitatively and quantitatively characterising the socioeconomic and demographic profile of Canberra, with a focus on centres of population and economic density; reviews the literature on LRT for low-to-medium density areas, focussing on Australia; and analyses what an LRT in Canberra would look like if it is to be financially, operationally and environmentally sustainable.

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1. Introduction

What is the critical mass of population size and density, economic activity and financial base beyond which 'structural' transit alternatives (i.e. bus rapid transit (BRT) and light-rail transit (LRT)) become viable for a given service area? This is a key question that small and medium-sized cities often must ask when considering investment in such alternatives.

Canberra, the capital city of Australia, is an example of such a city that is currently considering building an LRT. Opponents of such plans argue that the city is too small in population, not densely populated enough, full of car-loving people and does not have, nor never will have, the sorts of traffic congestion that would require expansion of transit beyond traditional buses. But proponents argue that there are viable service areas for an LRT and that population and development trends in the city will require structural transit investments. For this reason, the local Canberra government (the government of the Australian Capital Territory, the equivalent of a State government) recently submitted a bid to the Australian federal government to fund a light-rail system for the city.

This paper examines the issues of serving low and medium density communities with light rail, using Canberra as a case study. The study reviews the literature on LRT for low-to-medium density areas; qualitatively and quantitatively characterises the socioeconomic and demographic profile of Canberra; analyses what an LRT in Canberra would look like if it is to be financially, operationally and environmentally sustainable; and develops some 'lessons learned'.

1. Tipping points for LRT: what the literature says

What is LRT? One author cites the Transportation Research Board (TRB) definition: “Light Rail Transit: A metropolitan electric railway system characterised by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways, or occasionally, in streets, and to board and discharge passengers at track or car floor level.” He adds more informally that, “If a line or system is in fact a version of something that could legitimately be identified as streetcar, trolley, or interurban, then it is LRT.” (Boorse 2007, 443)

When it is viable to construct and operate an LRT? There are three basic dimensions to consider in answering this question: cost, density and operating environment.

First, cost. As the definitions above make clear, LRT represents a substantial capital investment for any area considering building one. A meta-review of literature on capital costs of LRT, focussing on North American systems, estimated that the average capital cost per route mile was $26.4 million (all figures in 1990 US dollars). The range for this capital cost was substantial however, from $9.4 million to $90.19 million across LRT systems. These average capital costs were more than twice as high as those for bus rapid transit

(BRT) but lower than those for traditional heavy-rail metro systems (Zhang, 2009).

Once built, the general rule-of-thumb is that LRT has lower operating costs because it offers higher passenger capacity per unit labour cost. However the literature does not seem to find this as a given. Zhang notes that per revenue-mile, LRT actually has higher operating costs as compared to BRT. Other measures, such as cost per rider and cost per mile often reverse this relationship. The key might be revenue collected per mile: LRT costs more to build than BRT and obviously much more than regular buses so if it fails to attract enough riders, or if fares are set too low, this would push up the revenue-mile operating costs. Vigrass and Smith (2005) note that in the United Kingdom, where LRT projects must demonstrate in advance that they recover operating and maintenance costs, such unit operating costs are lower than in France where there are no such requirements. It must also again be pointed out that there is a wide range of individual system costs, with some specific LRTs having lower operating and capital costs than some specific BRTs.

Density is the next dimension for LRT viability. In general the threshold for a viable LRT is seen as 9 dwellings per acre (equivalent to around 2223 people per square kilometer assuming 4 people per dwelling). This is as compared to a 4 dwellings per acre (988 people per square kilometer) threshold for traditional bus service (Zhang 2009, and author calculations). This metric does not consider economic activity patterns that generate trips; as an extreme example, a very dense population where all leisure and work takes place at home would not generate sufficient trips to support an LRT. Still, given 'average' activity patterns, these basic rules-of-thumb suggest the numbers needed to support a given transit mode, with LRT being on the higher end of the scale in terms of minimum density.

Finally there is operating environment. This is a catch-all term that includes factors such as fiscal capacity, governance institutions, socioeconomy, physical geography/topography and individual attitudes towards modes. If cost and density can be considered to be necessary conditions for LRT adoption, these other factors can be seen as the sufficient conditions that tip a community into or out of such adoption. For example many dense cities in developing countries do not have the fiscal capacity to build an LRT even though the fundamental economics might support adoption of such a mode. Similarly there are physically rugged island communities (e.g. Hawaii) that have dense populations pockets separated by impassable ranges. Communities of similar densities with different operating environments might well be able to build a viable system.

