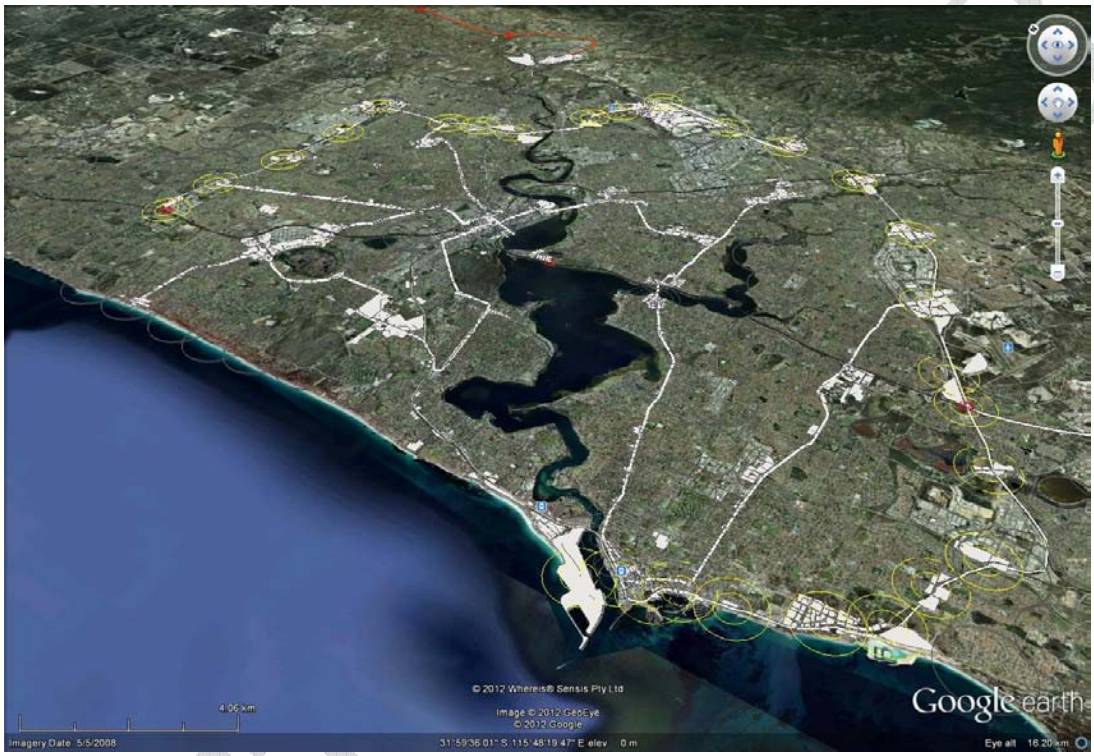
A Three Mode Plan for Perth: Connecting Heavy Rail, Light Rail and Bus with Urban Development to Achieve 21st Century Goals



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Abstract

This report proposes a Ring Rail for Perth supplemented by light rail and bus rapid transit. It should enable a doubling to tripling of the Perth public transport system. Urban development opportunities near the stations in the whole system could then absorb the next 30.6 years of housing and commercial work space without any further Greenfield development or entering far into the established residential neighbourhoods. The results would save $3.9 billion in residential infrastructure costs over the development build out, 1.14 tonnes of greenhouse gas per year and $2.6 billion in transportation costs over 50 years for the newly housed residents per year as well as significant transport cost savings for the rest of the population. External benefits would include health and productivity benefits from living in highly walkable centres of nearly $403 million per year. The heavy and light rail system is estimated to cost $4.4 billion and finance could be arranged for with a ring-fenced fund of value capture that on conservative estimates could pay for the entire rail system. Calculations based on just the new development sites along the transit lines suggest around $3.6 billion could be raised. The Plan will make Perth a 21st Century global city with high accessibility and a new set of important centres complementing the CBD.

Acknowledgements: This paper is still in development. We are releasing this for public comment as there is so much interest in the issues. We thank the Department of Planning for digital base map files and the ARC and CRCSI for providing scholarships.

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The point at which rail modes become superior depends, however, not only on demand, but in the availability of partially or fully separated ROW, requirements in terms of service quality and performance characteristics of alternative means of travel, and external effects such as compatibility with pedestrian oriented areas in cities and desired impacts on land-use developments. (Vuchic 2007 p.299)

Executive Summary

This report discusses future transport and land use options for Perth. These options expand on many of Perth's recent planning documents such as Directions 2031 (Western Australia Department of Planning 2011) and Public Transport for Perth (Western Australia Department of Transport 2012). However the detail provided enables us to see how a future based on rail and Transit Oriented Development can create a less car dependent region with significant economic, social and environmental advantages. The model is based on adding new rail lines – especially a Ring Rail (heavy rail) – supplemented by a light rail for the inner and middle suburbs. Residents and jobs are focussed around the rail stations. Bus rapid transit lines are proposed through the outer suburbs as a way to link these areas to the Ring Rail and existing heavy rail lines. This is then compared to a car-based future where residents and jobs are sprawled outwards from the road based network. The costs avoided and benefits accrued from resisting car-based developments are calculated based on the findings of Trubka et al (2010) and the approach developed by Newman and Kenworthy (1999). These will demonstrate the benefits for regional planning towards 21st century goals (UNEP 2012). The results should be of interest to any city concerned with 21st century transport planning, urban rejuvenation, lowering collective burden on the environment while improving a city's high quality of living.

The core infrastructure concepts are first a Ring Rail travelling the circumference of Perth's middle suburbs and connecting the existing main heavy rail lines. This plan for a Southern Ring Rail Line as a concept was presented in Directions 2031 and was first mentioned by Stephenson and Hepburn in their plan for Perth and Fremantle in 1955 (Western Australia Department of Planning 2012b) (See Appendix 2). The Ring Rail takes the route of the southern freight line. In the north and east the Northern Ring Rail follows the median of the Reid and Tonkin Highways. The Ring Rail builds on the successful practice of fast heavy rail with connecting buses developed in the past 20 years for Perth's Northern and Southern Rail Lines.

