



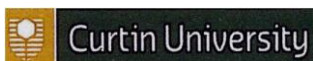
PATREC

Mass Rapid Transit for Perth & Peel @ 3.5 Million and Beyond

11 February 2016

Planning and Transport Research Centre

www.patrec.org



Contents

Executive Summary	4
1. Introduction	6
2. The urban planning context	8
3. The future context	11
4. Overview of Approach to identifying need for new network links	14
4.1 Principles to guide network development for 3.5 million and beyond	14
4.2 Maximum daily peak carrying capacity of present and committed MRT network	16
4.3 Estimating peak daily transit demand for 3.5 million	16
5. Overview of network enhancements to cater for Perth & Peel @ 3.5 million and Beyond	18
6. The Radial Network – Options for the north-eastern corridor	19
7. An inner city ‘Metro’ Distributor	21
8. Extensions to existing Radials	21
9. A new Stirling – Murdoch Orbital	22
10. Inner Orbital LRT	23
11. Other road-based connections	23
12. A Timetable for Perth and Peel MRT for 3.5 million and Beyond	24
13. Developing a ‘Public Transport Culture’	24
<i>Figure 1: TransPerth rail network and stations (2015) and committed network additions</i>	<i>7</i>
<i>Figure 2: The ‘Connected City’ spatial plan for Perth and Peel</i>	<i>9</i>
<i>Figure 3: Population distribution 2011 and 2050</i>	<i>10</i>
<i>Figure 4: Relationship between Population Size and Transit Usage for Work Trips</i>	<i>13</i>
<i>Figure 5: Passenger Boardings at 3.5 million on the mass transit network</i>	<i>18</i>
<i>Figure 6: A Vision for the Perth and Peel Mass Rapid Network @ 3.5 million and beyond.....</i>	<i>20</i>
<i>Figure 7: A Timetable for Perth and Peel MRT for 3.5 million and Beyond</i>	<i>24</i>
Acknowledgements	26
Working Papers	27
References	27

EXECUTIVE SUMMARY (Abstract)

Research by the Planning and Transport Research Centre (PATREC) in Western Australia, commissioned by the State Government of Western Australia (WA), examined strategic directions for public mass rapid transit (MRT) to serve WA's capital city Perth and Peel when the regions' combined population reaches 3.5 million (estimated to occur in about 2050), from a population of 2.02 million in 2014. The research did not include economic evaluation, as significant detailed planning will be required for route and technology selection, and to measure the effects of emerging disruptive communications and transport technologies, demographic and urban growth outcomes on demand for public transport trips. In the three decades to 2015 Western Australia electrified and substantially extended its 'heavy-rail'-based MRT system, operated by the State's Public Transport Authority (PTA), which in 2015 comprised a five-branch radial electrified network of 70 stations and 181 route-km, operating through the CBD hub, providing significant capacity for future years. The MRT network is supported by a timetabled bus feeder system, which was not a focus of this research. A 'sketch planning' methodology estimated capacity-critical week-day peak-hour public transport boardings for the 3.5 million population horizon. The urban development strategy of the Western Australian Planning Commission (WAPC) for 'Perth and Peel @ 3.5 million', which includes significant 'densification' and a focus of growth in and around designated 'Activity Centres', was used in estimating transit demand, but differing employment distribution scenarios were tested. A growth in all-day public transport market share from about 8% (2015) to at least 12% (@ '3.5 million') has been assumed. The desired growth strategy includes a strong CBD employment hub. The potential impacts of disruptive technologies on travel behaviours were considered but the long (three and a half to four decades) planning horizon precluded their quantification. Future MRT network development was based on recommended *Hi-Trans*[®] 'demand-based' principles, which seek to maximise service frequency to achieve as far as practicable 'turn-up and go' timetabling. Plans by the PTA for MRT network capacity enhancement until 2031 (including minimal network extensions) were the basis for network capacity estimation without significant new infrastructure. Findings regarding additional new infrastructure included options for a new line serving the inner north (east of and absorbing demand which would otherwise flow to the present northern railway, which will reach practicable capacity before 3.5 million), complemented by significant addition of orbital network lines (one 'heavy' rail and one LRT) joining strategic Activity Centres, by an inner city Metro distributor, and by a small number of new rail links aimed at enhancing network connectivity and improving operating resilience. An important aim of proposed new orbital lines and the new MRT corridor east of the northern line is to divert peak-hour boardings from the northern MRT radial, which will reach capacity before '3.5 million'. A substantial part of the extended network would probably be built in tunnels to avoid using major road capacity needed for road traffic, and to avoid adverse effects on TOD precinct designs. Variations from the planned land-use densification would necessarily affect the utility of future additions to public transport infrastructure, with less densification requiring reductions in investment, and conversely greater densification providing opportunities for greater network capacity and connectivity.



1. Introduction

The research reported here was commissioned from the Planning and Transport Research Centre¹ (PATREC) by the Director General of Transport in Western Australia (WA). It is part of a wider program aimed at better understanding the transport infrastructure needs of WA's capital city (the Perth and Peel regions) when it reaches a population of 3.5 million – forecast to occur in approximately 2050 – and beyond. The distribution of population we have assumed is described in the 'connected city' strategy of the Western Australian Planning Commission (WAPC), in its 2015 publication, *Draft Perth and Peel @ 3.5 million* (WAPC 2015).

The focus of our research has been on the infrastructure needed to provide for the day-to-day mobility of 3.5 million residents, in particular those who choose to travel to work and education by mass rapid transit. It is these travellers who will continue to create the peaks in daily travel by public transport and therefore determine the network capacity required.

By 'mass rapid transit' (MRT) we mean both high-capacity 'heavy rail' passenger trains, expected to remain the most effective technology for mass movement at high speed in the foreseeable future and slower but more agile inner city 'metro'-style train services. Light rail (LRT), bus rapid transit (BRT) and 'bus priority' services will provide connections where less capacity will be needed. All these forms of public transport will have a crucial role in supporting growth of the regional 'Activity Centres' identified by the WAPC, while growth in population density and of a 'public transport culture' will also support the development of a stronger public transport network.

To illustrate the starting point for our research, the present 'heavy-rail'-based MRT network of 2015 operated and maintained by WA's Public Transport Authority (PTA) is shown in Figure 1.

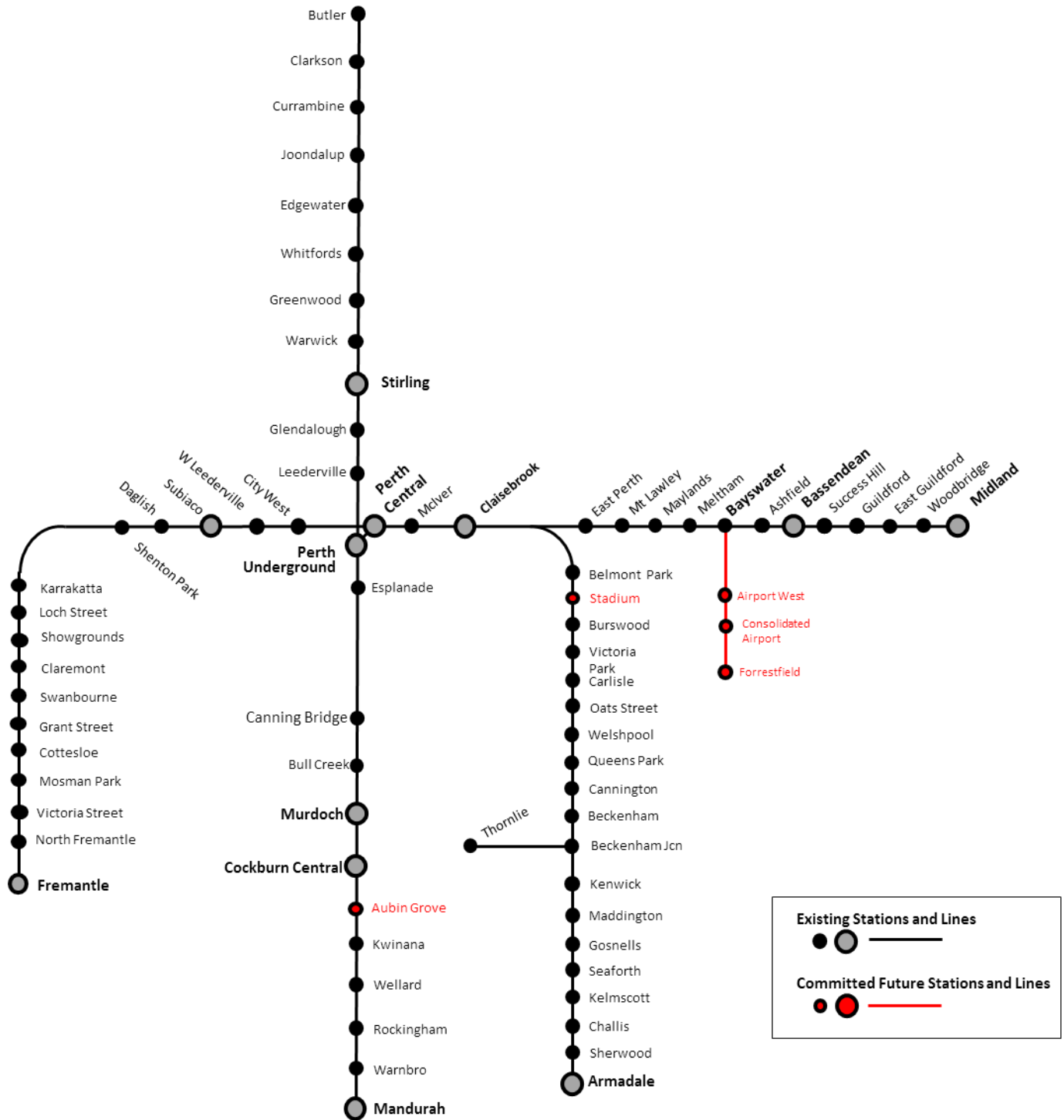
In less than a single generation – from 1988 to 2007 – the State rebuilt and extended all of the mass rapid transit network serving Perth and Peel regions. Rail, bus and ferry systems are under a single management regime, and supported by system-wide swipe-card ticketing. Total system boardings were 149 million in the year to 30 June 2015. Small additions to the rail network have occurred since 2007 and more are committed for the future. This infrastructure has substantial capacity for future growth in usage, which should be made possible until about 2030 and beyond by 'sweating the asset' with more and higher capacity passenger carriages, improved signalling and more station capacity. The next stage of MRT network improvements, to provide more links to cater for growing population, can then occur in the two remaining decades until Perth and Peel will reach 3.5 million. More additions to the network will probably be needed beyond that time.