Each of these dimensions will now be considered with respect to the case study of Canberra, Australia.

2. Canberra: a planned city

Canberra is one of a but a few cities in the world to be completely planned and created as a national capital. (Brasilia, Brazil and Washington, DC are two other prominent examples).

Canberra was created after the 1901 Federation as a compromise between potential sites and leading Australian cities Sydney and Melbourne. Situated inland, in the middle of rolling scrub country that Australians colloquially designate as 'the bush', there was little in the way of prior settlement, providing a blank slate for urban design. To contain the city a new administrative unit called the Australian Capital Territory (ACT) was created, being equivalent to an Australian State though without its full powers and much smaller in geographic size. New South Wales (NSW), the State containing Sydney, ceded the necessary land on its southern border.

The Australian government sponsored an international competition for design of the new city in 1911. The winner of that competition was an American architect named Walter Burley Griffin, a former collaborator of Frank Lloyd Wright, who came up with a design with streets organized along radial arterials (similar in concept to the Washington, DC plan), and an artificial lake separating north and south sides of the city. Griffin's original plan is shown in Illustration 1 (Birell 1964).

Griffin did not just devise a static master plan. He also considered how the new city should grow and adopted a modular approach in which small local communities, called 'suburbs', would be the basic building block outward from the core downtown (called “Civic”). Each suburb was designed to be relatively self-sustaining, with residents supplied by a set of local 'shops' for essentials. These shops would be within walking distance from everyone living in that particular suburb. In this way Canberra residents would retain a feeling of local community even as the larger urban area grew.

