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A comparative international review of suburban ring/loop metros to inform the Melbourne suburban rail loop project

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Abstract

This paper explores the case for the Melbourne Suburban Rail Loop (SRL), Australia's largest urban transport project. It reviews available research literature and compares the performance of the SRL against similar ring or loop Metro systems internationally. The research literature is quite limited in this field largely because ring transit systems of this scale are not very common. Nevertheless, there appear to be merits in terms of network structure for ring/loop metro systems though these would very much depend on the scale of cross corridor trips that are better served by them. Ring/loop metro systems also appear to have merit in enhancing non-CBD development which is a major rationale for SRL though none of the previous research presents conclusive evidence this will actually happen. Evidence on the travel time competitiveness of the SRL is outstanding compared to orbital SmartBus routes and in particular the private car.

The ring/loop metro comparative performance analysis looks at 8 existing systems and finds the SRL is:

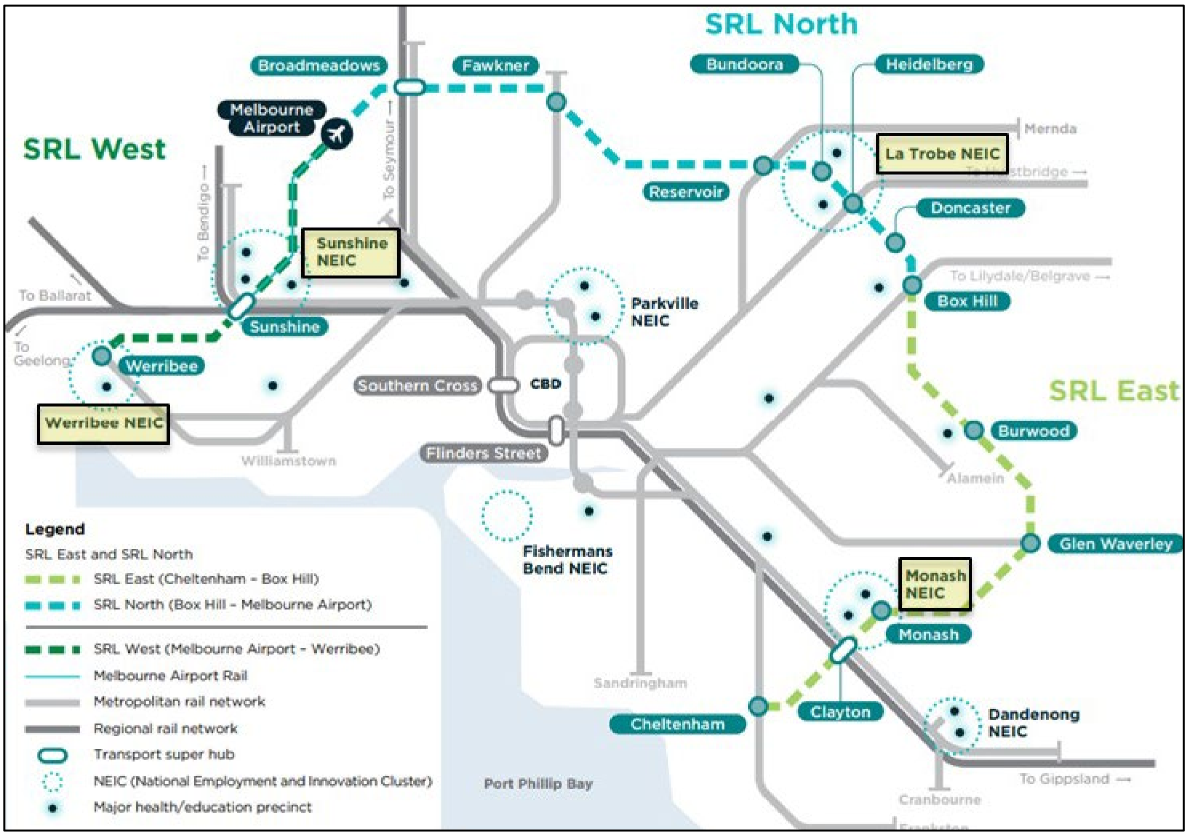
- by far the longest ring;
- it will cover a larger spatial area ;
- it will operate in the lowest current population density
- it will have low end ridership/route km
- it will operate in the lowest rail mode share context
- it will operate with stations substantially further away from the city centre
- it will have the longest station to station distances; but on the positive side; it will have the highest average operating speed.

Implication for research and practice are discussed.