The research questions addressed in this report are both simple and complex. The **simple questions** are how and where it will be necessary to augment the peak daily capacity of the present MRT network to provide comfortable, safe and reliable services for all wishing to use the system when the population of Perth and Peel reaches 3.5 million, and beyond. More network capacity – new links in the system – will be needed where it is probable that the peak daily capacity which can feasibly be provided by the existing network will be exceeded by demand, assuming all feasible action has been taken to maximise the capacity of the existing network. Comfort and safety will demand increased capacity, while sustaining reliability will also require added network connectivity and 'redundancy'.

The **complex questions** are about estimating future demand for travel by MRT. The starting point is a population of 3.5 million in the present Perth and Peel regions, where the population in 2014 was approximately 2.02 million. Current estimates suggest we will reach 3.5 million in about 2050, three and a half to four decades into the future. With the 3.5 million starting point, it was

¹ The Planning and Transport Research Centre (PATREC) is a collaborative research centre involving The University of Western Australia, Curtin University and Edith Cowan University, undertaking broad-based and independent research in transport and urban and regional planning and the integration of policy and practice in these areas.

Figure 1: TransPerth Rail network and stations (2015) and committed network additions



necessary also to estimate the fraction of the population which will be in the workforce, where they will choose to live, work, study, shop and attend to their personal business needs.

Estimates were also required of the daily habitual choices people will make of preferred travel modes – of ‘public’ or ‘private’ transport. There are inherent difficulties in estimating these choices at a distance in the future of 35 to 40 years. We need only think of the past at a similar distance (1975 to 1980) when there was no Internet, petrol was 15 to 30 cents a litre (Gargett 1975), the rail-based public transport system (in reality an extension of the state-wide passenger and freight network) was slow and uncomfortable, and Perth’s roads were uncongested.

The size of the commuting workforce in a future population of 3.5 million will be affected by aging and the extent of telecommuting. Its spatial distribution will be affected by many factors, including where families choose to live and from which to commence their daily journeys, alternatives to mass transit, improved road capacity, new automobile technologies (including electric-powered and autonomous vehicles), demand management policies, and the growth of ‘telecommuting’ and electronically-enabled education. There is also potential for work hours (and therefore peak travel intensity and times) to change under the influence of these and other factors. What is certain is that the mid-21st century world will differ from today’s in many ways, some affecting our travel to work behaviours. Estimating what part of the workforce and other ‘peak period’ travellers will use mass rapid transit 35-40 years into the future has been far from simple and has required innovative approaches with sensitivity testing of potential demand.

Reliable information about ‘external factors’ will become more available over time for future more detailed refinements of a long-term plan. To provide guidance for future transit system planners, we have tested the sensitivity of our findings regarding the future transit network to differing outcomes for the distribution of jobs across Perth and Peel when Western Australia’s capital city metropolis reaches a population of 3.5 million.

Useful direct comparison of Perth’s situation and opportunities compared with those apparent in other cities has been difficult due to different development histories, urban densities, climates and travel ‘cultures’. For example the mass transit systems in Sydney, Melbourne and many North American and European cities were developed during the nineteenth century when urban forms were typically compact and both population and employment locations were materially ‘denser’. Perth is a very (late) 20th century metropolis. This research has therefore relied on the expert advice of Professor Corrine Mulley, including benchmarking with other cities (Mulley 2015a: Working Paper 5), and the *HiTrans* © principles for network design (Neilson et al 2005).

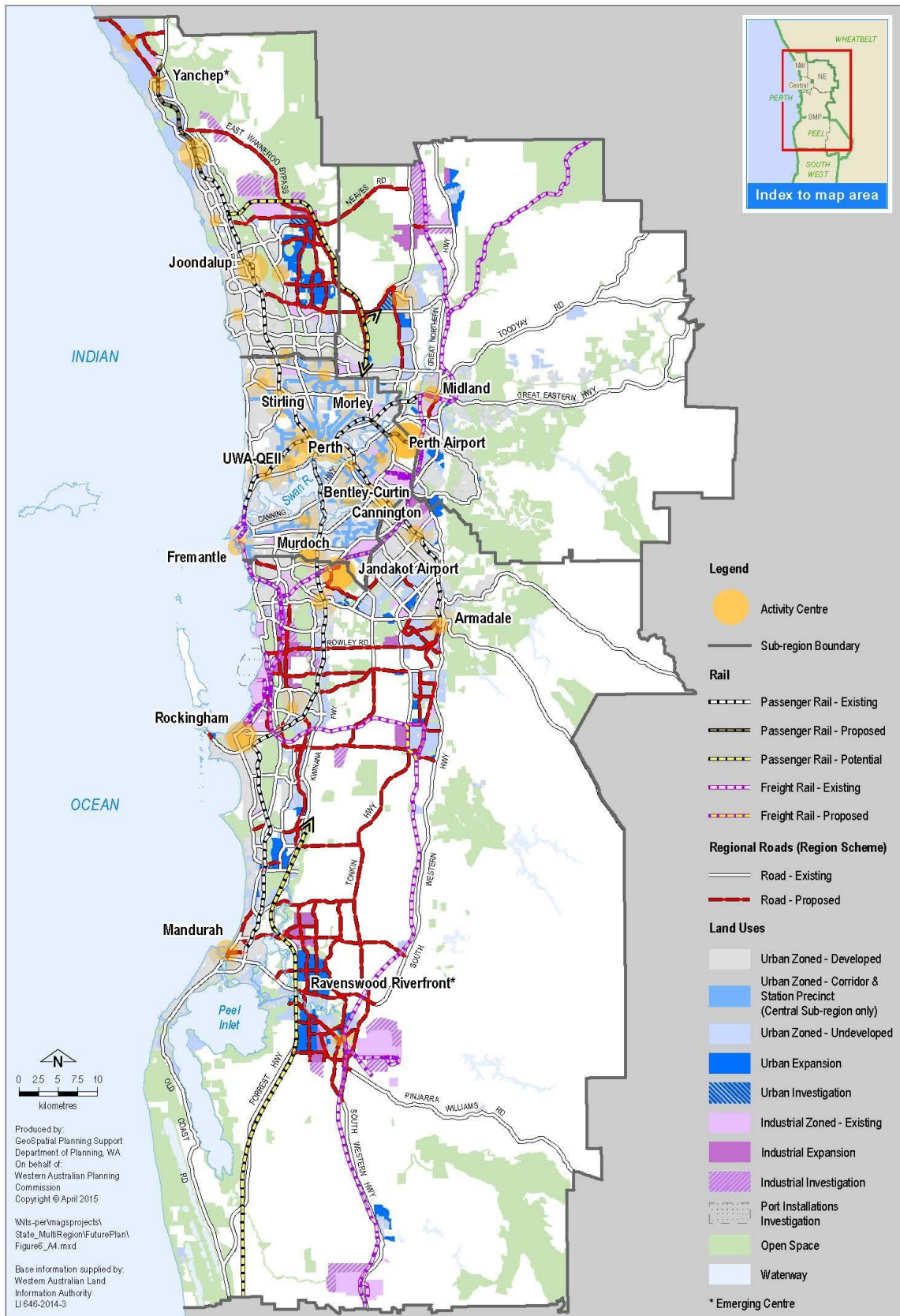
This study contains no benefit/cost appraisal of investment option. That will be appropriate for future studies in which detailed infrastructure planning will occur.

2. The urban planning context

A well planned public transport system will influence and support a chosen land use structure. The aspiration for Perth and Peel is to slow the seemingly inexorable linear expansion of urban development, by increasing population density. High quality public transit services are critically important to encouraging this desired ‘densification’. Conversely, growing population density will be critically important for the viability of public transport investments. Greater density especially in targeted ‘Activity Centres’ will increase the number of travellers on the mass transit network, provided they receive frequent and convenient services in step with demand, gradually stimulating the development in Perth of stronger habits – a ‘culture’ – favouring much urban travel by public transport.

The WAPC has provided the urban planning framework for a ‘connected city’ in which the public transport network and land use development policy will be mutually supportive (WAPC 2015). An aim of the ‘connected city’ is “to provide an efficient and effective regional movement network for people and freight that is integrated with land uses, links key employment opportunities and connects the sub-regions to the greater Perth and Peel regions and other parts of the State”.