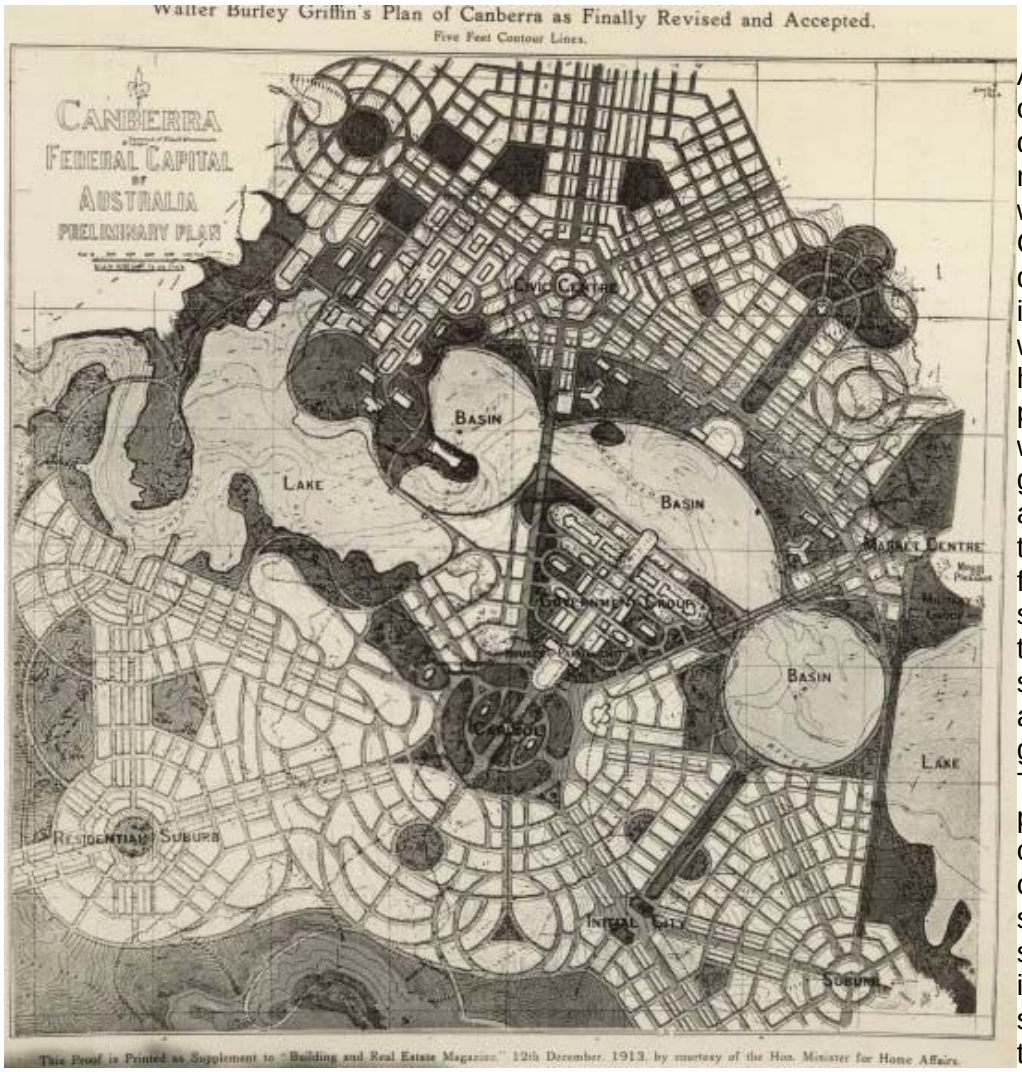

Illustration 1: "Canberra, Federal Capital of Australia, Preliminary Plan" - "Walter Burley Griffin's Plan of Canberra as Finally Revised and Accepted"Source Reproduction of plan from Supplement to "Building and Real Estate Magazine" first published 12 December 1913

An obvious question, which Griffin did not ignore, was how people were to get around the city, from suburb to suburb, as it grew. The presence of a core set of shops in each suburb that people could walk to limited the need for mechanised trips and had other social benefits besides but this design device did not obviously completely eliminate the need for such transport. Thus Griffin also built into his plan a tram system to serve the suburbs which would fan out across the major arterials. With these two struts of local shops and trams in place, Griffin's vision could be fulfilled in practice and without the full surrender to the automobile contemplated and celebrated by other

modernist architectural contemporaries such as Le Corbusier or even Wright, both of whom had ideas of high-rise pockets in broad plains where the car would spirit people from place to place in a grand liberation from the laws of Newtonian motion.

In fact, there was deviation from these two basic premises of Griffin's vision almost immediately, even with Griffin appointed for a time as planning czar for the new locale. In particular Griffin's concept of four radial avenues, Northbourne, Southbourne, Westbourne and Eastbourne, never got past the building of the first of that list. And perhaps more significantly from a transport point of view, the tram, which Griffin had planned for, even to the extent of placement of service yards, and a right-of-way in the middle of Northbourne Avenue, was shelved completely. Although there was an intention to build the system, delays in building the suburbs, followed by the financial scarcities of the Great Depression, caused this element to wither away.

However Canberra has proceeded to grow along the lines of Griffin's vision of suburbs. The building of local shops has not always been followed through in the construction of more contemporary suburbs and some existing shops have faded away with time. Still, while spread out, Canberra has mostly avoided the suburban sprawl that other communities of its size and density have exhibited.

3. Canberra's spatial and demographic outlines

Illustration 2 shows the City of Canberra (the patchwork pattern delineating the outlines of the various suburbs) and how it fits within the broader ACT jurisdiction. The overall area of the ACT amounts to 2,358 square kilometers. In 2006 the Australian Bureau of Statistics (ABS) estimated the population of the ACT to be 333,940. The ACT is surrounded by territory of NSW. Canberra is the major population center in the area, though its next door NSW neighbor of Queanbeyan has an estimated population of approximately 36,000 and Bugendore (approximately 2,200) and Yass (14,000 in the larger government area though the actual town of Yass is much smaller) have significant concentrations of people. Sydney is approximately 200 km to the northwest, the closest large city.

Canberra has experienced rapid population growth over the past 50 years, though the rate of growth has slowed significantly over the past ten. From a population of only around 10,000 in 1939, and with a renewed commitment in the mid-1950s by the Commonwealth government to fully develop the ACT and locate of the public service there, the city grew to approximately 50,000 by 1960, to 200,000 by 1976 and continuing to add another 70,000 by 1988. The remaining 70,000 residents have been added since then and growth is projected to continue at about 1% per annum through 2030 (ABS 2008).
The building of new dense centres with low-rise urban cores, especially in the south of the city, were a key tool to service this growth. The Woden Valley suburb of Hughes was built in late 1963, Belconnen in 1967, Weston Creek in 1969 and Tuggeranong in 1973. Accompanying this residential and town development was the building of large-scale public

office blocks to house public agencies and their activities. The existing suburbs of Canberra are shown in Illustration 3.