The second core infrastructure concept is light rail as largely set out in the State Government's Public Transport Plan for Perth (Western Australia Department of Transport 2012). Around these heavy and light rail lines detailed assessments were made of the potential to absorb new residential and employment development at reasonable densities.

The third core infrastructure concept is to use extensive feed-in bus rapid transit lines (BRT). These BRT lines will enable the outer suburbs to be linked into the Ring Rail and current heavy rail network.

The three mode plan for Perth: heavy rail, light rail and bus rapid transit should enable the transit system to double and then triple as it provides for more options than at present. The development

of these modes need not all start at once and will overlap as capital becomes available or where needs become greatest. The key point of this plan is that these three modes of public transport can enable transit rich urban development to be focussed inside the Ring Rail rather than extensive car-dependent development on the outer fringe. The results of this inner and middle suburb redevelopment are accumulated and compared to the expected demand for Perth in years of potential development based on the housing industry's own current predictions (HIFG 2012). The totals are then assessed for their costs and benefits compared to urban fringe development.

A map showing the key rail an infrastructure and development site is presented in Figure 1 below.

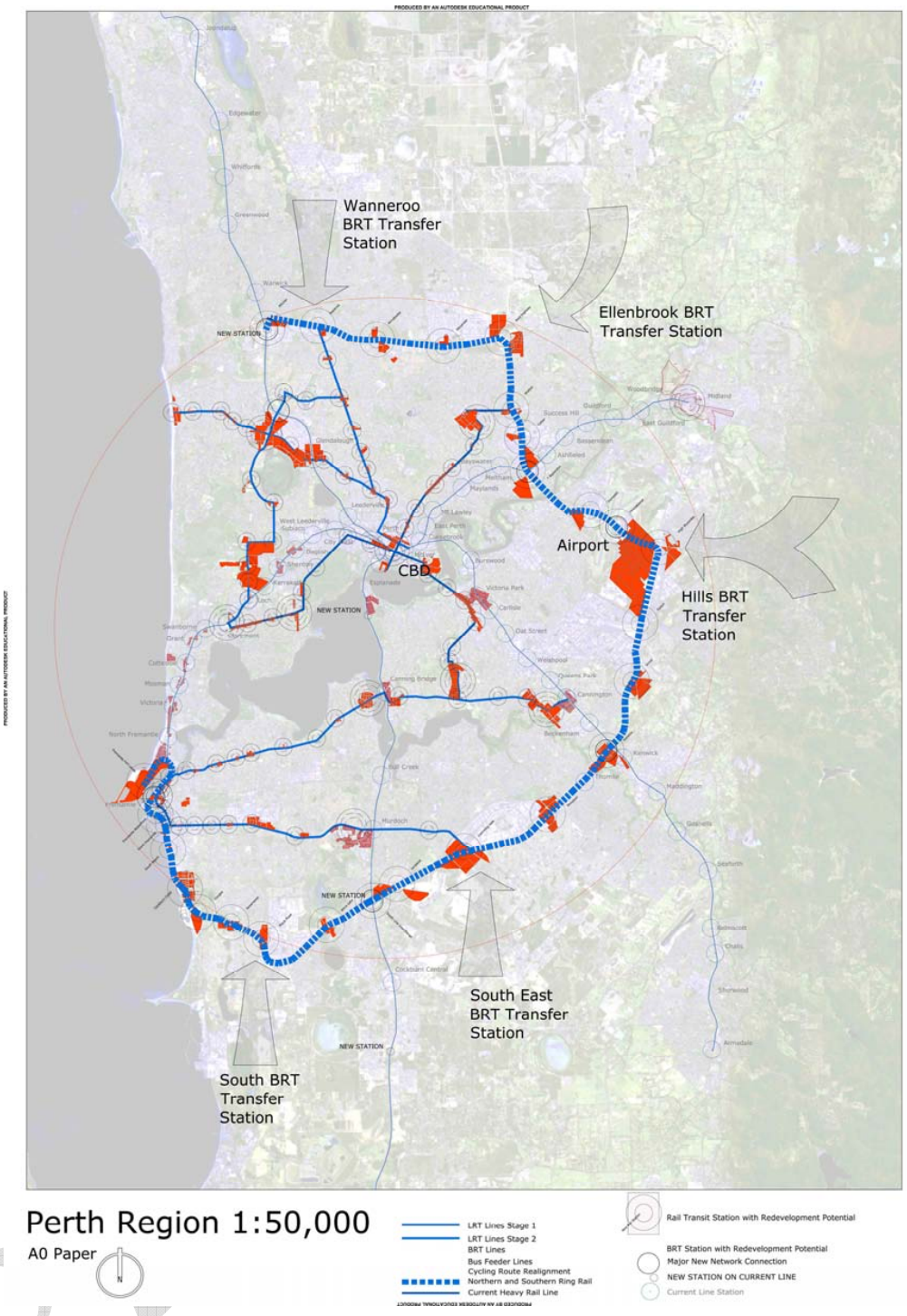


Figure 1 A future Perth of a highly connected networked of rail lines and urban development

All of the red polygons of rail based redevelopment as seen on Figure 1 have a sum total of over 3045 hectares of land which includes some land along the present heavy rail lines. This is enough area to support the policy goals of Directions 2031 if appropriately developed.

Key Findings:

The Ring Rail has been divided into two sections – Northern Circumferential Line and the Southern Circumferential Line.