1. Introduction

The Melbourne Suburban Rail Loop (SRL, Figure 1) is Australias largest urban transport project with an estimated cost of between $100B to $150B (Koziol, 2018). SRL is a 90km underground circular metro designed to connect major suburban activity centres, address rapid population growth resulting in car based traffic congestion, target growth to middle rather than outer and inner suburbs and redirect the historical development focus of Melbourne from its monocentric CBD to encourage surbuban activity centres (Suburban Rail Loop Authority, 2021). The project has attracted much controversy because it was announced during the state election and despite its significant scale, was not even mentioned in the states urban development plan; Plan Melbourne (Department of Land Water and Planning, 2021) or the states Rail Network Development Plan (Public Transport Victoria, 2012).

Figure 1: Melbourne suburban rail loop project



Note: NEIC=National Employment and Innovation Clusters

A key feature of the SRL is its loop/circular structure (Figure 1) which is circumferential to the city and a radical departure from conventional radial rail line structure adopted in most Australian capital cities. While this is an unusual design for an Australasian context there are several cicumferential or ‘ring/loop’ metros designed to achieve similar objectives in international cities.

This research paper explores the case for the Suburban Rail Loop project and compares its performance against existing ring/loop metro systems from around the world. The paper starts with a review of the research literature about ring/loop metros, network design issues, ridership impacts and evidence on growth impacts in activity centres. The approach to the comparative assessment is then presented followed by a detailing of the results. The paper concludes with a summary of the major implications for research and practice.

2. Research context

This section reviews available published literature relevant to the SRL project. In practice specific coverage of the topic is rare, probably because ring/loop metros are not a common feature of cities. This section assembles what is directly available on the topic including some coverage of topics related to benefits sought of the SRL.

2.1 Ring/loop metros design and rationale

Although the Suburban Rail Loop is transport project, it has several city-shaping and urban planning objectives and implications. Development into a polycentric city would require large-scale public transport connectivity to intensify activity around National Employment Innovation Clusters (NEICs) (Buxton, 2018). Spiller emphasises that the SRL should aim to effectively redistribute jobs and housing to enable sustainable growth (Spiller, 2019). Improved public transit efficiency through a more flexible, high-speed network aims to stimulate economic growth around these nodes. One study found that percentages of work trips by trains decreases the further away a resident lives from a station in Melbourne, particularly in middle suburbs (McCloskey et al., 2009). The same study found that residents who live near a station but work in a location inaccessible by rail lines may not use the train. Strategic placement is therefore necessary to ensure optimal connectivity throughout Melbourne's inner-suburbs, ensuring major activity centre catchments are served effectively.

Saidi et al. (2016) review the optimal location and radius of circumferential rail lines and applies this to the City of Calgary Canada, generating an optimal ring loop of 6-9km away from the CBD (in comparison the SRL is broadly 15k-16km from the CBD). The scale of Calgary limits the application of this model to Melbourne, due to the significant differences in urban sprawl. In Melbourne patterns of dwelling density are relatively low between 0-20km from the CBD (2001-2006) (Chhetri et al., 2013).

The proposed location of the SRL route is aimed at providing maximum accessibility throughout Melbourne's suburbs, particularly areas exhibiting increasing economic growth rates (Suburban Rail Loop Authority, 2021). With a high dispersion of jobs throughout middle suburbs, access by public transport is often not available or requires multiple mode changes (McCloskey et al., 2009). This would suggest that private vehicle reliance may be reduced with improved access and connectivity that is competitive with car travel times.

Another study by Saidi et al. (2014) on suburban ring lines highlighted the prominent trend of higher ridership in European and Asian cities compared to North American cities. They suggest that public transport is not as attractive as private vehicle use in these cities, reflected by their high private vehicle ownership rates. Australia exhibits similarities with North American cities, with significant urban sprawl and high private vehicle ownership. If Melbourne is to achieve sustainable population growth, a shift of modal share towards public transport use similar to Asian and European figures may be necessary and a ring Metro might assist in this regard.

2.2 Improved connectivity and travel path directness

Circumferential rail loops aim to provide stronger connectivity through a city's network by enabling circular access around a major city hub. Multiple studies have indicated that radial-based networks leading directly into a city centre cause concentrated passenger load in the city centre due to lack of rail lines orbiting circularly through surrounding suburbs (Saidi et al., 2016, Laporte et al., 1997). This is particularly evident in cities with monocentric rail transit behaviours, such as Melbourne. Creating alternative transport routes with the SRL may reduce unnecessary transfer activity in the central hub (CBD) and redistribute ridership along the circumferential loop. (Saidi et al., 2014) note a global rail network trends towards the development of ring line networks, where polycentric cities are often serviced by rail networks interconnected by a ring-based transit.

Mathematical modelling by Laporte et al. (1997) suggests that stronger connectivity and path directness is achieved using “cartwheel” networks rather than traditional radial networks (“hub-and-spoke”). The increased connectivity and directness of rail path design have been studied to stimulate stronger public transport use (Derrible and Kennedy, 2009). Laporte et al. discussed the effectiveness of a cartwheel network in providing higher connectivity, much higher in relation to a traditional radial network (Laporte et al., 1997). Saidi affirms in his study of ring-line transit that higher connectivity also improves network reliability, where there is greater flexibility to travel between stations in case of service disruption (Saidi et al., 2014).