Figure 2: The 'Connected City' spatial plan for Perth and Peel



(Source: Draft Perth and Peel @3.5million, WAPC, May 2015, Figure 6, p 25)

Figure 3: Population distribution in 2015 and at 3.5 million population

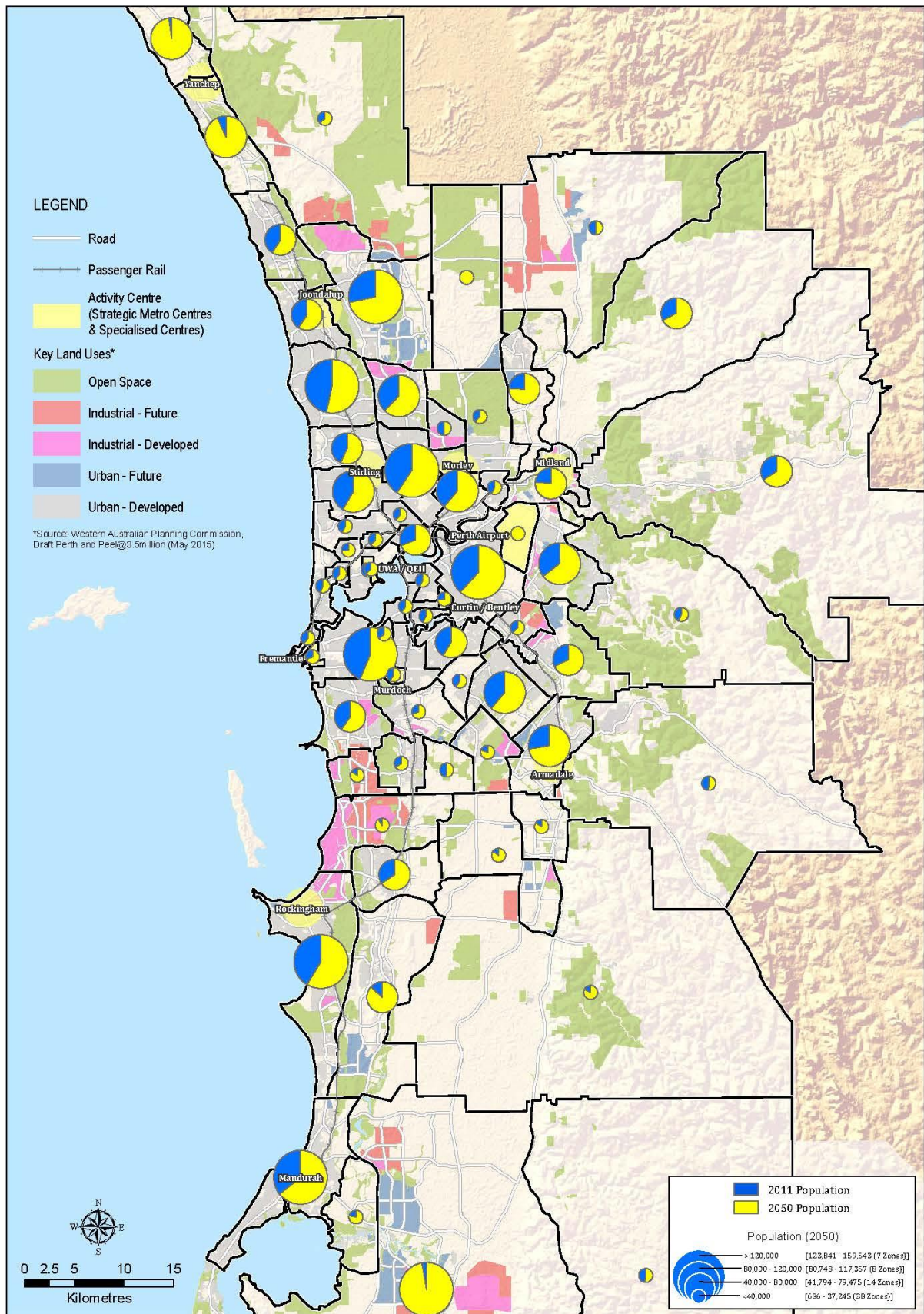


Figure 2 shows the 'Connected City' spatial plan for Perth and Peel, including existing 'mass rapid transit' passenger rail lines and 'Activity Centres' (WAPC 2015). For the urban movement system the aim of this policy, which supports denser land use, is consistent with the aim of creating a strong "level of 'choice' rather than 'capture' in public transport use." (Mulley 2015).

For this research, the size and spatial distribution of population (Figure 3) and employment (except for employment scenario testing mentioned above) have been provided to us by the WA Department of Planning on behalf of WAPC.

Demographic and employment data for this research are therefore consistent with the chosen 'connected city' growth pattern, the principal features of which are *inter alia* (WAPC 2015):

- A strong central business district that is the business, finance, service, retail, cultural and entertainment centre of the State.
- A network of connected Activity Centres with high-quality public transport and road linkages.
- High-quality global and local infrastructure networks including public transport, and
- Urban form that maximises the use of existing infrastructure assets in parallel with extending infrastructure into developing areas of the outer sub-regions.

There is much debate about the wisdom and practicality of the present urban planning growth path, especially of its goals for 'densification'. Critics have labelled it both insufficient and excessive. Our brief has been simply to advise on infrastructure requirements for the chosen policy and related distributions of population and employment. If the desired policy outcomes do not occur, then the infrastructure proposed by our research will need to be reconsidered.

3. The future context

It is certain that the Perth and Peel in which 3.5 million people will live in three and a half to four decades from now will differ materially from our present experience, and that this will affect our individual work and travel choices. The changes which have occurred over the same span of time to 2015 have in many spheres been very great, in technology, employment types and locations, housing preferences and social norms. We can expect more of the same, some of it now visible in current trends, some as yet unknown to us. Significant 'disruptions' to technology, work and social norms will affect the nature and location of urban activities and the connecting travel between them.²

Whatever our imagination can conjure in relation to these trends, it would be wise to recall that in the past there have been large 'cultural' shifts in the use of public transport attributable to disruptive technologies. For example, the plunge in public transport's modal share over a few decades due to rising car ownership and use, from 45% in 1940 (before the effect of wartime and post-war petrol rationing) to its nadir of 10% in the 1980s. Dramatic changes are possible, indeed likely, in future. However, it is impossible to gauge the impacts any of these potential changes might have on our travel habits four decades into the future, in particular, the effects these might have in aggravating or diminishing the 'peakiness' of daily travel and/or in altering materially the mode share of public transport. Sensitivity testing on employment scenarios carried out during this research has aimed to assess what effects are possible.

Areas where present trends, past experience and 'futures' thinking suggest there is significant potential for change, and for impact on travel behaviour, are:

² This section of this report draws from Working Paper 1: *Future Trends and Mass Transit 2050*.

- *Housing preferences:* The 'planning framework' assumed for this research foresees material change in the mixture of available housing styles, so there will be many more medium and high density homes (WAPC 2015). 'High density' has been seen by some to be undesirable, but current trends in new residential building and household formation suggest this view is changing. Trends towards smaller families including singles living is likely to accelerate growth in medium and high-density housing. Increasing acceptance and use of modular and other construction technologies – e.g. '3D printing' of construction modules – making higher density housing forms more affordable, is likely to further boost the trend towards higher density urban development. Homes in most higher density contexts will have good access to public transport, including in walkable 'transit oriented development' precincts. These trends have the potential to increase the use of public transport, provided it is available.
- *Employment changes:* More portfolio-type careers are likely, combining multiple part-time roles and project-based jobs. It is also possible that loss of some employment opportunities and types through automation, together with anticipated rising levels of self-employment, flexible work arrangements, part-time work, variable work hours, workforce 'casualisation', telecommuting and co-working, will also result in time- and space-distributed work with less demand for peak period mass transit. Similarly, more distributed retail and tertiary education models with on-line services replacing some face-to-face activity, could potentially generate less demand for mass transit.³ There is some evidence, however, that information and communication technology (ICT) can be both complementary to and generative of physical travel, but this travel might be less peakily distributed travel across the entire network, with less requirements for mass transit along a few, specific routes.
- *Car use and ownership:* Car ownership is still increasing in Australian cities including Perth at a higher rate than population growth.⁴ Trending in the converse direction, there is evidence that across the world and in Australian cities, including Perth, 'peak car' has been reached with average car passenger-kilometres travelled per capita declining since around 2004/5, while public transit travel is increasing.⁵ 'Millennials' purportedly have less interest in car ownership and an emerging preference for public transport. With population growing, it is likely traffic congestion will also continue to grow, in spite of demand-management policies, and travel by car will reduce in effective speed. These trends could translate to fewer trips made by car and shorter distances travelled. Reinforced by changes in urban form, and in employment types and locations, it is very plausible that in future decades a growing number of commuters and other urban travellers will choose public transport.
- *Demand management policies:* Successful implementation of a range of complementary policies to reduce single occupancy vehicle travel, generally with the aim of reducing congestion, could result in increased demand for public transport but could equally be overtaken by other factors mentioned here, especially disruptive technologies.
- *Intelligent Transport Systems (ITS):* Congestion reduction through the use of real time information to manage road transport systems could result in attracting more road-based travel, further enhanced by increased trends of autonomous vehicle uptake. However, in the face of population growth during the four-decade horizon of this research, it is unlikely ITS will limit indefinitely the growth of traffic congestion, sufficiently to counter other trends towards greater public transport use.
- *Autonomous vehicles:* It is uncertain how these will affect car ownership and use, and critically choices to use public transport. Whatever their effects, it is likely they will be significant three and a half to four decades from now, with autonomous vehicles capturing a

3 Department of Transport 2015. *External Factors likely to affect current travel patterns*, author Hugo Wildermuth.

4 Committee for Perth 2013. *The Rising Cost of Living in Perth* <http://www.committeeforperth.com.au/pdf/CostOfLiving/CostOfLiving5a.pdf>.