The Northern Circumferential Line (NCL) will accommodate 88,674 dwellings for 177,347 residents, providing 5.2 years of housing at a Floor Area Ratio of 2.6 with a maximum building height of 10 floors on precincts over 100,000 square meters (10 hectares). This will provide retail spaces for 31,300 workers and commercial office space for almost 208, 000 workers. All this while reducing 194,000 tonnes of GHG from transport per year, saving an estimated $445 million in transportation costs over 50 years, providing an additional 104,000 km of walking trips per year with $7,500,000 in health benefits accrued due to improved health from living in highly walkable environments and $68,600,000 benefits due to higher productivity.

The Southern Circumferential Line (SCL) will be able to accommodate 150, 000 dwellings for 300,000 residents, providing 8.8 years of housing at a Floor Area Ratio of 2.9 with a maximum building height of 10 floors on precincts over 100,000 square meters (10 hectares), providing retail spaces for 21,500 workers and commercial office space for almost 130,000 workers. All this while reducing 329,000 tonnes of GHG from transport per year, saving an estimated $756 million in transportation costs over 50 years, providing an additional 176,000 km of walking trips per year with around $12,000,000 in health benefits accrued due to better health from living in highly walkable environments and $116,000,000 of benefits due to higher productivity.

The overall new system – with the Light Rail network in the inner city areas working in combination with the Ring Rail – will provide 3045 hectares of urban land. This will accommodate 531, 440 dwellings for almost 1,063,000 residents, providing 30.6 years of housing at a Floor Area Ratio of 2.3 with a maximum building height of 10 floors on precincts over 100,000 square meters (10 hectares). This will provide retail spaces for almost 80,000 workers, and commercial office space for over 400,00 workers while reducing 1,164,000 tonnes of GHG from transport related activities per year, save an estimated $2,622,000,000 million in transportation costs over 50 years, providing 622,000 walking trips per year with $45,000,000 of benefits and savings accrued to improved health from living in highly walkable environments and $411,000,000 of benefits due to higher productivity.

Rail Transit investments, such as a Ring Rail for Perth, will not only provide for regional trips by mass transit but also spur these benefits:

- redevelopment of ideally suited sites to house the changing demographics,
- this new housing can provide for a lower carbon lifestyle, lower Greenhouse Gas emissions and lower Vehicle Kilometres of Travel,
- improve local air quality,
- provide for urban forms which are more conducive to walking and cycling,
- enable the current infrastructure, already built, to provide more service,
- avoid costs to households and State/Local infrastructure costs,
- gain social amenities such as recreation, medical and educational facilities in close proximity to residents,
- protect and maintain ecosystem services at the urban fringe of farm and forest,
- enable value capture to pay down capital rail expense,
- increase global competitiveness,
- be an incentive to build less single occupant vehicle infrastructure, and
- be a part of the growing, globally significant shift for car-based cities to a more rail-based future.

This project shows how to make these aspirations implementable in the urban fabric. These acts inherently improve the economy of daily life for the majority of Australians, most of whom live in cities.

Table 1 Benefits of transit investments

The total number of residents and jobs attracted to these rail-based locations can thus absorb around 30 years of Perth's present expected growth without another strictly car-dependent house or job being placed on the urban fringe. It will save over $3.9 billion in residential infrastructure costs required to subsidise urban fringe development (paid for over the next half century at current known expenses).

An estimate of the costs of construction for the rail systems that would catalyse these changed urban development patterns has been made using recent Australian infrastructure project budgets (Martin 2011). This cost estimate, based on $28 million/km for heavy rail and $24 million/km for light rail, arrives in the range of $4.4 billion for all the heavy rail and light rail upgrades. The true economic value of doing transit-oriented developments around train stations is that it can enable a financing mechanism through value capture (alongside the social and environmental benefits of

living in more compact and complete neighbourhoods). A cursory value capture has been estimated at $3.6 billion, based on 1% of the value of the land as well as parking fees, and could be used to pay for the new system. When a detailed assessment is made of the costs and benefits of these rail systems a highly positive outcome is expected as there are significant savings in time made when redevelopment of middle and inner city locations are created compared to outer development, as well as improved time savings for the whole network that would flow through to the rest of Perth's population.

Paper Scope:

Currently, Perth has a very successful rail transit network which, despite many predictions over the last 40 years, has survived and is thriving. The southern Mandurah Line alone moves daily the same numbers of persons as would be required by 8 lanes of free flowing freeway and is quite often at full capacity during peak hours (Newman, Glazebrook et al. 2013). This is a world-class example of pent up demand for higher-order transit in the existing background of car-based cities. It is also an example of how transit provisions may spur housing and job-related developments along its length while providing the transit network with patrons. It brings mass-transit to the masses and masses to the transit. Everything presented in this paper takes Perth as it is currently and imagines using its underlying skills, talents and infrastructure to its best advantage much as the Mandurah Line has accomplished.

This paper will focus on the benefits accrued and cost avoided for the Perth Metropolitan Region if it were to continue this process and build a ring rail, a network of light rail transit and a series of bus rapid transit lines. The outcomes are based on the premise that Public Transit, along with a comprehensive planning for Transit Oriented Developments (TOD) as infill on greyfield and brownfield sites, will be positively appreciated when an accounting of the costs avoided and benefits accrued are placed beside the capital costs to construct.

This paper will focus on TOD as a mechanism to achieve regional goals. Goals such as lower greenhouse gas emissions, lower Vehicle Kilometre of Travel, decreased parking ratios, increased transit use, increased Public Open Space, maintained ecological services from forest and farm land, avoided costs for expensive infrastructure and transport, captured value from the increase in property to help pay-down the costs of the transit and to, ultimately, combat the rise in obesity and lost workplace productivity due to excessive car dependence. All these 21st century goals will be assessed with their quantum outcomes, in dollars or tonnes, under a future focused vision.