Ridership may vary in effectiveness due to population behaviours, attitudes, and station accessibility. Derrible and Kennedy (2009) model ridership for underground-only stations around the world They found statistically significant explanatory variables were network coverage, directness and connectivity. With Melbourne’s monocentric travel patterns resulting in major transfer activity in CBD stations (Flinders Street, Melbourne Central, Southern Cross), integrating a circumferential rail loop to produce a rail network with multiple transfer points may prove beneficial.

While the literature identifies a range of benefits of ring/loop metro design, consideration must also be added regarding the obvious substantial costs associated with constructing such large and extensive infrastructure.

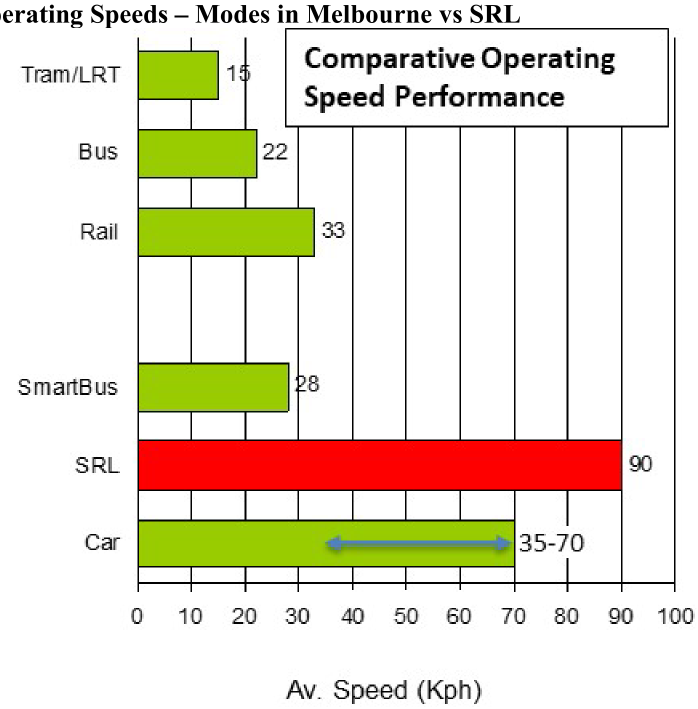
2.3 Increased public transport ridership and decreased automobile usage

Rail system ridership is strongly correlated with coverage, directness, and connectivity (Derrible and Kennedy, 2009), often resulting in a faster, more efficient transport route. Orbital rail lines aim to decrease travel times of various routes by improving these three variables. Indeed, several other factors may affect modal choice such as travel-costs and private vehicle ownership, further extending out to non-quantitative factors such as comfort, social norm, convenience, and safety. This section will focus on network speed as the primary factor.

The low public transport usage for Melbourne inter-suburbs trips (serviced primarily by the bus network) may be caused by high travel-times of bus routes in comparison to private vehicle travel. Loader’s analysis of suburban travel patterns identifies these trends, with growing residential suburbs exhibiting low public transport usage when travelling to suburban employment clusters (typically ranging between 1%-5%) (Loader, 2011). Comparing these metrics with PT-share to inner-city employment hubs (57%-73%) indicate the effects of travel-cost and time savings offered by a rail line to the city (petrol cost, road tolls, parking fees, congestion). The SRL may not reduce travel-cost savings to the magnitude of inner-city travel but may provide significant public transport speeds to the suburban network.

To contextualise this, Figure 2 shows some simple average travel speed calculations of the planned SRL compared to car, rail, bus and light rail alternatives in Melbourne plus the orbital smart bus routes[1]. SRL considerably outperforms all modes in terms of travel speed and is even better than car. Smartbus routes, orbital bus routes with a similar circumferential structure to the SRL have at best an average speed of 28kph. This means a SmartBus route (903) from Frankston to Melbourne airport would take 3hr 50 mins while a car might take only 64 minutes (based on timetable and google trip planner data). SRL clearly has a significant speed advantage although this only applies for those with trip ends around SRL stations.

Figure 2: Average Operating Speeds – Modes in Melbourne vs SRL



2.4 Increased growth at connected activity centres

To develop into a polycentric city, Melbourne will need to establish current National Employment Innovation Centres as major employment hubs (Buxton, 2018). Improved accessibility at activity hubs through efficient rail transit may encourage increased economic and social activity at these locations. Buxton indicated that developing these key activity centres through fast and efficient public transport service is significant for Melbourne's transition into a polycentric city. Several urban planning mechanisms contribute towards the development of these centres. As highlighted in Plan Melbourne 2030, a holistic transit-oriented approach is required to catalyse major job precinct growth(2003). Enabling new transport routes through interconnecting suburbs (serviced by the SRL) is aimed to encourage mixed-use urban development and further generate employment opportunities in the future.