Illustration 2: Canberra City and the wider Australian Capital Territory

Being a national capital it could also be added that the ACT is above national averages in terms of education of the population and household income.

From a transport point of view Canberra thus has a mix of elements both favourable and hostile to transit. On the one hand it remains relatively small in size and relatively spread out (though actual settlement remains clustered within a relatively small portion of the overall Territory). On the other hand there are definite town centres and population/activity clusters that could serve as the basis for transit stops and communities. How these factors have played out in Canberra's past and in its current situation are the subject of the next section.

Illustration 3: Suburbs of Canberra (larger names denote areas)

4. The past and prospect of LRT in Canberra

Throughout its history thus far, Canberra has relied solely on traditional buses for passenger mass transit. The administration of these buses has moved into and back out of the structure of the ACT Government, currently being administered by an agency known as ACTION, but basically it is run as a municipal bus service.

Buses in Canberra attract relatively little patronage. In 2001, cars carried 83 per cent of work trips, with public transport carrying 7 per cent, walking 4 per cent and cycling 2 per cent. Compared to Australian averages Canberrans drove and cycled more, walked about the same and used public transport less. It should be noted, though, that the overall Australian usage of transit is not especially high, around 10 per cent (ABS 2008).

This state of affairs has long seen as static and unchanging. Canberra has been characterised as a 'car town' by people no less prominent than the Territory's Transport Minister. However in 2008 there was a shift at the political level regarding official attitudes.

This shift had two election cycles behind it. The first was a national election that swept a new Labor Party government in November 2007, displacing the more conservative 'Coalition' government of Prime Minister John Howard. The new Prime Minister Kevin Rudd announced that he was creating a new body called Infrastructure Australia (IA) which would be considering and funding new investments of 'strategic' significance.

The second election cycle was within the ACT the following November (2008). The ACT is a long-time Labor Party stronghold, and although that party was now holding power at a national level for the first time in 11 years, the long-serving ACT Chief Minister John Stanhope saw a danger of losing his own re-election because of a sense of 'staleness' on the part of local electorate. With his party now in power nationally and with that government calling for infrastructure ideas Stanhope sensed an opportunity. He therefore announced, several months before the election, that his government was going to submit a proposal to IA for an LRT in Canberra.

The 'proposal' consisted of a press release costing an LRT at $1 billion (Australian dollars as are further figures below). Beyond that details were scarce and the press release consisted of an undetailed LRT and a number of seemingly extraneous elements including road improvements. The political motivation was obvious, particularly since the ACT was hoping for full payment of the project by the national government. Nonetheless the policy shift was significant: an LRT was now an official policy objective of the ACT government.

In October 2008, the Stanhope government lost its majority in the Territory Assembly but remained as a minority government supported by the Green party. (The primary opposition party, the Liberals, failed to capitalise on voter fatigue and actually lost one seat). Although rebuffed, John Stanhope remained as Chief Minister and with the Greens part of his

legislative support (they chose not to seek seats in the cabinet, choosing to remain 'independent' but nonetheless explicitly aligning themselves with Labor) the LRT proposal remained as part of the policy agenda.

The proposal continued to make its way through official processes. IA asked that the ACT government prepare a 'business case' for its proposal and the government contracted with Price Waterhouse Coopers (PWC) to prepare and submit this case. (That contract is public but not the resulting report). Then in December, IA announced that a Canberra LRT was on its 'shortlist', and revealed a single line-item costing it at $A2.95 billion. What is actually in this particular shortlisted proposal or whether IA will actually fund the project when it announces decisions is not clear but thus far the project has survived.

5. Density, cost, environment and LRT in Canberra

Canberra could now be facing the question of what an LRT there should look like. And if it fails to get national funding for the project, or gets only partial funding, the question of viability is going to be particularly pressing. Using the three dimensions above – cost, density and operating environment – does a Canberra LRT actually make any sense?

The first element to start with is population size and density. The ACT's 2006 population of 333,940 raises one question: is this large enough to justify an LRT investment?