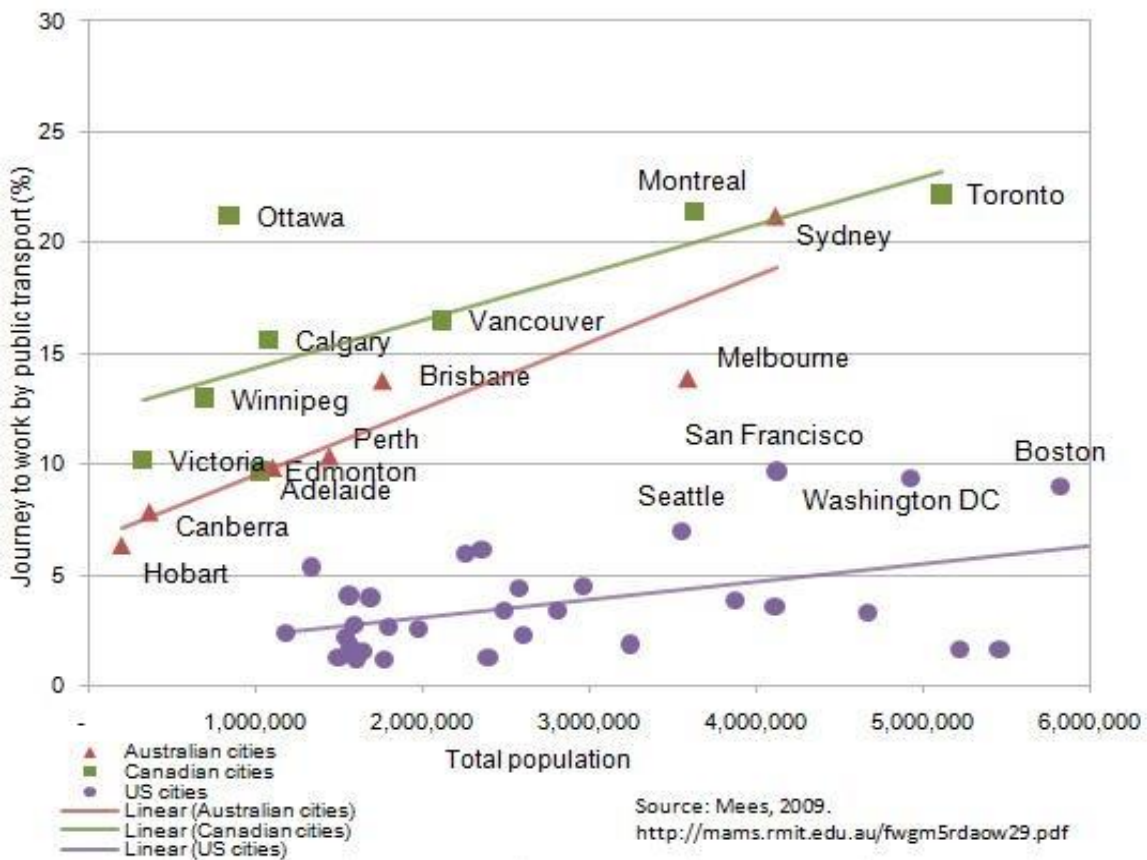
5 Newman, P & Kenworthy, J 2015. *The End of Automobile Dependence - How Cities are Moving Beyond Car-Based Planning*, Island Press, Washington DC.

substantial – possibly a majority – share of all vehicle travel by 2050⁶. There are views that shared autonomous vehicles could complement public transport by enhancing access to public transport stations and ‘stops’, and therefore replace shorter distance public transport where mass transit does not confer a time and access benefit. Conversely, growing traffic congestion will reduce the attraction of all forms of individual or group car travel.

Careful monitoring will be needed to assess the potential long-term impact of these trends and counter-trends on the mode shares achieved by public transport in coming decades.

The potential changes identified above will be ‘exogenous’ to Perth’s future public transport system – that is, originating from outside it. Experience in Perth and in other comparable cities suggests that changes in the public transport system itself, coupled with continuing growth in population, also have the potential to change travel preferences, albeit only gradually. The ‘market share’ of travel in Perth and Peel using public transport was approximately 5.6% in 2014 (PTA 2015). The average annual increase in public transport usage between 1999 and 2013 was 2.08% (PTA 2015). Simple extrapolation of this growth in public transport usage – from growth in network coverage and in population – would potentially result in the ‘market share’ of public transport in Perth increasing to 8-9% by 2030 and 11-12% in 2050. This would be broadly consistent with relationships between populations (and by implication population density) and transit usage for work-trips in other comparable cities (Wong 2009), and illustrated here in Figure 4. The greatest potential for increasing the public transport mode share is in the provision of attractive and competitive services to and from major Activity Centres, mimicking the already significant role that mass rapid transit has in serving the CBD.

Figure 4: Relationship between Population Size and Transit Usage for Work Trips



6 Litman, T 2015. *Autonomous vehicle implementation predictions – implications for transport planning*. Victoria Transport Policy Institute. <http://www.vtpi.org/avip.pdf>.

4. Overview of approach to identifying the need for new network links

Future needs for additions to the mass transit network will arise from:

- Shortfalls in the capacity of existing radial links in the network compared with estimated transit demand.
- The need for greater orbital connectivity between these radial links, and for improved network operating integrity, safety and efficiency.
- The need to provide services to areas not adequately served by the present MRT network.
- The need in the CBD, and eventually beyond, for distribution systems which are separate from the main-line MRT network, as the flow of commuters to the CBD increases and as demand for short-distance services increases from inner-city residents, shoppers and people attending sporting fixtures close to the central area.

To identify future shortfalls in network capacity, our approach has been to quantify:

- The estimated 'one-hour' peak daily demand for travel on all present MRT network *links and stations* for a population of 3.5 million.
- The maximum daily peak-period carrying capacity of each principal network link after completion of all network improvements identified by the Public Transport Authority up to 2031, including the contributions to new carrying capacity of increases from additional and higher-capacity passenger carriages, improved train control and signalling systems, expanded stations and network additions.⁷
- The difference between the feasible capacity on present MRT network links and stations and estimated future demand for a population of 3.5 million.

From these estimates, we identified options for new network links and stations able to provide the extra capacity needed to carry the indicated 'overflow', to provide improved connectivity between major Activity Centres and efficient and safe access to the growing Perth central area, and to ensure network operational 'robustness'. Where judged to be feasible we have highlighted opportunities for system innovation, including options for the application of contemporary 'Metro' technology, light rail and bus rapid transit.

The value of the MRT system cannot be measured solely by its ability to effectively serve travellers in the 'peak'. Matching this peak capacity requirement simply ensures that the system can provide a quality service to all comers when at its busiest. In this regard, Working Paper 4 comments, "In the sensitivity analysis, the results are based on the peak travel demand between 7:30 and 8:30am, assuming not only that this is the most pressing issue (ensuring carrying capacity), but also that this traffic is the determinant of daily ridership for the mass transit. However, ... the daily ridership [is more] relevant for the economic viability of any mass transit infrastructure, [and] may potentially be higher on other O-D relationships and throughout the day, for purposes other than commuting, e.g. education, health, shopping, recreation."

4.1 Principles to guide network development for 3.5 million and beyond

The shape of a long-term plan for the MRT network serving Perth and Peel requires clear principles. It is important for achieving the urban development goals for Perth and Peel that increasing numbers of urban travellers routinely select public transport, especially for journey-to-work trips. For this to occur their choices must be supported by a strong 'network effect', that is by frequency, speed and perceived ease of transfer between services on the network. This 'network effect' is reinforced when travellers are willing to make transfers, as routinely occurs in large city transit systems. Congestion in transfer stations and transit vehicles deters choice.

Shaping the network must perforce take one of two directions: "matching services to demand or matching services to need" (Mulley 2015a). Networks adapted to traveller *demand* aim to provide

⁷ Information on these for this research was provided by the PTA (Public Transport Authority 2015).

service frequency and journey times which compare well with private car travel times. On the other hand, networks which match services to *need* aim to provide broad geographic coverage, sacrificing frequency and journey times. To provide high frequency services, demand-based networks require corridors where demand is concentrated. Frequency can be varied by time of day to more closely match demand. High frequency (2 minutes 'headways' in the peak) provides 'turn-up and go' convenience which will attract riders to mass rapid transit services.

A 'demand-based' network is the choice made for this research, with 'coverage' achieved by connecting distribution and feeder services. The relatively low density of Perth's population, even after increases sought by current urban development policy, will continue to make it imperative that passenger movements be concentrated on fewer lines. The alternative would be less frequency, fewer travellers choosing to use public transport and the financial consequences this would bring.

We have also based our selection of links for inclusion in the long-term future Perth and Peel MRT network on physical design and performance criteria aimed at avoiding more costly or otherwise undesirable options. This means "building on the existing radial structure to the extent that this is possible." (Mulley 2015b)

We have used the following nine principles to identify and locate desirable new network links:

- The primary aim of the MRT network should be to serve growth corridors and link designated strategic Activity Centres. The predominantly 'heavy rail' MRT network should be supplemented by Metro, road-based LRT (light rail), bus rapid transit (BRT) and bus priority services, where they will strengthen the demand-based MRT network.
- New radial links should be provided where they will ensure the future capacity of the MRT network can accommodate forecast patronage to 3.5 million and in the years 'beyond'.
- New 'orbital' links should be provided where warranted to provide connections between Activity Centres and the radial network, and to enhance network capacity where necessary.
- New radial and orbital links should be provided where necessary to enhance network operating robustness.
- Where feasible, new technology should be employed to enhance the travelling experience and lift operating performance (capacity, frequency and/or speed).
- Links to provide for entry to and distribution within the Perth central area should aim to protect the efficient operation of existing 'through-routing' rail-based services. In the 'beyond 3.5 million' years this will require an inner city 'metro' distribution system in the Perth central area separate from the present 'heavy-rail' MRT network.
- The MRT network should avoid using any part of controlled access highway corridors which are prescribed for strategic freight transport, to preserve space in road reserves for future growth in road freight. MRT rail tracks and freight rail tracks must remain separate.
- Where practicable new MRT links should be placed in controlled access highway corridors, provided they will not impact future capacity to accommodate freight vehicles or compromise the quality of potential future transit-oriented development precincts, and otherwise be placed in tunnels.
- Provision of all new links in the MRT network should strengthen the chosen 'demand-based' network structure aimed at achieving user-friendly high-frequency services.