Saidi et al. indicated that a circumferential rail line may encourage higher density, mixed-use development along the corridor (Saidi et al., 2014), suggesting that the SRL may stimulate growth around activity centres along the line. Saidi et al. further highlighted the Origin-Destination patterns being a significant factor in circumferential networks. This suggests that orbital accessibility through suburbs would stimulate stronger public transport use through these routes, given that efficient infrastructure is available. Directional travel behaviours are widely dependent on a city's job market distribution, which may be correlated with activity

[1] The transit system average speeds are based on annual report data indicating kms travelled and hours of operation of transit systems. SRL speed are based on the reports cited. Average road speeds are typical values sourced from VicRoads

centre distribution across the metropolis (Saidi et al., 2014). Current and future origin-destination patterns are not currently clear for SRL stations so actual impacts on development are uncertain.

To explore these issues further analysis sought to compile data from existing SRL like lines for comparison with know SRL data.

3. Research approach

Established suburban ring metro like services were identified and targeted to identify and collate performance data for comparison with the SRL project. As is often the case in compiling practice data, only limited amounts of basic data are available and often of variable quality so some critical assessment of data to be included was required as system was being compiled.

The analysis sought to explore the planning dimensions of performance including population, urban density, line length, station distances, ridership performance and scale of city. Criteria such as length of loop line, city population, and public transport ridership also provided the basis for selecting relevant circular lines for analysis. A loop length of 25km was used as the minimum requirement as we do not want to cover smaller systems. Although arbitrary, rail loops of this length generally exhibited consistent data appropriate to their scale. Lines such as Glasgow's Circle Line (10.4km in length) were omitted due to their inconsistent ridership measurements and low ridership rates. The goal was to identify circumferential rail lines that provided meaningful transport utility to the entire network. Ideally, lines should orbit around the city centre to provide an appropriate comparison with the SRL.

After review the following lines were selected:

- Shanghai Metro Line 4 (China)
- Moscow Central Line (Russia)
- Berlin Ringbahn (Germany)
- London Circle Line[2] (United Kingdom)
- Circle MRT Line (Singapore)
- Beijing Line 10 (China)
- Seoul Subway Loop 2 (South Korea)
- Yamanote Line (Tokyo, Japan)

These lines have similar rationale to the SRL: to provide circumferential route access around a city. Other lines considered but rejected from the analysis were the London Overground (United Kingdom) and the Grand Paris Express (France, still under development). The London Overground's integration with other rail systems is of relevance to the SRL's rationale but it is not a circumferential railway so is not considered further.. Grand Paris Express is under construction, but the circumferential connectivity throughout surrounding suburbs merits consideration for future research.

A variety of sources were used to obtain data that was recent and relevant. Ridership data was particularly difficult to synchronise in a consistent way with demographic data, with the former sometimes being several years older. Public transport usage rates may also be inconsistent

[2] Technically the London Circle line is no longer a loop; however it is still marketed as one. We have included it in the review as it is a high profile example.

depending on the source and data collection methods. Forecast ridership and population metrics were used for the SRL (Suburban Rail Loop Authority, 2021).

4. Results

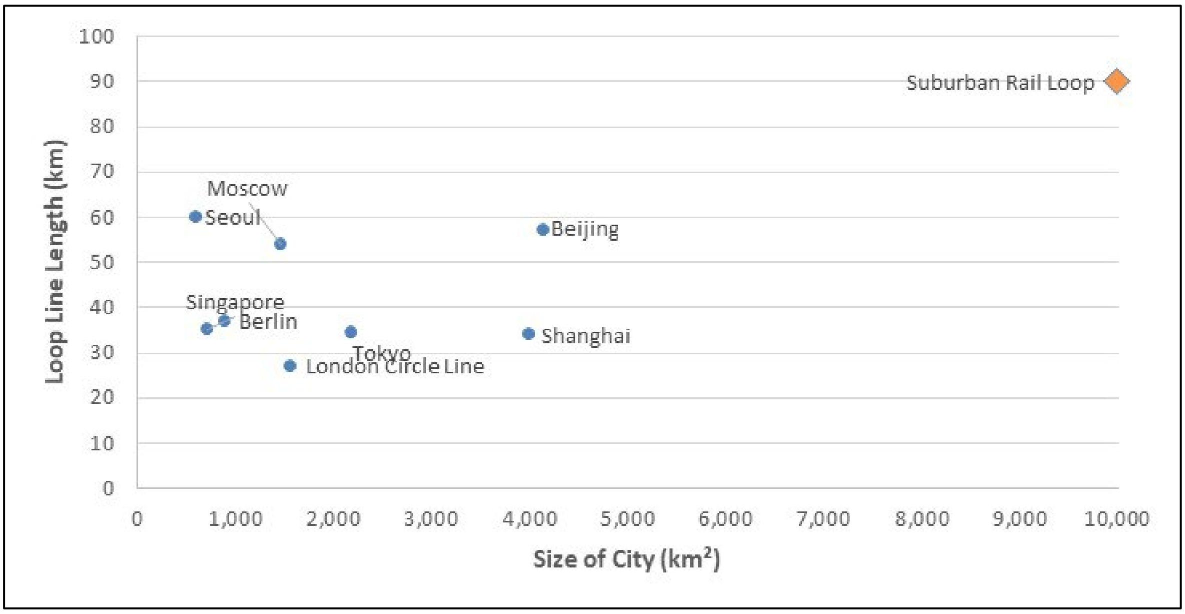
Attachment A present the raw summary data for the ring metro data collected. The following sections summarize what was found in the comparative analysis. Five sets of analysis explore system scale, ridership and operational performance. These were the areas which available data can provide insight. Each analysis plots system performance with one performance measure variable compared to another. This acts to explore dimensions of performance against each other. They include:

- Loop line length and spatial scale of city
- Ridership rates per route km vs population density
- Daily loop ridership by urban rail ridership mode share
- Average station-station distances vs average speed
- Average station to station travel time by average station distance from the city.

4.1. Loop line length and spatial scale of city

Figure 3 illustrates loop line length data vs urban area size (km^2).

Figure 3: Loop line length and spatial scale of city

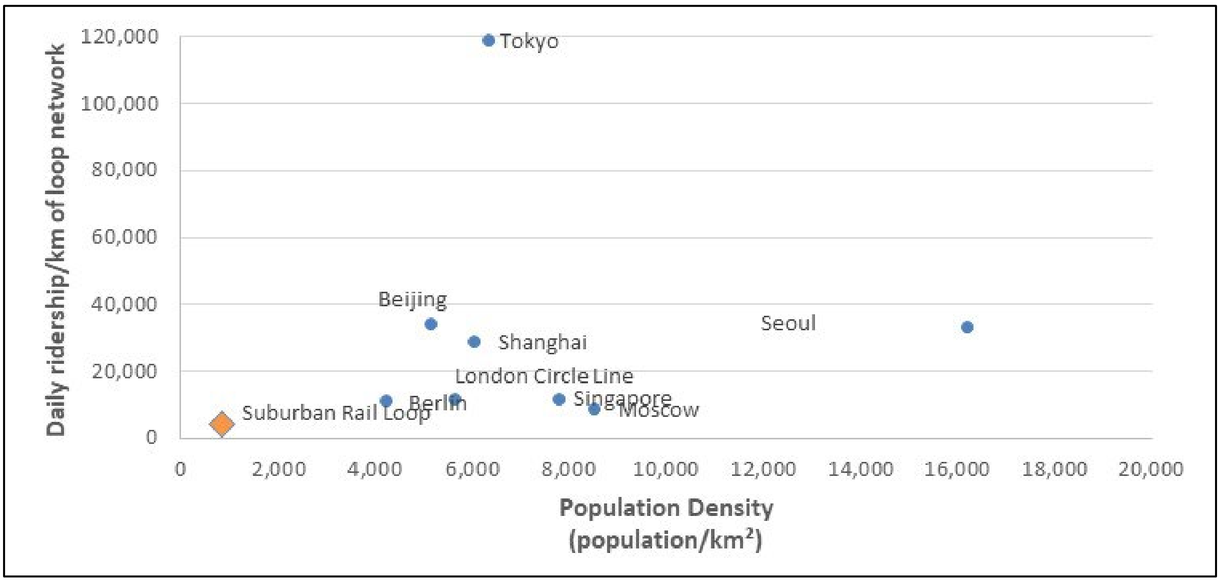


SRL will be longest loop line compared to all others measured. It will also cover the largest sized city in terms of spatial size (km2). All the loop lines measured covered an area below half the size of the SRL. SRL is more than 50% longer than the longest loop line measured (Seoul).

4.2 Ridership rates per route km vs population density

Figure 4 shows the results for ridership rates per route km vs population density.