The future vision is that Perth will craft a ring rail around its middle suburbs and create a network of street-level Light Rail Transit (LRT) intersecting with the future and current rail network. These visions are based on previous plans such as:

- Stephenson Hepburn plan in 1955 which suggested a ring rail in the south;
- Directions 2031 which suggested a Ring Rail (see Appendix 2); and,

- Public Transport Plan for Perth 2031 which further suggests a range of potential light rail lines.

The three stage vision of a Southern Ring Rail, a Northern Ring Rail and an extensive set of Light Rail, will give a place for, and reason to create, walkable complete centres of infill development. The vision will be complete with a series of Bus Rapid Transit (BRT) lines, where LRT may not be a suitable fit for the task, working to feed the centres and rail lines. Regular buses will also feed the rail lines from the deeper and less dense neighbourhoods. This network of rail and bus will be complimented with a complete network of safe and destination-oriented cycle ways, and lastly, construction of quality pedestrian thoroughfares creating safe crossing and comfortable surfacing. The fine details of how we get there is not the focus of this paper, rather the focus is to assess the major benefits in achieving such a vision.

The results of the propositions for ring rail and light rail will be presented via a series of maps showing where and how they could be built. These are significantly more detailed than anything in the State Government's plans. These rail lines will be followed by charts showing the benefits of rail Transit Oriented Development. The results will furthermore indicate how and why Perth needs to undertake such a bold vision by assessing quantitatively the benefits of doing this kind of development compared to Business as Usual development in a car-based urban fringe approach. The results will show dramatic drops or increases in all those 21st century aspirational goals that most modern cities are seeking. It will show that the policy, financing and design to turn Perth into a world leading city living within its financial and ecological means is in our reach.

The results will also clearly show that investing in a ring rail and a light rail network has incredible savings to tax-payers, despite the initial capital and ongoing operational expenses. Capital budgets devoted to rail transport will have to be created to keep Perth from halting due to congestion as there are limits to the car-based city once they reach a certain threshold. It is far preferable to invest in the future, early while it is inexpensive, than continue with a development pattern of the expensive past. What is really at question though, is what type of region does Perth want to be?

1. Why Heavy Rail?

It is aspired to that ring rail, linking all the existing 5 heavy rail lines and the airport, will reinforce the Directions 2031 policy document resulting in a series of polycentric compact centres[1] with lower single occupancy vehicle (SOV) use, lowered greenhouse gas emissions though lowered SOV use and shared-wall living, higher rates of walking and concomitant higher economic productivity.

1.1. Rationale for Ring Rail

Many cities have ring rail and or at least a highly integrated network which offers multiple destination choices on several lines. Perhaps the most famous of these is Moscow with two 'rings of rail' connecting all the outer lines well in advance of the city centre (see Figure 2 below). Paris is building two new ring rails and London is building a much more interconnected system through its Cross Rail. Many cities have a high degree of rail connectivity (Vuchic 2005; Vuchic 2007). What this connectivity does is offer multi-dimensional destination choice as well as multi-dimensional redevelopment opportunities. It maximises the nexus of land use policy and transportation planning to its ultimate end. It links the ideas of up-zoning, to create higher-density and higher-amenity delivery in planned centres, with rail transport as a means to move the residents and workers. It supplies mass to the mass-transit and mass-transit to the well-housed masses. When this is commonly spoken of in contemporary academic literature and professional planning circles it is described as Transit Oriented Development (TOD) or more broadly as Land Use and Transport Integration (LUTI). Ring rail brings together the functional aspects of a transit system and makes them more than the sum of their parts.

The other important element of ring rail, rather than radial rail, is that land development is encouraged where the transport systems intersect. Thus a more highly connected city has more sub centres than a city with a radial system that primarily focuses development on its CBD. Melbourne is a highly radial rail system and its city is highly focussed on its CBD (extended out somewhat through its large tram network). Sydney on the other hand has a more connected rail system and thus has more and larger sub centres. Perth is at a stage where it is planning more sub centres (Western Australia Department of Planning 2012a) and a ring rail will assist in this process.

The linkages possible with a genuine network, rather than having all transport focussed on one CBD, mean that many more business opportunities are possible as businesses may have a broader range of choice to locate according to their needs for space, rents, prestige, amenities which employees may wish to have access to, or other such reasons. People likewise have a wider choice of places to live, to be closer to work, closer to extended families, parks, waterfronts or price-points. It opens the market to fulfil many of the latent needs of businesses and people to achieve what they need of an urban environment: choice.

[1] These types of communities in various forms have been sought after since at least the time of Ebeneezer Howard forward and in various guises.

The one-centre focus in a radial transit system has three effects:

- congestion on board the transit service in one direction with near empty haul-backs at peak;
- a great deal of trips are not served by transit as the bulk of investment is in one direction rather than broadly across the region. These trips then become car based by necessity; and
- people may not have housing choices adjacent to fixed-guide transit meaning they must, then, travel by car or be 'captive' on a CBD oriented bus transit system which forces long winding routes in mixed traffic.

Ring rail won't solve all these issues, but will certainly help to alleviate a great deal of congestion as cross city transit trips may avoid the CBD and serve to open areas for real estate investment which make more destinations closer to residents. Rail-based development below have multiple advantages: they will have an impact on lowering Greenhouse Gas (GHG) contributions thorough compact shared-wall housing and less driving, they reduce Vehicle Kilometre Travel (VKT) thereby reducing costs to individuals and governments, they avoid costly greenfield expenditures and provide for Value Capture (VC) (McIntosh, Newman et al. 2011) of the developments to help pay down the cost of the Rail Infrastructure. There are therefore many reasons why ring rail should be pursued as a planning policy in Perth. The full list of benefits are listed in Table 1 above.

These strategic investments can be accurately called 'Green Economic' (UNEP 2011; UNEP 2012)as they serve to achieve many of the sought targets while making sound business sense for individuals, private developers and governments. The Green Economy will be comprised of business operating in the free market and hiring people, as usual, but with a distinctly different flavour regarding what is being created and purchased with preferred societal and environmental values coming to the fore. Once societal shifts occur such as those outlined, technological innovation and prosperity spread. The signs of this beginning in Perth are there but the next steps need to be planned.