New links in the MRT network have been identified as likely to be required for patronage generated by a Perth and Peel population of 3.5 million (in about 2050) and in the years beyond. We have also identified links which are likely to be required in the years after the population of Perth and Peel reaches 2.7 million (in approximately 2030) but before it reaches 3.5 million.

Until the 2.7 million population horizon is reached, the main, though not exclusive, requirement will be for lines built on the surface in current transport corridor reserves. In the years between the 2.7 million and 3.5 million horizons, and beyond, construction of extended radial lines, new

orbital links and an inner city 'metro' distributor will be required. Much of this construction to the 3.5 million horizon and beyond is likely to be in tunnels.

Exploiting the benefits gained from the 'network effect' described in this report will require effective and well-connected stations in these locations. Primary objectives should be integration into the urban form, compliance with functional transport requirements and accessibility from all connecting modes including bus transfer, drop-off and pedestrians and cycling routes.

Careful structure planning of new station precincts will therefore be important to the success of responsive urban development opportunities. Some critical factors in transit station planning and design are "attractiveness", service quality and network links. Attractiveness is a combination of convenience (access) and ease of use (amenity).

To be attractive to users, and help in developing a long-term 'transit culture', transit stations must be well located, visible, accessible, comfortable, safe, and protected from the elements. Relevant urban structure planning should be undertaken in conjunction with long-term planning for new transit corridors. Many future stations will be incorporated into the existing urban form, and some will require major adjustments to existing road networks and urban structure plans.

4.2 Maximum daily peak carrying capacity of present and committed MRT network

Capacity constraints on all present radial corridors are most severe at their entry to the CBD and on platforms in the Perth Underground and Perth Central stations. These are important potential choke-points in the present system. Assumed passenger capacity limits for present MRT corridors are: for North (Yanchep/Joondalup-City) and South (Mandurah-City) 26,400 per hour and for the Fremantle, Armadale and Midland lines 18,000 per hour (PTA 2015). These limits will require on-going assessment in the light of future system investments.

The future-looking *Route Utilisation Strategy* being developed by the Public Transport Authority proposes a suite of capacity-enhancing investments across the urban passenger rail network, sufficient to cater for forecast patronage to at least 2031. These include passenger carriages with higher carrying capacity and more doors to reduce boarding and detraining times, signalling system and station improvements.⁸

Where passenger boardings in the morning peak hour estimated for 3.5 million population exceed these levels, network capacity enhancement will be needed.

4.3 Estimating peak daily transit demand for 3.5 million

It is conventional for public transport network planning to be guided by complex computer-based statistically-driven 'four-step' demand models,⁹ which estimate future commuter trips in a 'target year' across complex networks to and from each of a large number of urban 'travel zones'. These have commonly been used, including in Perth, where planning horizons are up to a decade or two in the future. Public transport planning in Perth uses STEM (the 'Strategic Transport Evaluation Model') which has been progressively upgraded to use the most recent available evaluation tools.

It is our view that the uncertainties arising from the very much longer planning horizon in this research – three and a half to four decades – require a more transparent and simpler approach in

⁸ Train configurations assumed are: for the North/South lines (Mandurah/City/Joondalup) 6-cars C series carriages (1,100 passengers per train) @ 24 trains/hr; for the Fremantle, Armadale and Midland lines 6-car B series carriages (total 900 passengers per train) @ 20 trains/hr.

⁹ See for example, www.massdot.state.ma.us/Portals/17/docs/StatewideModel/StatewideModelDescription.pdf. Models to assist Perth metropolitan transport infrastructure planning were reviewed by PATREC in 2014; see Taplin, John, Michael Taylor, Doina Olaru and Sharon Biermann 2014, *Transport Modelling Review* (http://www.patrec.uwa.edu.au/_data/assets/pdf_file/0003/2578710/2014-Transport-Modelling-Review.pdf).

which key variables can be more openly, simply and quickly varied to gauge the sensitivity of outcomes to differing estimates of these key variables.^{10, 11}

Estimates of the maximum carrying capacity required by the future mass rapid transit network have been based on the demand for travel-to-work trips by public transport, for travel on public transport to education, and other public transport trips typically occurring in the peak one-hour morning and evening travel times. This requires estimation of total work and related trips and of the percentage of travellers choosing to travel by mass rapid transit ('modal share').¹²

The starting point for estimating peak demand for MRT trips has been to estimate the numbers of people employed and their workplace distribution in locations across the Perth and Peel regions at 3.5 million population; 68 geographic 'zones' were used. Peak travel demand has been expressed as one-way trips between residential and workplace zones in peak travel times. The weekday daily travel 'peak hour' used was 7.30 a.m. to 8.30 a.m. 'Central' estimates of inter-zonal travel demand were validated by STEM modelling using the same population and employment estimates; variance from STEM estimates were in the acceptable range of +/- 1% to 5%.¹³

To assess how variability in the required capacity for the AM peak was associated with sources of uncertainty in the 'sketch-planning' model inputs, sensitivity analysis was undertaken for six elements: the percentage of employees travelling to work in any given work day, the percentage of trips at peak hour, the percentage of commuting trips from the 'outer' and 'inner' regions to the main destinations by public transport, and the percentage of trips made by students and for other purposes at peak hour.¹⁰ This analysis was needed as it guided the designer and user of the model on where to focus their efforts for more robust data and/or more detailed modelling.

The results indicate that the percentage of trips for other purposes, trip 'generation' for employment and education, and the 'peak-hour' proportion are the most influential elements that can change the patronage. The assumptions made for these inputs have distinct effects, varying by corridor, and thus require additional investigation.¹⁰

Also tested for its impact on peak-hour travel demand was an employment distribution scenario with a higher concentration of the workforce in the CBD (53% rather than our Base Case 49%). The impact of this alternative employment distribution scenario on patronage demand was only slight. For a substantial lift in critical patronage numbers to occur, employment in the CBD would need to increase to 'European' proportions.

To avoid under-estimation of total travel to work and public transport modal share, we have increased our 'raw' estimates of future MRT travel demand by 33%, comprising 10% for potentially higher Perth central area employment, 10% to allow for greater demand as population

10 The approach used for estimating patronage in this research, and sensitivity analysis of key variables, are described in our Working Paper 4: Oлару, D, Piggott, L, Biermann S, Smith, B, McCarney, G, Patterson, D. (2015), *Sensitivity Analysis for Mass Transit Options*.

11 This approach to network modelling and planning is authoritatively endorsed by the authors of the *HiTrans Best Practice Guide* for public transport planning: "Network planning is hard work.... The tools of practical planning should support a process of drafting, analysing and redrafting network proposals. Even in the time of the ever more powerful and user-friendly computer, the traditional tools of the map, coloured pencils and sketching paper are very practical in facilitating open and creative discussion among planners." Public transport – Planning the Networks. *HiTrans Best Practice Guide 2* 2005, page 10. Sketch planning models have a long history of applications in transport modelling, where the traditional four-steps are simplified or only partially applied, depending on the problem at hand (see Working Paper 4: *Sensitivity Analysis for Mass Transit Options*, page 7).

12 The assumed proportion of student peak hour trips on public transport has been estimated at 2% on all lines except Fremantle, for which 11% is the estimated proportion. Non-work trips in the peak hour are estimated at 1% on all lines. Public transport mode shares have been provided to us from empirical research and modelling by Arup Consultants, as follows by destinations: (a) for the CBD, 70% from outer suburban locations and 40% from inner suburban origins; (b) for Midland, Rockingham, Mandurah and Claremont, 20% from distant origins and 25% from closer origins; (c) for Fremantle, Murdoch, Curtin and UWA/QEII, 35% from distant origins and 45% from closer origins; (d) for Morley, Shenton Park and Subiaco, 40% from distant origins and 35% from closer origins.

13 Employment scenario modelling carried out during this research is reported in Working Paper 2: McFarlane, Jason and Robert Kyne 2015, *Employment and Population Scenario Modelling*.

grows beyond 3.5 million, and 10% for possible estimation error. The resulting estimates of peak-hour passenger demand at 3.5 million population on key segments of the MRT network (present, committed to 2031 and proposed in this report) are shown in Figure 5 below.

Figure 5: Passenger Boardings at 3.5 million population on the Mass Transit Network

Existing Network links, additions and combinations	Northern (Joondalup) line	Southern (Mandurah) line	Proposed North-East Radial	Proposed Stirling /Murdoch Orbital		Midland and planned Airport Forrestfield link	Armadale	Fremantle
				Stirling/UWA	Murdoch /Shenton Pk			
1. Current Network (Note 1)	34,000	24,100	-	-	-	17,700	15,000	5,300
2. Plus: Stirling to UWA only (Notes 1 & 2)	28,000	24,100	-	6,000	-	17,700	15,000	5,300
3. Plus: Murdoch to Shenton Pk only (Notes 1 & 3)	34,000	19,300	-	-	4,800	17,700	15,000	5,300
4. Plus: NE Radial only (Note 3)	21,000	24,100	20,600	-	-	17,700	15,000	5,300
5. Plus: All (Note 1)	15,000	19,300	20,600	6,000	4,800	17,700	15,000	5,300

Notes: (1) Patronage shown here are sketch planning estimates results plus 33% (see text above).