Figure 4: Ridership rates per route km vs population density

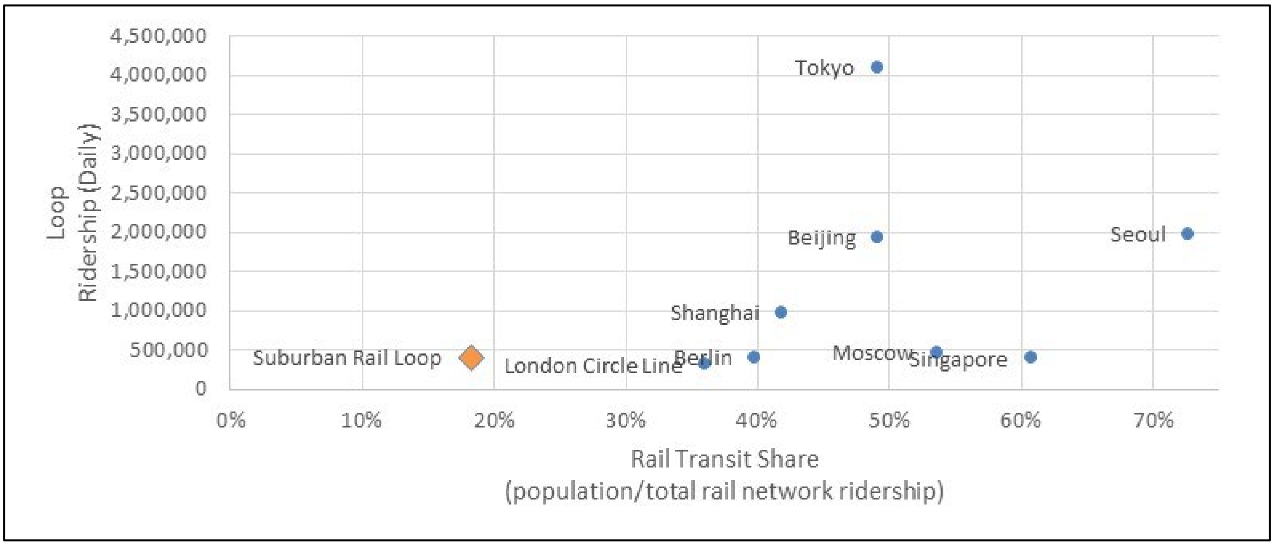


SRL will be the lowest density loop line of all the lines measured. It will also have ridership per route km which is lower than any other system though it will be broadly comparable to Moscow and Berlin. Tokyo is a standout outlier for both urban density and ridership per route km.

4.3 Daily loop ridership by urban rail ridership mode share

Figure 5 illustrates Daily loop ridership by urban rail ridership mode share

Figure 5: Daily loop ridership by urban rail ridership mode share



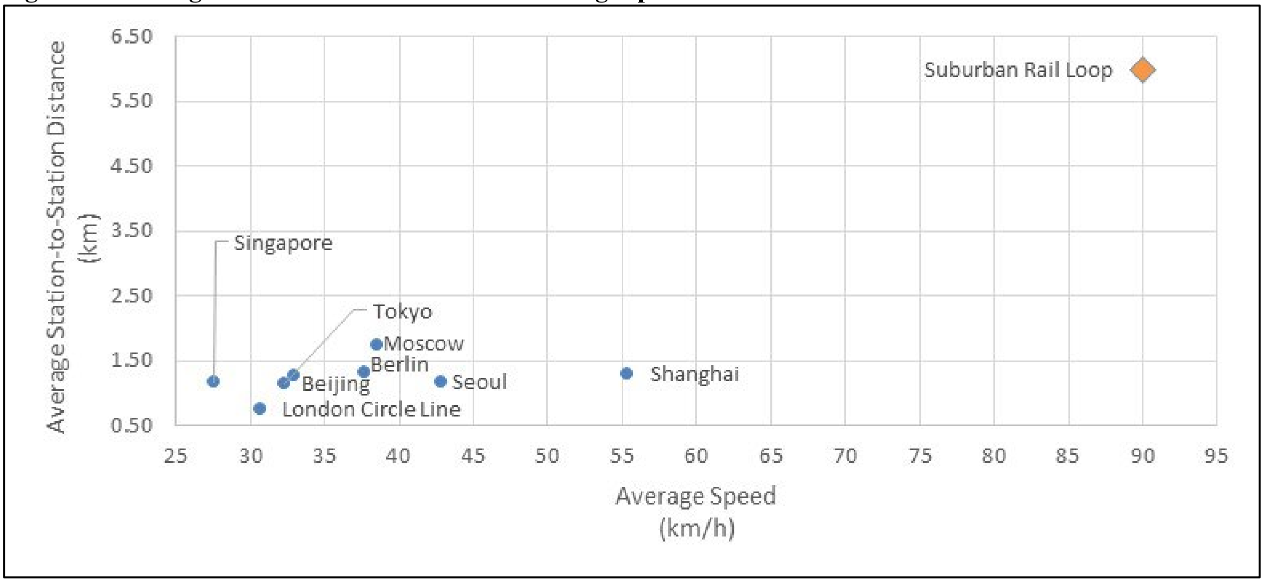
Note: SRL ridership is from forecasting undertaken by Govt Authorities (SRL Authority, 2021)

This indicates that Tokyo, Beijing and Seoul have the highest ridership levels and also the highest rail mode shares. SRL has amongst the lowest levels of ridership in the class; similar to London, Berlin and Mosco and also the lowest rail mode share.