As Perth becomes a more highly connected and transit-oriented region there will also be significant flow on effects as persons and businesses will choose to relocate to Perth due to its greater number of options in residence and work. The economy in Perth with its new opportunities in energy, minerals for the Asian market will become even broader with a variety of options for housing, workplaces and lifestyles. These opportunities of lifestyle are likely to spur more growth than currently imagined.

At the same time it is difficult to imagine how growth can be accommodated with the Business-as-Usual (BAU) approach. BAU with an increase in roads and more road based developments of low rise single-family product will create more congestion, high GHG, high VKT, loss of surrounding land, more obesity and lost productivity. More BAU only delays the inevitable that Perth needs to 'grow up' to take advantage of its golden opportunities. Beyond even the base of personal and regional benefits which may accrue, Perth needs to use its latent opportunities for it to compete with the top-tier of cities in a globally competitive world for talent and investment. Demonstrating that Perth can plan and deliver some very fundamental spaces linked by mass transit will raise the Perth region in the ranks of globally important cities. At present Perth is delivering fewer apartments than any of

the other major urban regions in Australia(SOAC 2012). An assessment of Directions 2031 has found that redevelopment at higher densities within the suburbs has been the least successful of its policies (SOAC 2012; Western Australia Department of Planning 2012c). The Ring Rail and associated sub centres that it will facilitate can enable this to be reversed.

That a Ring Rail is even a possibility is due to two existing factors in its favour. The first is an availability of highways and current freight reserves and the second is an already announced Airport rail line (PTA WA 2012a). This Ring Rail will support the regional goals of healthy living in more compact and complete communities, with less SOV dependence, with cleaner local air and lower global ecological impact. How a Ring Rail and a light rail network will help Perth achieves these diverse goals is discussed below.

Figure 2 Moscow Rail Network

Image from :(Urban Rail 2012)

2. Why LRT and BRT?

Rail Transit is successful in Perth; patronage has risen from 7 million in 1992 to 31 million a year in the 2003 to 63 million in 2011 (Mees and Groenhart 2012; Australian Government 2012b p.49; PTA WA 2012c). Despite many expectations of failure in the past (Newman 2011) and despite earlier efforts to remove rail from Perth's urban patronage is on the rise. As more people become familiar with the transit system's existing benefits, as traffic congestion worsens, and as the cost to own and operate a Single Occupancy Vehicle (SOV) increase (OzInsure 2012) (see Appendix 1), patronage is expected to rise. This is a global phenomenon as cities turn to rail for the multiple benefits it provides, including the efficiencies in land and transport that can be associated with its planning (Newman, Glazebrook et al. 2013). This paper sets out how Perth can now choose to augment its rail transport to achieve its 21st Century goals.

Perth has been effective with its completion of several major rail projects to the north and south. Heavy rail mixed with an efficient feeder bus network has been very successful beyond the expectations of many transport planners who worry about transfer penalties between modes. Perth's success has been based on fast heavy rail (average speed of over 90kmph compared to 45 kmph in Melbourne for example) as well as efficient integration between the modes (80% of the Southern Rail patronage is bus transfer). This mixed mode aspect means one can leave the car at home or even not need to own a private car. Though road capacity increase (road widening) is often discussed in terms of 'easing congestion', road capacity fills as soon as more is built (Litman 2012).The building of Single Occupancy Vehicles (SOV) infrastructure has only momentary gains in capacity (Cervero 2003) and long term losses in air quality (Kozawa, Winer et al. 2012)and land use quality (Kenworthy and Laube 1999). These competing visions for transport provision will be discussed in this paper. This paper will discuss the Costs Avoided to governments for infrastructure and to citizens for transport, as a part of the benefits stemming from well positioned Public Transport (PT). Additionally, there will be answers to questions of where sufficient land will be found to accommodate population growth, what sorts of amenities might be derived from this growth of population in more compact city scenarios, and if aspirational targets to reduce Greenhouse Gas and Vehicle Kilometre Travel are achievable. The Value Capture opportunities (McIntosh, Newman et al. 2011) along with infrastructure, transport, health and air quality benefits (Trubka, Newman et al. 2010) of these rail-proximate developments are multi-fold, as will also be explained in the results sections below.

2.1. LRT

Light Rail transit has become a very important part of the global transport mode mix. It provides areas, cities, regions with high quality, reliable, comfortable public transport. LRT provides much greater ridership capacity and requires less labour (drivers) per kilometre than buses and less construction expense than conventional underground 'metro' rail transit. LRT can provide great advantages to cities intent on developing compact, walkable, mixed use network of neighbourhoods where personal car ownership is not a prerequisite. However, LRT is only a mode-choice; it takes legislated re-zoning of land, underground service upgrades, clear incentives to develop and a marketplace ready for the advantages of urban living. The city building LRT needs to have a clear land use and transport integration policy, be prepared to carry the additional passengers in the short

term and to have the patience to bear the fruits of urban redevelopment in the medium to long term.

LRT services ranges from street running 'tram/streetcar' type operations with low speed but high accessibility in central city areas, to street median operating on semi separated Right-of-Ways with moderate amounts of mixing with traffic and queuing at traffic lights and variable speeds, to completely separated RoW matching high speed with very reliable timetables and high mobility across metropolitan areas. One of the distinct advantages LRT retains over other modes is that one line might have any or all of these three operating conditions; it is flexible and can fit into most urban settings. Perth has many forms of urban settings and as such Light Rail will be an opportune transit mode to reinforce the redeveloping urban-infill areas of the Perth region.