One way to answer this question is to benchmark against other places that currently have an LRT. Comparisons with other Australian localities would be the first choice of benchmark but Australian settlements follow a basically bimodal distribution: large cities and their suburbs or 'country towns.' Because of its planned nature, Canberra's size is unique in Australia.

One alternative could be the US. The US, like Australia, covers a very large geographic area and has many communities of a similar size. Moreover some of these communities are relatively isolated, not part of an overall dense network as is the case in much of Europe. Thus, for rough comparative purposes, the US was used as a benchmark.

US cities that have LRTs operating for urban populations equal to or less than that of Canberra include Tampa, Florida; Trenton, New Jersey; Galveston, Texas; and Tacoma, Washington. One of these, Trenton, is the state capital of New Jersey, a symbolic parallel to Canberra and the ACT. It is perhaps of some importance to note that most other country capitals around the world have rail transit, though of course most of these cities are far bigger than Canberra (though Washington, DC's population is not especially large in gross terms at 588,292 as of 2007). (APTA 2008)

Of course most cities with light rail are nonetheless far bigger than Canberra, especially if metropolitan populations are taken into account. Indeed many rail systems serve metro areas rather than just urban cores and Canberra's metro population is not especially large as

far as any proposed service area for transit would be concerned. And if one looks at overall population density, Canberra's density of 142.1 people per sq km (as of June 2006) is well below that of most other cities with rail transit.

However, density figures as generally reported can be misleading since they cover jurisdictional boundaries that usually do not correspond to service areas for transit, areas that might well be much denser than the overall city itself. (Of course this can work the other way as well). This is where the story in Canberra becomes more interesting, for population densities and growth in population vary widely across the suburbs. Many of these suburbs have densities similar to US cities that currently have light rail.

According to ABS estimates for 2006, a majority of Canberra suburbs have population densities greater than 1,000 people per square kilometre (the actual count is 58). More than a few, such as Braddon, Turner, Page, Scullin, and Banks, have densities greater than 2,000, sometimes well above 2,000. (Kingston is just short with 1975.3). Palmerston has the highest population density in the ACT at 3038.3 (ABS 2008).

Densities such as these are comparable to the densities of US cities that have light rail including some big ones. There are 30 urban light rail systems in the US and seven of them have population densities between 1000 and 1600, putting them well within the range of the majority of Canberra suburbs. These include cities such as Tampa, Houston, Dallas, San Diego and Denver. The large and growing system in Salt Lake City actually covers an urban area with a population density of just 643.3. And Canberra does have significant pockets of density that approach densities in older and tighter cities such as Cleveland, Pittsburgh, San Jose, CA, St. Louis, Minneapolis and Seattle. (APTA 2008)

It is also interesting to see where population growth is occurring in the ACT. From 1996-2006, there have been clear growth pockets well above the average for the ACT and Australia as a whole in three major areas – The Civic core; Gungahlin and surrounding suburbs to the north of Civic; and Kingston-Manuka which is to the south. There is also some well above average growth in pockets of the Woden Valley. These happen to be areas where the ACT government is funnelling a lot of the development and all of these areas currently have high population densities, certain to increase with time. There are also quite a few dense suburbs adjacent to these growth pockets that have very high densities (e.g. Hackett with 1526.9).

To an outsider the particular suburb names where there are high densities do not mean much. What is important from an LRT perspective is that these suburbs represent (mostly) economic centres of activity that could serve as transit stops and that these suburbs generally run along a north-south axis with the downtown (Civic) at its centre. A local transit advocacy group has plotted out a map containing its ultimate 'wishlist' and this is reproduced in Illustration 4 as a useful guide. The route running from "EPIC" in the north (the Exhibition Park in Canberra) through "Civic" and down to "Woden" is a route that passes through or near

most of the population centres noted above and is generally the consensus for where initial structural transit alternatives should be placed. North of Civic they also happen to be along or near Northbourne Avenue, which is where Griffin placed rights-of-way for his tram system (ACT LRT 2008).