(2) Patronage from the proposed Stirling-to-UWA and Murdoch-to-Shenton Park lines are likely to be higher than shown due to opportunistic land-use development and higher mode shares.

(3) North-East line patronage is based on serving all trips to/from north of Currumbine plus the East Wanneroo zone. With a different operating strategy could balance the Joondalup line (15,000) and the North-East line (20,600) to be about 18,000 each.

Our research concluded that estimates of probable (high scenario) peak hour patronage on the MRT network with the 3.5 million population in Perth and Peel, assuming implementation of the network enhancements proposed in the PTA's 2015 draft *Route Utilisation Strategy*, severe capacity limitations on the MRT network are likely to occur only on the north-south corridors.

The capacity limitations imposed by the Perth Central railway station complex (Perth Central Station and Perth Underground Station, and adjacent Perth underground bus station – under construction) make it the important potential choke-point in the MRT network. Access by rail tracks from north and south, station platforms (especially in Perth Underground station), and communicating pedestrian walkways, escalators and lifts between all parts of the multi-station complex will become increasingly congested in coming years. It is important therefore to avoid loading more connections on this 'system'.

5. Overview of network enhancements to cater for Perth and Peel @ 3.5 m and beyond

Our research identified a need for the following principal network enhancements to cater for a Perth and Peel population of 3.5 million and beyond:

- Enhancements of capacity and service on the present rail-based MRT network proposed by the PTA in its 2015 draft *Route Utilisation Study* (upgrading the carriage fleet, signalling system and selected stations), completion of the proposed airport/ Forrestfield link and possibly extension of the present north-west line from Butler to Yanchep (the most northerly extension consistent with the WAPC's urban growth strategy for 3.5 million, to Byford on the Armadale line and to Bellevue on the Midland line. These investments will add network capacity sufficient to meet demand forecast for a population of 2.7 million.
- One new radial link to the east of the present northern line (referred to in this report as Inner and Outer Northeast radials), to connect growing suburbs and Activity Centres to the MRT network, to be completed in stages between the 2.7 and 3.5 million population horizons.

Selecting the alignment for this new radial corridor will require further detailed assessment of probable future growth of Activity Centres and of other factors affecting this corridor.

- Orbital links providing access between major Activity Centres at UWA/QEII through the Perth central area to Victoria Park and Curtin/Bentley, which could also relieve capacity constraints on the present north-south line and potentially on the road network.
- Completion of links connecting Thornlie Station to Cockburn Central and to a station serving the Canning Vale area, by the 2.7 million population horizon, and to Murdoch 'Beyond 3.5'.
- A 'Metro' CBD distributor, providing bi-directional connections between the Perth central core, East Perth, West Perth, Northbridge, Leederville, and the City terminus of a proposed North-East corridor line.
- New connections from the rail-based MRT network to Ellenbrook, Scarborough and Spearwood (by light rail, bus rapid transit or bus priority), some not until the years beyond 3.5 million. Road-based links could also be required to Morley (by 2.7 million) and to East Wanneroo depending on the timing and alignment selection of an option in the north-east corridor.

These new mass rapid transit links are shown in Figure 6.

6. The Radial Network – options for the northeast corridor

It is important that an MRT service be provided in the northeast corridor, for several reasons:

- This corridor is in the only metropolitan quadrant currently lacking the level of public transport service which can be provided by mass rapid transit.
- To provide MRT access to northeast Activity Centres, to strengthen their levels of economic and other activity.
- To relieve pressure on the existing northern railway coming from the growth of its catchment (which is directly north of the Perth central area, especially in the area east of Wanneroo Road and south of Joondalup) and due to its proposed extension to Yanchep.
- To relieve the pressure of passenger flows into and through the emerging choke points of Perth Underground station and Elizabeth Quay station.

The following are two possible alternatives for providing MRT service in this corridor connecting key Activity Centres in the corridor and from either of them to the Perth central area:

- (a) A new MRT line diverging from the northern line near Currambine and running southwards via a proposed highway around the eastern boundary of East Wanneroo, Tonkin Highway and the Morley Activity Centre. Trains running from north of Currambine could potentially divert city-bound patronage from the present northern line.
- (b) A new more central MRT route which would diverge from the northern line between Edgewater and Joondalup stations and run southwards via Mirrabooka, Dianella, and Edith Cowan University's Mount Lawley campus. This line would also relieve pressure on the northern line by serving demand from the catchment east of Wanneroo Road.

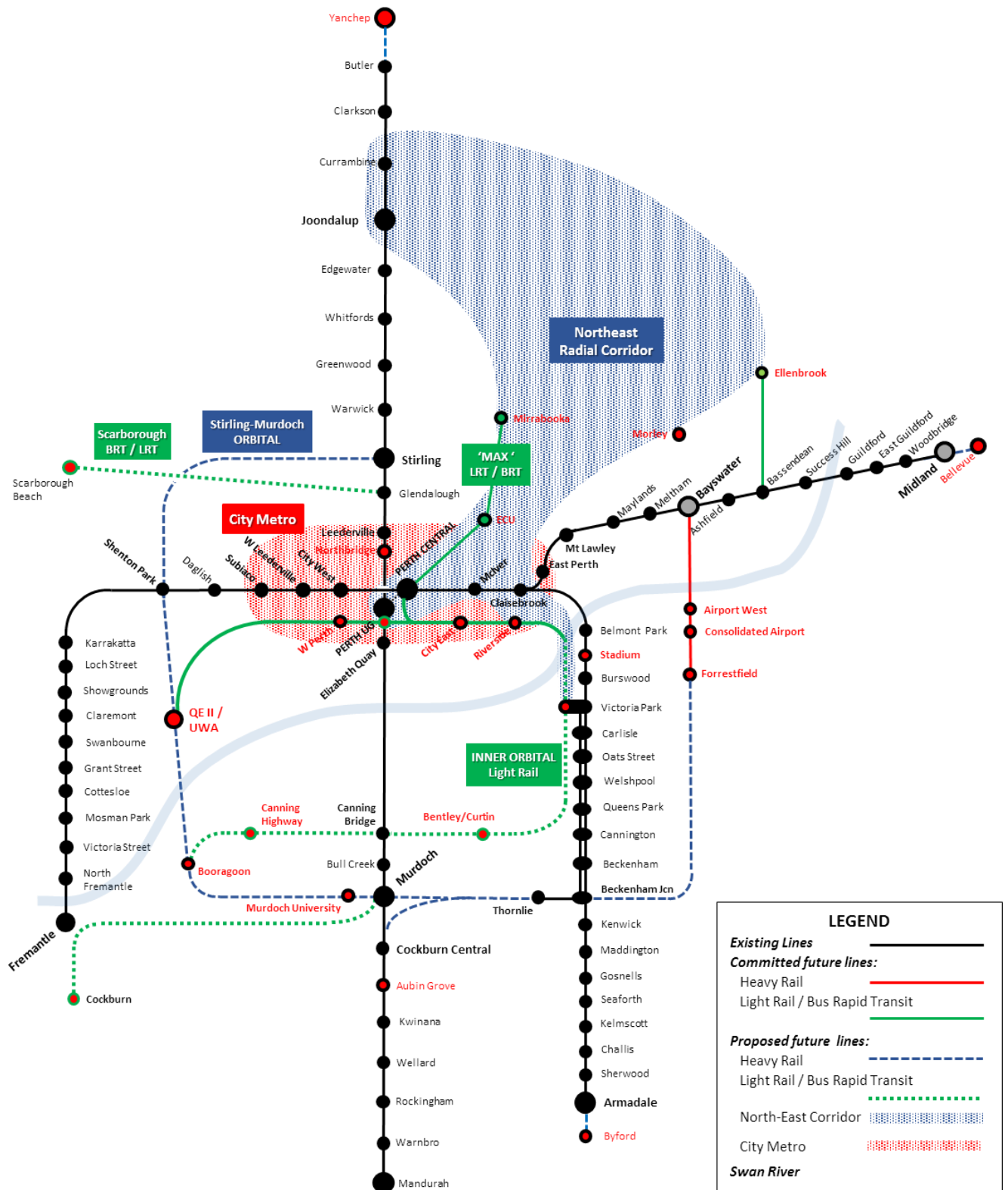
At this stage there is no obviously favoured option.

Both options could connect to the Perth central station complex, and continue to underground to Victoria Park via a new underground station at 'Riverside' and beneath the Midland line at either McIver or Claisebrook.

This new northeast corridor line could continue southward beyond Claisebrook via a new 'Riverside' station (near the Causeway) and terminate at Victoria Park station. Duplication of the Armadale line from Victoria Park to Beckenham Junction would also be necessary.

The current MAX LRT proposal could be reconsidered in light of the chosen option in the inner north corridor. MAX could remain as currently proposed (on-road LRT or BRT) or be replaced

Figure 6: A vision for the Perth and Peel MRT Network for 3.5 million and Beyond



by option (b) above. Depending on the solution chosen, an interim Bus Priority stage might be appropriate.

Assessment of competing alternatives in the northeast corridor should include road-based orbital links to Activity Centres including routes such as Stirling-to-Bayswater via Dianella and Morley and to Ellenbrook. These will be important to provide access to these Activity Centres and good feeder services to MRT stations.

7. An inner city 'Metro' distribution system

As previously stated, the current Perth central city station complex (Perth Central Station, Perth Underground Station, and the adjacent Perth underground bus station now under construction) is a potential choke-point in the MRT network. Access by rail from north and south, station platforms (especially in underground stations) and communicating pedestrian walkways, escalators and lifts between all parts of the multi-station complex will become increasingly congested in coming years. It is important therefore to avoid adding more connections to this vitally important central city 'terminal system', and to minimise the complex web of connections.