4.4 Average station-station distances vs average speed

Figure 6 shows average station-station distances vs average speed

Figure 6: Average station-station distances vs average speed

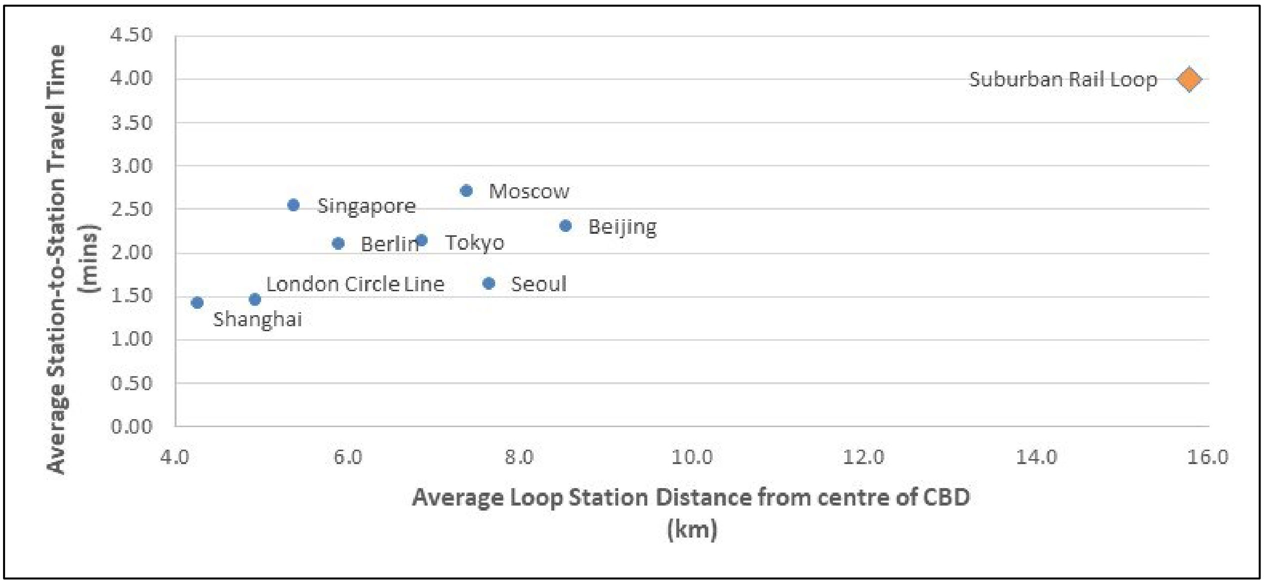


SRL is forecast to have the highest average operating speed (90kph) of all the lines measured. Existing lines have speeds ranging between 27 and 55 kph. SRL also has the largest station to station distances (6km). Most average station to station distances are around the 1 to 1.5km mark.

4.5 Average station to station travel time by average station distance from the city

Figure 7 shows the average station to station travel time by average station distance from the city.

Figure 7: Average station to station travel time by average station distance from the city



This indicates that the SRL will have the longest station to station travel time (4min) which is consistent with the long station to station distances (average 6kms). Most loop metros have travel times between 1.5 and 3 minutes between stations.

SRL will also have the longest average station distance from the CBD (around 16kms). Most ring metro stations lie between 4kms and 9kms of the CBD.

5. Discussion and conclusions

This paper explores the case for the Suburban Rail Loop in Melbourne. It reviews available research literature and compares performance of the SRL against similar ring or loop Metro systems. The research literature is quite limited in this field largely because ring transit systems of this scale are not very common. Nevertheless there appear to be merits in terms of network structure for ring/loop metro systems though these would very much depend on the scale of cross corridor trips that are better served by them. Ring/loop metro systems also appear to have merit in enhancing non-CBD development which is a major rationale for SRL though none of the previous research presents conclusive evidence this will actually happen. So authorities face a difficult trade-off between an enormous transport investment and the risk that the investment will not create the land use outcomes they seek. Certainly it seems that good land use planning will be an important part of any success in this regard yet that has been lacking in the SRL's development to date. Nevertheless the travel time competitiveness of the SRL is outstanding compared to orbital SmartBus routes and in particular the private car.

The ring/loop metro comparative performance analysis suggests the SRL is very much an outlier compared to other metros. In summary compared to other ring/loop metros:

- It is by far the longest ring;
- It will cover a larger spatial area;
- It will operate in the lowest current population density;
- It will have low end ridership/route km;
- It will operate in the lowest rail mode share context;
- It will operate with stations substantially further away from the city centre; and
- It will have the longest station to station distances; but on the positive side; it will have the highest average operating speed.