2.2. BRT

Bus Rapid Transit has been notable in several significant cities for delivering fast, high quality, high capacity and regularly scheduled public transit service. It has been very successful in Curitiba and Bogotá where these fundamental needs were present: high quality transit for the masses; low cost to implement; fast construction times. In these two cities the buses operate on separated RoWs, have distinct stations and excellent transfer points making for a high quality image. BRT has also been successful in Ottawa and Brisbane where, despite a more car based development pattern, the service has been so successful that the cities are constructing or considering, respectively, upgrading the service to LRT due to capacity constraints. BRT can be surprisingly effective at delivering service to and from work to home and beyond. BRT is most successful is when it has these characteristics to work with: few stop (one kilometre apart at minimum) along a very recognizable transit corridor; separated RoW; very little or no diverging off of the corridor if without separated RoW; a strong origin and destination; signal priority; and, several business zones long the length of the corridor.

BRT ranges in a spectrum of service from a fast operating bus with few stops and signal priority all the way elevated separated tyre tracked buses with specially designed stations and termini which are almost indistinguishable from some commuter rail or metro but for the internal combustion engine for propulsion and rubber tyre surface contact.

BRT has often been noted for being less likely to drive a real estate evolution in a neighbourhood. This is attributed to the bus engine noise, exhaust fumes, braking and tire squeal, and the transitional (less fixed) character of a bus all of which drive down the image of the bus. The ride comfort is often less than rail and when combined with the more limited width of carriage means the pleasure of riding a bus can been poorly experienced.

BRT will be most appropriately applied in Perth on corridors with higher than average densities within a broader area, up to a four kilometre buffer, as the stations will be best served as focal points for the localities and as transfers stations from the regular bus fleet serving the deeper neighbourhoods. BRT will reinforce the active development of compact centres such as Kalamunda, Mundaring, Ellenbrook, and others.

3. Why TOD's alongside the rail transit?

3.1. TODs as a mechanism

Transit Oriented Development can be thought of as a mechanism to achieve a suite of targets. It is an urban typology of great long heritage (MTI 2002 p.96), it just hasn't always had the appellation or the notice it now receives[2]. If we are speaking about desirable urban types what we are talking about are spatial dimensions of particular characteristics and eventually the production of 'place'. Though what is about to be presented may sound very mechanistic, and hardly 'place' producing, the ultimate aims are to create *genuinely* urban environments where desirable urban environments *ought* to be. This is the opposite of trying to make a place fundamentally unfit-to-purpose resemble something it is manifestly not through aesthetic applications (Benfield 2013). Transit Oriented Development is not a style or a pattern so much as set of targets to be achieved. In this case it is a planning approach that enables sub centres and redevelopment to be facilitated. But it must also be planned in such a way that creates real opportunities for places that are memorable, attractive and liveable (Gehl 2001; Gehl 2010).

What is aimed for is the creation of mixed-use, pedestrian friendly, transit served precincts which are flexible to accommodate more growth within their bounds over time and reduce the need for a region to grow outward into greenfield areas(Benfield 2013). This may involve some sort of new towns but more often as a set of semi-standalone centres which have homes, jobs and retail distributed where they are best connected each to the other by rail and to their surrounding neighbourhood through safe pedestrian-oriented multi-modal streets. This is about placing homes where people will want to live due the pre-existing amenities and where more amenities might reasonably follow. It is in personal and societal fiscal interest to cluster this development around rail stations so that new residential areas avoids infrastructure and travel costs while providing ecological and cultural benefits. Evidence from TODs shows that people who live there use cars around 50% less than in other non-TOD areas and that they have one less car per household leading to substantial household savings which are generally spent locally (Newman, Beatley et al. 2009). These are the targets we aim to use TODs to achieve in Perth. But to achieve these targeted cost reductions and benefits accruing we must know how much space is available to be leveraged and know where to place these train lines and stations.

All objectives for higher-level sustainability require an understanding of the space available factored against the space required to satisfy the tasks of housing and jobs in everyday life. Sometimes, high level policy may be asking for too many tasks to be placed against a space (or series of spaces) without enough resources, 'over-tasking and under-prescribing'; this might be called 'overcrowding'. Overcrowding denotes the worst of slums and tenement housing of the Industrial Revolution in Europe or as currently experienced in many developing countries. More often though, especially in the developed Anglophone world, space is very much 'under-tasked and over-prescribed'; this might

[2] TODs have existed since the advent of transport. Ostia of ancient Rome might have been a TOD, much as The Cantonment of Benares (Varanasi) in India might be a TOD. For more of the contemporary discussion see the MTI 2002 report.

be called 'sprawl'. Sprawl denotes SOV lifestyles of a sedentary nature due to low-walkability, poor connectivity, low urban amenity and growing expense both to personal and government budgets (Marohn 2012). The space we have available needs to be leveraged to fulfil precise tasks and those tasks must be designed to fit into the natural and human environment. This paper uses a methodology that aspires to accurately task a parcel of land with higher density residential along with an appropriate level of services and amenities so that the two are mutually reinforcing and not out of balance. The methodology for achieving a balanced design of land use outcomes is outlined below in Chapter 5.

This is a complex task as it depends on a variety of local government policies. It is even more complex than policy however; context matters just as much. It is necessary to consider that each site has several background aspects within its bounds and just as many contextual constraints outside of its bounds. The sites are not all alike, and each is different. The sites' differences, when properly analysed, will help determine what type of development is more appropriate for any given location. For example, it is imprudent to suggest that a high degree of residential properties will be developed or saleable within the bounds of an industrial park adjacent to a highway and train line. Such uses will never be proposed and nor are they fit to that purpose. However, what might happen on such sites are more and better, organised along an industrial ecological basis, jobs in the light manufacturing, processing of materials, back-office managerial and technical office space, storage and other such sectors. Though we do want a mix of uses as most would advocate (NRDC 2012; Smart Growth BC 2012), it is likely that some sites are best left with the primary uses they currently occupy but with an expected programme of up-zoning and higher requirements for several small retail shops, such as coffee and food services, along an incentivised path. In short, some TODs **may be** the leafy residential, pedestrian images of so much architectural rendering activity over the last years and other TODs **may be** somewhere on a continuum between those leafy neighbourhoods and highly functional blue-collar work areas best accessed, for workers and materials, by ring-rail transit.