For this reason it will also be necessary to provide an efficient Perth central-area distribution system, which should be independent from the radial MRT network but effectively connected to it by transfer points.

This need could be met by an inner city 'Metro' system which would provide high-capacity high-frequency distribution among all stations in the broad CBD area, including all those on the radial MRT network. Instead of detraining in the existing Central or Underground stations, CBD-destined commuters could transfer to the Metro Distributor at stations stacked under or adjacent to the radial lines, using the Metro to travel to their destinations in the broad CBD. The 3.5 million population scenario will include a larger CBD area.

It is necessary that this inner city Metro distribution system be separated from mainline rail services. Unacceptable risks to safety, service quality and reliability would be created by mixing long-distance high-frequency through-running close-headway mainline commuter trains with similarly high-frequency but slower, smaller local 'loop' trains, using the same platforms, due to inevitable timetable slippages and platform congestion.

Expert technical advice obtained for this report shows that a horizontal and vertical alignment for a CBD Metro distributor is available to acceptable standards.¹⁴ This would enable construction of a Metro distributor on the most difficult potential distributor location – along the southern side of the CBD, under Esplanade Station and under the Freeway – with sufficient elevation to allow construction of a station in West Perth. This Metro system could extend from the eastern CBD as far Subiaco and parts of Northbridge.

8. Extensions of existing radials

Three extensions to existing MRT radials are proposed. These are from Midland eastward to the nearby developing Bellevue area, from Armadale to Byford, and joining Thornlie to the existing north-south radial through Cockburn Central and Murdoch. Care is needed however, to avoid northward and southward extensions of the MRT network 'pulling' the metropolitan area 'footprint' into as-yet undeveloped areas where it will aggravate the tendency for 'sprawl'.

A link between the Thornlie branch and Forrestfield should be completed in the years beyond 3.5 million. This link would increase operational connectivity by providing opportunities for additional non-CBD depot locations serving the whole network and for efficient train repositioning when required.

14 See Working Paper 7, Hoare, J, *Preliminary Assessment of Options for a Metro City Distributor in Perth* (2016).

9. A new Stirling – Murdoch Orbital

The need for one rail-based *orbital* line linked to selected *radials* has been identified, most of it for completion before the 3.5 million population horizon. The distribution of population in 2050 illustrated in Figure 3 provides visual evidence for the future need for this service.

This would link significant Activity Centres in the near western suburbs, The University of Western Australia (UWA), Queen Elizabeth II (QEII) medical complex and the Murdoch Activity Centre, including Fiona Stanley Hospital, St John of God Murdoch private hospital and Murdoch University. By providing opportunities for transfers at Stirling (which are destined mainly to the western suburbs and other destinations on the Fremantle line), this new orbital route will also provide relief to the critical inner segment of the northern radial line and Perth Underground Station, where capacity will be under most pressure as Perth and Peel approach 3.5 million. It is likely that patronage will be enhanced by opportunistic development, and ongoing spare capacity on the Fremantle MRT line will provide other opportunities.

This line, with connections between major Activity Centres north and south of the Swan River, has the potential also to reduce or defer the need for a new road crossing the river, by diverting some north-south travel from road to MRT. An underground MRT crossing extending southward from the UWA campus would require none of the large approach works associated with a major road crossing.

There is a strong imperative to ensure the radial network is able to provide a high frequency of service at peak times. However, in the longer term there will also be a growing need for orbital services to provide easier access between major Activity Centres without transfers in inevitably congested CBD stations. The Stirling/Murdoch orbital link has been selected from the options evaluated. This should be supplemented by LRT and other road-based links (see below). In the decades before implementation of this part of the 'vision' there will be many opportunities for innovation in transit technology.

It is proposed the Stirling-Murdoch Orbital connect to the Fremantle line through a redeveloped station at Shenton Park, and proceed to stations serving QE II and UWA. This partial orbital could form a worthwhile Stage 1, to be completed by the 2.7 million population horizon.

Stage 2 of this orbital line, to be completed by the 3.5 million population horizon, would continue to Murdoch via Booragoon. As indicated in Figure 6, other stations should be located on this line between Stirling and Shenton Park and between QEII/UWA and Murdoch. The Stirling-Murdoch Orbital would require extensive tunnelling (mostly bored, but partly cut-and-cover), the costs for which are reducing.

Complementing Stage 2 of the Stirling-Murdoch Orbital, it should be extended to allow trains to operate and people to travel eastward from Murdoch to Thornlie and northward to the CBD on the Armadale line, making a near complete circle.

Stirling and Shenton Park are preferred transfer points from the Northern and Fremantle lines to this Orbital. A new transfer station could be accommodated at Shenton Park where there is a large area of surplus land (previously the Royal Perth Hospital annexe) soon to be redeveloped. Separate stations should be provided in the QEII medical precinct and UWA (the locations of these have not been examined in detail). From Stirling to Shenton Park there are opportunities to avoid tunnel boring by cut-and-cover tunnel construction in Pierson Street and Selby Street, around Herdsman Lake and possibly elsewhere.

In the years approaching the 3.5 million population horizon, the indicated peak-hour patronage on this orbital, deduced from inter-zonal travel-to-work boardings, are in the single-digit thousands daily, but it is our judgement that travel on this orbital link would attract significant latent demand for travel in this 'knowledge arc', which will link the CBD, the growing western extension of the CBD, collaborating research-hospital medical precincts, and the broader research and educational campuses at UWA and Murdoch. There is also potential for development of

university-owned land to the west of Shenton Park station. It is our judgement therefore that the Stirling/Murdoch Orbital should be available for use when the Perth and Peel population reach 3.5 million.

There are alternatives to the route followed by this new orbital. Two have been examined and rejected in favour of the Stirling/Shenton Park/Murdoch link. These could include transfer stations at Subiaco (instead of Shenton Park) and at Cockburn or Canning Bridge (instead of Murdoch) and transfer to the radial network in the eastern CBD. Our assessment is that these alternatives would provide less strategically and collaboratively important linkages and at higher cost. An orbital linkage between UWA, the CBD and Curtin/Bentley would in our judgement be better provided by an 'Inner Orbital' LRT system.

10. Inner Orbital LRT

By the 2.7 million population horizon, there will be a need for an inner orbital link. This should be a road-based Light Rail Transit orbital connecting UWA/QEII via the central and eastern CBD, Victoria Park and Curtin/Bentley to Canning Bridge (a substantial portion of this route was committed as part of the MAX Light Rail project). This would provide transfer opportunities from the rail-based radial network and the northern corridor at West Perth (with connection to Fremantle), Perth Underground/Central railway stations, Perth Central Underground Bus Station, the eastern CBD and Canning Bridge. These opportunities for transfers would also provide relief to the congested central CBD stations.

For this road-based Inner Orbital, in the period beyond the 3.5 million population horizon, there will be a need for further orbital links in the MRT network complementing the Stirling/Murdoch link. This loop would provide transfer opportunities from the rail based radial network in the CBD with connection to Fremantle and other locations.

Calculating the patronage for this link requires detailed analysis, using models such as STEM, rather than the 'sketch planning' method used in this study. The need for and the timing of this route will depend on densification beyond what has been proposed in the Perth and Peel 3.5m Plan (WAPC 2015).

Even though the 'sketch planning' method is too coarse to provide sufficient information on patronage levels for a detailed design solution, it has the flexibility for quick assessment that shows that many of the potential inner links such as Stirling to Morley or Murdoch to Fremantle cannot justify LRT without substantial increases in urban density. They can however justify effective 'Bus Priority' measures.

11. Other road-based connections

To complete the network it is likely that a number of road-based links ('bus rapid transit' and 'bus priority') will be warranted before the 3.5 million population horizon. These would link 'Activity Centres' not served by rail to the rail network, or to the road-based Inner Orbital.

A bus rapid transit (BRT) systems should be considered to serve Ellenbrook by a connection to Bassendean via the Upper Swan Growth Corridor or to the Northeast line.

Bus Priority links should be considered:

- To connect Morley to Bayswater Station to access the airport line and provide an alternative route to the CBD via the Midland rail line.
- To connect Fremantle to Booragoon via Marmion Street, providing transfers also the north and south on the Stirling/Murdoch loop line.
- To connect Murdoch to Fremantle.
- To connect Cottesloe to UWA/QEII via Stirling Highway.

12. A Timetable for Perth and Peel MRT for 3.5 Million and Beyond

Figure 7 summarises the timing envisaged by this research for implementation of the network enhancements outlined above.

Figure 7: A Timetable for Perth and Peel MRT for 3.5 Million and Beyond

Network Segment	By 2.7 million	By 3.5 million	Beyond 3.5 million
Inner North: (City/Victoria Park – Morley or Mirrabooka)	✓		
Outer North (Morley or Mirrabooka – Edgewater or Currambine)		✓	
Inner City ‘Metro’ Distributor			✓
Stirling-Murdoch Orbital: Stage 1 (Stirling – UWA/QEII)		✓	
Stirling-Murdoch Orbital: Stage 2 (UWA/QEII - Murdoch)		✓	
Inner Orbital Light Rail: Stage 1 (QEII/UWA to Victoria Park)	✓		
Inner Orbital Light Rail: Stage 2 (Victoria Park to Canning Bridge)		✓	
Inner Orbital Light Rail: Stage 3 (Canning Bridge to Booragoon)			✓
Beckenham Junction – Forrestfield			✓
Cockburn Central – Thornlie	✓		
Murdoch – Thornlie			✓
Radial Extensions (Yanchep / Byford / Bellevue)	✓		
Scarborough Beach BRT	✓		
Scarborough Beach conversion to LRT		✓	
Murdoch – Fremantle / Cockburn LRT			✓

13. Developing a ‘Public Transport Culture’

This report presents a vision for the future development of mass rapid transit in Perth and Peel until mid-century and beyond, which is based squarely on rational analysis of empirical data and the Western Australian Planning Commission’s plan for future urban development, including a significant increase in population density.