It is difficult to see this evidence providing a strong context for the projects justification; nevertheless it remains a committed project of the Victorian Government and its first phase (SRL East) is being implemented. It is also no alone in Australia; Sydney has a similar project being planned of a similar scale. The Melbourne authorities have undertaken a project evaluation which provided a BCR or between 1.1 and 1.7 (Suburban Rail Loop Authority, 2021) thus providing economic justification for the work. Nevertheless this evaluation has come under some critique as the review of alternative options was very limited (Victorian Auditor Generals Office, 2022). It clear that technical assessments based on actual data such as this review provide much value for a large project of this kind. More evaluations of this nature are needed.

The state Government opposition however have not supported the project. Since its implementation has a 35 year time frame its future will thus be vulnerable to political shifts in Victorian politics. In short its future will be the subject of political rather than planning or transport and land use debate. However its success will require a good deal of focus on the latter not the former.

What does this research tell us about future practice or research? Clearly there is a considerable practice and research gap regarding the actual impact of a project of this scale on urban development as well as transport outcomes. As an outlier amongst ring/loop metros it is going to be difficult to look to existing experience to inform us of its likely performance. Land use transport modelling thus looks to be a feasible future way forward to explore the project design and its impact.

From a practice perspective planners and engineers must consider pragmatic approaches to best achieve positive outcomes for the scale of investment being made. Alternatively practice could focus on the project's potential to be a 'white elephant' and the substantial gap it represents between effective long term planning process and best practices given its genesis as a political tool to win an election. Regardless of the readers ideology, the project is politically popular and reflects a growing public recognition of the need to create a significant shift in transport and planning in Australia's suburbs. It is the job of researchers to highlight the differences between reality and fantasy when planning is driven by political visioning rather than reason.

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Attachment A: raw data from loop/ring metro systems

Rail Line	Suburban Rail Loop	Shanghai Loop	Moscow Central Circle	Berlin Ringbahn	London Circle Line	Singapore Circle Line	Beijing Subway Loop	Seoul Subway Loop	Tokyo Loop
Loop Ridership (Daily)	400,000	976,000	460,000	400,000	313,973	398,000	1,931,000	1,972,603	4,099,000
Total Network Ridership (Daily)	1,518,466	10,160,000	6,700,000	1,500,000	3,208,219	3,400,000	10,544,000	7,123,288	6,840,000
Loop Rail Ridership Share of Total Network (%)	26%	10%	7%	27%	10%	12%	18%	28%	60%
Loop Line Length (km)	90.0	34.0	54.0	37.0	27.0	35.0	57.1	60.0	34.5
Total Network Length (km)	495.0	676.0	467.0	331.5	429.0	203.0	699.0	327.0	195.0
Loop Proportionof Total Line Length (%)	18%	5%	12%	11%	6%	17%	8%	18%	18%
Size of City (km^2)	9,992	4,000	1,464	892	1,572	722	4,144	605	2,188
Population (millions)	8.30	24.28	12.50	3.77	8.90	5.60	21.45	9.80	13.93
Population Density (population/km^2)	830.7	6,070.0	8,537.0	4,227.4	5,666.0	7,800.0	5,176.2	16,198.3	6,366.5
Rail Transit Share (population/total rail network ridership)	18%	42%	54%	40%	36%	61%	49%	73%	49%
Total Public Transit Share (%)		33%	39%	27%	37%	44%	26%	66%	51%
Stations Along Loop	15	26	31	28	36	30	45	51	30
Stations (total network)	205	413	275	166	369	122	405	728	882
Loop's Station Share (%)	7%	6%	11%	17%	10%	25%	11%	7%	3%
Loop Radius (km)	14.3	5.4	8.6	5.9	4.3	5.6	9.1	9.5	5.5
Average Loop Station Distance from centre of CBD (km)	15.8	4.3	7.4	5.9	4.9	5.4	8.5	7.6	6.9
Daily ridership/km of loop network	4,444.4	28,705.9	8,518.5	10,810.8	11,628.6	11,371.4	33,817.9	32,876.7	118,811.6
Average Daily Ridership/station	26,666.7	37,538.5	14,838.7	14,285.7	8,721.5	13,266.7	42,911.1	38,678.5	136,633.3
Round Trip (minutes)	60.0		84.0	59.0	52.8		104.0	84.0	64.0
Average Speed (km/h)	90.00	55.38	38.57	37.63	30.71	27.51	32.94	42.86	32.34
Average Station-to-Station Distance (km)	6.00	1.31	1.74	1.32	0.75	1.17	1.27	1.18	1.15
Average Station-to-Station Travel Time (mins)	4.00	1.42	2.71	2.11	1.47	2.54	2.31	1.65	2.13