So, where may these TODs be best built? On which transit lines and which targets are achievable? The answers to these questions will be indicated on the following pages.

3.2. Plan

The plan below, Figure 3, will serve to illustrate where this ring rail may travel. As stated in the introduction, this rail line is not only possible; it is needed for a variety of reasons. To reiterate, the Ring Rail will henceforth be referred to as the SCL, or Southern Circumferential Line and the NCL or Northern Circumferential Line. Though they will do similar types of operations, that is collect patrons at rail stations from the local area and those coming in via bus and bus rapid transit, they are split this way due to the engineering design of the two lines have their unique challenges.

The design and engineering required for each will be touched on at the end of each of the following descriptions of the ring rail lines. Please note there a six (6) connections to the overall existing transport system.

3.2.1.NCL:

The section from the Joondalup Line to the Airport will be referred to as the North Circumferential Line (NCL). Leaving from a new station along the Joondalup Line – a major first connection into the transit network (1) - and using the Reid Highway median[3] the ring-rail will turn to run down the Tonkin Highway median in much the same way, crossing the existing Midland line – a second network connection (2) - near Bayswater Station. Continuing over the river, this becomes the section of line already announced for the Airport and High Wycombe-Forrestfield by the Western Australia government. This last section will require tunnelling under the airport to reach the stated destination of High-Wycombe (PTA WA 2012a). As this last section will be the most expensive, it is an ideal situation to build from this commitment to further expand the network to the proposed extent. However, it may also be possible to upgrade a far less expensive section of rail around the airport (from Guildford) and avoid expensive tunnelling and bridge construction.

Design and engineering: The NCL will need to have a new station built on the Joondalup line to work either as a transfer point between lines or a switching centre where some trains get diverted around the city rather than continuing north or south. The tracks will run down the highway median with catenary overhead. There will also have to be widening out the medians for the train stations and associated relocating of the lanes of vehicle traffic outwardly where the median narrows, such as at intersections and train stations. The engineering design works will become especially more complex once Guildford Road, the Swan River and the airport are approached when bridges and tunnelling, respectively, are likely to be required. This engineering work may be avoided if the line were to run parallel with the Midland line to Guildford to then run along the existing freight line to High Wycombe where it will meet the Southern Circumferential Line, or SCL. Several overpasses will need to be built on this section to avoid rail crossings but these are being planned for freight and traffic purposes at this time.

3.2.2.SCL:

The SCL will leave from the Port of Fremantle and run along the existing freight line as far as High Wycombe-Forrestfield, near the airport, where it will join with the NCL to be one complete outer lateral giving strength to the transit system. The Thornlie spur is the start of this SCL as it currently runs along the freight line RoW. Extending this part of the line to the Mandurah line will be a relatively easy engineering process.

It is envisioned that the Port of Fremantle will over time transfer its bulk handling, container and livestock capacity to the more open for berthing, unloading and handling facilities in Kwinana. This will open a great deal of ex-industrial waterfront to be redeveloped much as has been done in many cities around the world perhaps best exemplified by the Sporenberg redevelopment in Amsterdam, Puerto Madero in Buenos Aires, Darling Harbour in Sydney and Docklands in Melbourne. The current freight line operates from this port and it might best be used as a terminus for the Southern Circumferential Line. Though Perth need not wait for the Fremantle Port to relocate before

[3] The Reid and Tonkin highway medians are of the same dimension as the Kwinana Freeway's median in which the Mandurah Line runs quite successfully.

installing the SCL line, it might be just one more good reason to have a regional reconsideration of freight traffic movements. Alternatively, the line may begin at the existing Fremantle Station.

The line will join with the current Fremantle line to run south to Fremantle - making a third connection into the existing rail network (3) - run via the freight line to the Fremantle Waterfront, South Beach, Coogee, Spearwood, and Bibra Lakes. Before running onto the wide open land of brownfield (ex-industrial) lands with great swathes of areas ripe for redevelopment, there will need to be a new station constructed on the existing Mandurah Line – making the fourth connection (4). Further along the train line continues following the same existing freight track passing Canning Vale, Nicholson, Kenwick – making the fifth major intersection of rail lines (5) - with the links to the Thornlie and Armadale Lines. The tracks will then follow onto a station on the Tonkin Highways and to High Wycombe which is located several kilometres from the Kewdale Freight Terminal[4], and immediately adjacent to the International Airport terminus. This is where it will make another – the sixth fundamental connection into the overall transport network and perhaps the most import in regards to international trade and competitiveness (6) – at the airport (see Results section 6.2 for a discussion on the Airport). This is also where the SCL will connect to the Northern Circumferential Line.

Design and engineering: The SCL will first negotiate with the freight line operators for access in their right-of-way, place separate tracks within the Right of Way (RoW), share track and have very accurate signalling in some places such as between Fremantle and South Beach where the RoW narrows, have electric power transmission installed via catenary, accommodate on-going rail-freight, and build stations of sufficient capacity to receive the estimated passengers per day. In this instance there need not be any other infrastructure costs such as underground utilities or overhead grade separated roadways as this work has already been accomplished for the freight trains. Several overpasses will need to be built on this section to avoid rail crossings but as these are being planned for freight and traffic purposes at this time.

3.2.3.SCL and NCL: The Ring Rail

The two lines, the SCL and NCL, running together do open up a great array of opportunities. There will be land development opportunities which will house a portion of the increase in population in transit served, walkable, mixed use, amenity rich communities and provide places of work, shopping and play. A complete accounting of all the benefits is provided below.