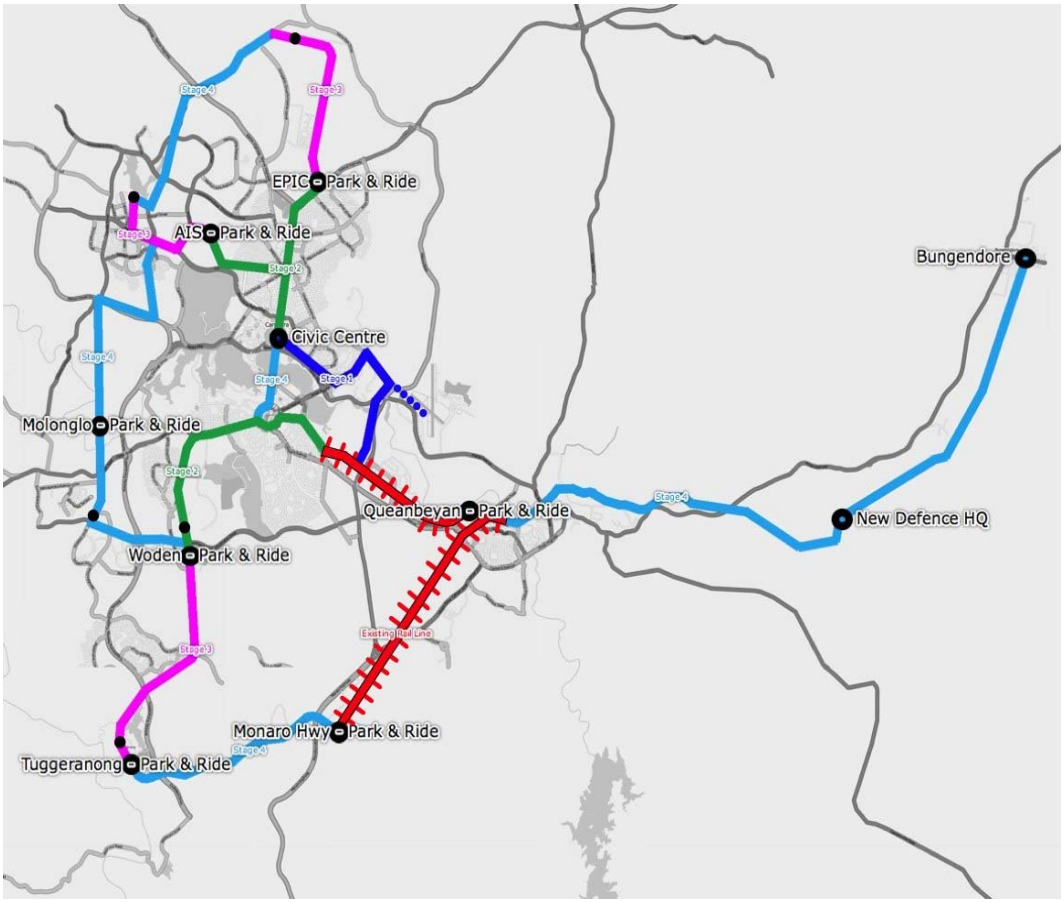

Illustration 4: Various ACT possible LRT routes (proposed by ACT Light Rail) (ACT LRT 2008)

So in a broad sense the ACT does have enough density, either currently or potentially, and has it in adjacency patterns that might support a LRT. One important note, however, is that many of the current densities are below the minimum notional density thresholds for LRT though this applies in some of the US cities discussed as well.

This is where cost becomes important. A proper costing of a Canberra LRT does not appear to have been done and if it has been done has not been made available. The route that would have the most density in terms of stops would run roughly from Gunghalin, a relatively new suburb with a dense town centre, down Northbourne Avenue into Civic, and then potentially down to Woden, an older suburb but another one with a very dense town centre. There are some alternative start and end points, such as Belconnen in the northwest but generally the core spine runs approximately 20 kilometres.

To be conservative, if one were to use Zhang's high end estimate for LRT, this would entail an average unit capital cost of $US90 million per mile in 1990 dollars, $US146.8 in 2008 dollars (approximately $US91 million per km in current dollars); that would entail a capital cost of $A2.75 billion (at exchange rates of 0.66 $A per $US, the trading range for the past quarter and reflating to 2008 dollars). This figure is far above the initial request that the ACT government submitted to IA though, as noted above, that proposal consisted of multiple elements in addition to the core LRT and had no definite route or length. A lower end estimate is the average unit capital cost given by Zhang of $US26.40 million per mile ($US42.91 in 2008 dollars) which would yield a cost $US16.41 per km ($US26.6 in 2008 dollars) or a total cost of $A808 million in current dollars, an estimate below the official proposal cost though, again, there were non LRT elements included there.