However, this report is not a ‘plan’ for infrastructure investment. Much detailed urban planning and its successful implementation, as well as related infrastructure planning and design will be required before financial and other commitments could be made to the envisaged enhancements. In the meantime the legacy of urban rail investment in the past 25 years has provided substantial network capacity allowing for this detailed planning and design to proceed in an ordered way.

The greater reach and capacity of the future mass rapid transit network described in this report have been aimed to accommodate estimated patronage at the 3.5 million population ‘horizon’ during daily morning commuter ‘peaks’. But it will be appropriate to measure the full value of the network (when implemented) only in terms of its use by the whole population across the whole day, every day through every year to that time horizon.

The extent of this use will be related directly to the future urban environment in Perth and Peel and the future ‘culture’ of urban travel prevailing in our metropolis in three and a half to four decades. More people working and living in planned Activity Centres across the metropolis (i.e. greater population density), with easily accessible MRT and supporting wide-area public transport will generate greater MRT system usage, driven by more habitual day-to-day ‘turn-up and go’ cross-town MRT trips ... if the experience of most other large cities is any guide. It is likely

that trends supporting these outcomes will be strengthened by the future context of changes in technology, work and housing choices mentioned in section 3 of this report.

Travel by public transport to and from the larger and burgeoning Activity Centres should also more closely resemble the large role it now has to and from the CBD.

Some will identify these trends, when they occur, with development of a 'public transport *culture*', in which public transport is the default option for travel to work, school, shopping, sport and entertainment for the majority. This *public transport culture* is the norm in the majority of large cities across the world.

This culture will be strengthened by growing density of population and employment, because it will be possible to provide conveniently located, frequent and fast public transport services where the amount of MRT 'usage' fully exploits the services on offer. Experience across the world shows that a public transport culture and therefore large-scale system 'usage' can be directly correlated with people living and working in urban precincts well served by public transport.

The density of population envisaged for the Perth and Peel metropolis in mid-century will still be modest compared with many European and North American cities, and very much less than in fast-developing Asian cities. Our vision for Perth's mass rapid transit 'understands' this, and that if population density levels in Perth and Peel do not reach those envisaged in current land use planning for a future population of 3.5 million, some parts of this vision for Perth's mass rapid transit network will need to be scaled back or slowed in their implementation.



ACKNOWLEDGEMENTS

Oversight of this research was provided by a committee comprising:

Adjunct Professor Fred **Affleck**, BA (Hons) *Brit Col*, PhD *Lond*, FAICD, FCILT(Life), Chairman, Advisory Board, Planning and Transport Research Centre (convenor).

Eric **Lumsden** PSM, MBus, MPlg, LFPIA, FAIM, FLGMA, Chairman, Western Australian Planning Commission.

Adjunct Professor Stuart **Hicks** AO, BEc *Monash*, FAIM, FCILT, FAICD.

Research management was the responsibility of:

Professor Sharon **Biermann**, BSc *Witw*, MSc PhD *SAf*, Director, Planning and Transport Research Centre, School of Earth and Environment, The University of Western Australia.

Laurie **Piggott**, AssocCEng *WAIT*, MIEAust, FIPWEA, Laurie Piggott Consulting Pty Ltd.

The people listed below have contributed to or collaborated in the completion of this research. They do not necessarily endorse all or any of its findings.

Professor Graham **Currie**, BSc Hons *Huddersfield*, MSc *Cranfield*, PhD *Monash*, Chair, Public Transport, Faculty of Engineering, Monash University.

Professor Carey **Curtis**, BSc (Hons); MSc; DipTP; PostgradCert.Teaching in Higher Education *SEDA UK*; PhD, MPIA, MRTPI, Professor of City Planning and Transport and Director of the research network *Urbanet*, Curtin University.

Paul **Fisher**, AIT(WA) GradDipComputing MEng, MSc(Astronomy), Principal Consultant, Transport, GHD Pty Ltd.

Laura **Gladstone**, BA (Hons) *W.Aust*, LLB *W.Aust*, Research Officer, Planning and Transport Research Centre, The University of Western Australia.

John **Hoare**, BE (Civil) *W.Aust*, FICE, Principal, Concord Consulting.

Evan **Jones**, BA, GradDip Planning, GradDip Urban Design, FPIA, Principal, Responsive Environments.

Robert **Kyne**, BCom *Curtin*, GradDip Sustainability Studies, *Curtin*, Senior Analyst, Pracsys.

Jason **MacFarlane**, BSc *W.Aust*, MBA *Cal State East Bay*, Principal Consultant, Pracsys.

Gary **McCarney**, Honorary Research Fellow, School of Earth and Environment, The University of Western Australia.

Professor Corinne **Mulley**, BA(Hons) *Nott* MSc, PhD *Lond*, FCILT; Chair in Public Transport, Institute of Transport and Logistics Studies, The University of Sydney.

Professor Peter **Newman** AO, BSc, PhD *W.Aust*, Dip ES&T *Delft*, Professor of Sustainability, Curtin University Sustainability Policy Institute.

Dr Doina **Olaru**, BSc PhD *Bucharest*, Senior Lecturer, The University of Western Australia Business School.

Darryl **Patterson**, BE Civil *Queensland*, Consultant, Arup.

Dr Brett **Smith**, BA GradDipMaths *E.Cowan*, PhD *W.Aust*; Lecturer, The University of Western Australia Business School.

The research team expresses its gratitude to staff and senior management in Western Australia's Department of Transport, Department of Planning and Public Transport Authority for their assistance received throughout this project.

WORKING PAPERS

Working papers have been researched and written by the project team, academic collaborators and consultants solely for use in this research and have not been peer reviewed.

1. Gladstone, L. (December 2015). *Future Trends and Mass Transit 2050*, 28 pp (385 KB).
2. MacFarlane, J. and Kyne, R. (October 2015). *Employment & Population Scenario Modelling*, 9 pp (300 KB).
3. Piggott, L. and Patterson, D. (December 2015). *Peak Daily Transit Demand Estimation Using a Sketch Planning Model*, 17 pp (22 MB).
4. Olaru, D., Piggott, L., Biermann, S., Smith, B., McCarney, G., and Patterson, D. (December 2015). *Sensitivity Analysis for Mass Transit Options*, 22pp (6.8 MB).
5. Mulley, C. (December 2015a). *International Learning on Network Planning and Its Contribution to Perth and Peel @ 3.5 million*, 20 pp (4.7 MB).
6. Smith, B. (January 2016). *Option Generation and Assessment*, 13 pp (1.65 MB).
7. Hoare, J. (2016). *City Metro Mass Transit Assessment*, 4 pp.

REFERENCES¹⁵

- Committee for Perth 2013. *The Rising Cost of Living in Perth*. <http://www.committeeforperth.com.au/pdf/CostOfLiving/CostOfLiving5a.pdf>.
- Curtis, C & Scheurer J 2015, *Perth Public Transport Accessibility: Spatial Network Analysis for Multi-Modal Transport systems* (SNAMUTS).
- Litman, T 2015. *Autonomous vehicle implementation predictions – implications for transport planning*. Victoria Transport Policy Institute. <http://www.vtpi.org/avip.pdf>.
- Mulley, Corinne 2015b, *Network Planning Principles and Issues*, presented to workshop by the Planning and Transport Research Centre.
- Newman, P 2015, *Integrating transit, land use, finance and everything else*, Curtin University Sustainability Policy Institute, presented to PATREC workshop.
- Newman, P & Kenworthy, J 2015. *The End of Automobile Dependence - How Cities are Moving Beyond Car-Based Planning*, Island Press, Washington DC.
- Nielsen, Gustav, John D Nelson, Corinne Mulley, Goran Tegner, Gunnar Lind, Truls Lange 2005, *Public transport – Planning the Networks. HiTrans Best Practice Guide 2*.
- Ortúzar, Juan de Dios and Luis G. Willumsen 2011. *Modelling Transport*, 4th Edition, Wiley.
- Public Transport Authority of Western Australia 2008, *48 Months, 48 Minutes: Building the Perth to Mandurah Railway*, West Perth.
- Public Transport Authority of Western Australia 2015 (Draft), *Route Utilisation Strategy*.
- Taplin, John, Michael Taylor and Sharon Biermann 2014, *Transport Modelling Review*. www.patrec.uwa.edu.au/_data/assets/pdf_file/0003/2578710/2014-Transport-Modelling-Review.pdf.
- Transport, Department of (Western Australia) 2014. Technical Note 4: *External Factors likely to affect current travel patterns*, author Hugo Wildermuth.
- Weller, Richard 2009, *Boomtown 2050*, Perth, The University of Western Australia Press.
- Western Australian Planning Commission 2015, *Draft Perth and Peel @ 3.5 million*.
- Wong, Julia 2009-11-18, *Table 1. Density and method of travel to work in selected US Canadian and Australian cities* (PDF 2p 95kb).pdf [Online, Document], RMIT University, Melbourne, Vic, Available from: [/browse;ID=fwgm5rdaow29.pdf](#) and <http://www1.rmit.edu.au/browse/About%20RMIT%2FHelp%2F;ID=fwgm5rdaow29.pdf;STATUS=A>.

15 Additional references used in Working Papers are listed at the rear of each of those papers.