Of course even if this capital amount is fully funded by the Australian Commonwealth Government, the system would need to be operated and this could be a significant ongoing cost. It is difficult to estimate most metrics of LRT without information about operations (e.g. passenger loadings). The measure requiring the least such information is $ per 1000 place mile which is the cost per total capacity including seatings and standings. Zhang provides an average estimate of $US96 per place mile (1990 dollars; approximately $US156 in 2008 dollars or $A236). A minimal network for Canberra would be roughly a maximum of 4 single vehicle trains serving a 20 km network using four LRT vehicles of 510 total seatings and standings. On a single two-way spine network of 20 km round-trip this would provide a minimal but decent service with likely approximate headways of 15 minutes.

A definitive cost based on the minimal route and vehicle information now available is difficult to make. Perhaps the Buffalo system, a 6.6 mile system serving roughly 20,000 people daily might be a rough cost comparison (though that system uses heavy rail vehicles and is not noted for being efficient). Zhang notes that the 1992 operating on-street costs were $US67 million (roughly $US102 million in 2008 dollars, or approximately $A154 million).

This is not an insubstantial amount, obviously. The total expenditure of the ACT government

in 2007-08 was $A3.1 billion. The total budget for ACTION, the bus system, was $A96.5 million, with an ACT government contribution of $A59.7 million. Total boardings for the system were 16 million (in 06/07), and farebox recovery amounted to 19.5% (ACT 2008a). Thus if an ACT LRT behaved like the Buffalo system in terms of cost and ridership, its operating costs would swamp current bus expenditures and deliver half as many riders (approximately 7.3 million, assuming 20,000 riders 365 days per year).

6. Conclusions

What is the 'bottom line' on Canberra LRT and what might its experience imply for other cities its size and density that are considering LRT?

Because of the expense of LRT, advance planning in smaller, less dense communities, is even more critical than it might be in larger communities. Canberra has not been a particularly good example in that regard. Its initial proposal was motivated by the prospect of 'free' capital funding from the federal government; this proposal was largely unspecified and was loaded with non-LRT elements. The proposal has been refined since then but its details remain hidden from the public and the prospect of funding seems to be 'wagging the LRT dog' which is not really how things should go. If there had been detailed advance planning the ACT government might have decided to put forward a different transit alternative altogether, perhaps a BRT or enhanced buses, that would be cheaper and more effective.

Canberra however does demonstrate another point: LRT is not necessarily just suited for a big, dense urban area. It is possible to have sufficient densities situated closely enough to one another to justify an LRT. There actually has not been enough analysis done to demonstrate definitively that Canberra offers such a case, but the very rough sketch offered above does show that neither can the viability of LRT be dismissed easily. In general detailed service areas need to be conducted before taking the next step of putting forward specific transit alternative plans.

Which leads to a third point: the importance of urban and land use planning. Here is where one element of the operating environment, the third leg of the LRT tripod, comes in. Canberra is relatively unique in being completely (if often imperfectly) planned. The fact that it has population centres located in patterns that could potentially support an LRT corridor or other structural transit spine has arisen in no small part because of that planning. Future planning could make the difference between a good viable structural alternative and bus-served sprawl. And this is a general lesson for other, similar, communities even if there is not a tradition of master design templates.

Finally, even for a wealthy community with a well-endowed government like the ACT, operating costs of LRT are perhaps more important that capital costs. Canberra might end up being the cautionary tale of being careful of what you wish for and of perverse incentives of federal capital funding. No firm numbers are offered here but even for a minimalist service

the ongoing fiscal burden of a Canberra LRT will be substantial and at least equal to what the current bus service costs, delivering many fewer riders.

Of course many successful LRTs have started small and expensive and grown to be viable and accepted and efficient carriers of people. Canberra has the planning apparatus and wealth that, properly executed, could yield such a system and from that perspective, federal capital funding of an LRT there might make this an especially compelling long-term investment. And certainly some structural transit, perhaps BRT, does seem to be suggested for the ACT. However many basic questions have remain unanswered. The process thus far could have been better. Hopefully the process going forward will be improved and yield the transit system that will best serve Canberrans.

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