Each of the stations can become a terminus for a Bus Rapid Transit system, as conceptually proposed in Figure 4 below and further elaborated in Figure 34, offering speedy transit to the new transit oriented villages to the outside of the ring rail such as, but not limited to, Wanneroo, Ellenbrook, Kalamunda and the large area to the south of Perth between Armadale and Rockingham. Each station might also serve as a terminus to much broader and precise service level of feeder buses in

[4] To create the entire outer ring-rail the Southern Circumferential Line (SCL) will need to run alongside the existing freight line, having priority signalling over where they must share track, such as at the Round House in Fremantle until such time as the port is completely relocated to Kwinana.

the middle suburbs of Perth, as can be viewed in Figure 50. In this way the Ring rail moves more people per hour, in a multitude of directions, creating a multi-fold increase in possible residential density which will support the regional goals of Directions 2013 by lowering GHG, VKT, expenses on wasteful infrastructure as outlined above. The whole system helps create and achieve 21st Century Goals. Figures 33, 34, 50 below provide an illustration of possible LRT, BRT and bus routes may link into these ring-rail stations respectively.

The Ring Rail also does one other very important thing. It allows the operator to create variable rail routes. For example, if a train is running to Fremantle from Perth, it could very well be run along the SCL and then switched onto the Mandurah Line, or to the Joondalup Line, or to the Armadale line or to the Midland Line and the same goes for any of the current heavy rail rolling stock and lines. This will be a very useful tool during special events such as high order access to the new AFL stadium in Burswood. It will be especially useful in the case of an emergency or just to give wider options in transit trips to passengers as required when the totality of the redevelopment potentials come to bear. In short, the two Ring Rail lines running together open the entire transit network to much higher integration and flexibility; this is a more resilient transit system. That the RoWs are available already makes this a very promising investment in Perth's infrastructure for all the reasons given above, and to be explained below in the next sections.

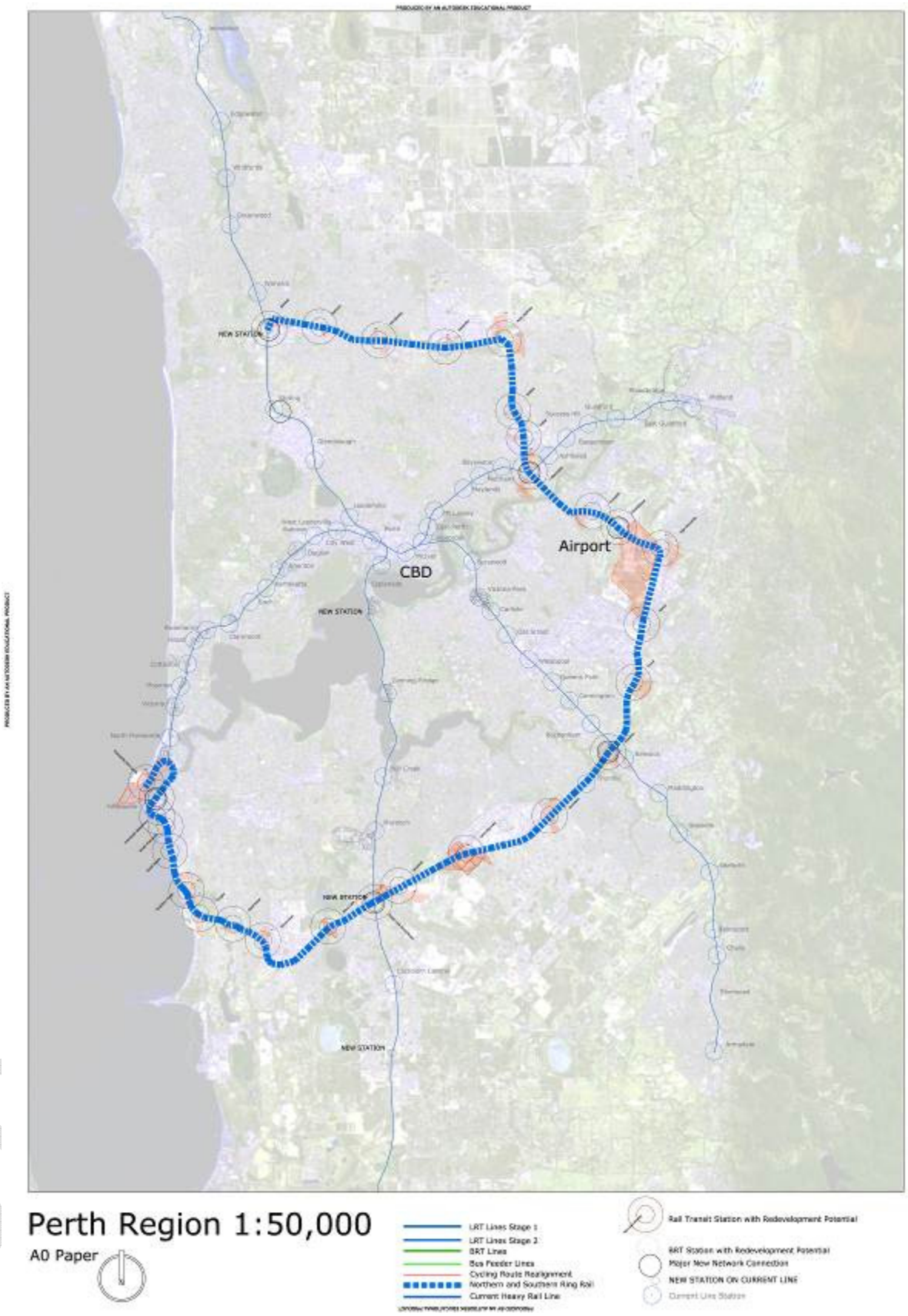


Figure 3 Ring-Rail of Southern and Northern Circumferential Lines (SCL, NCL).

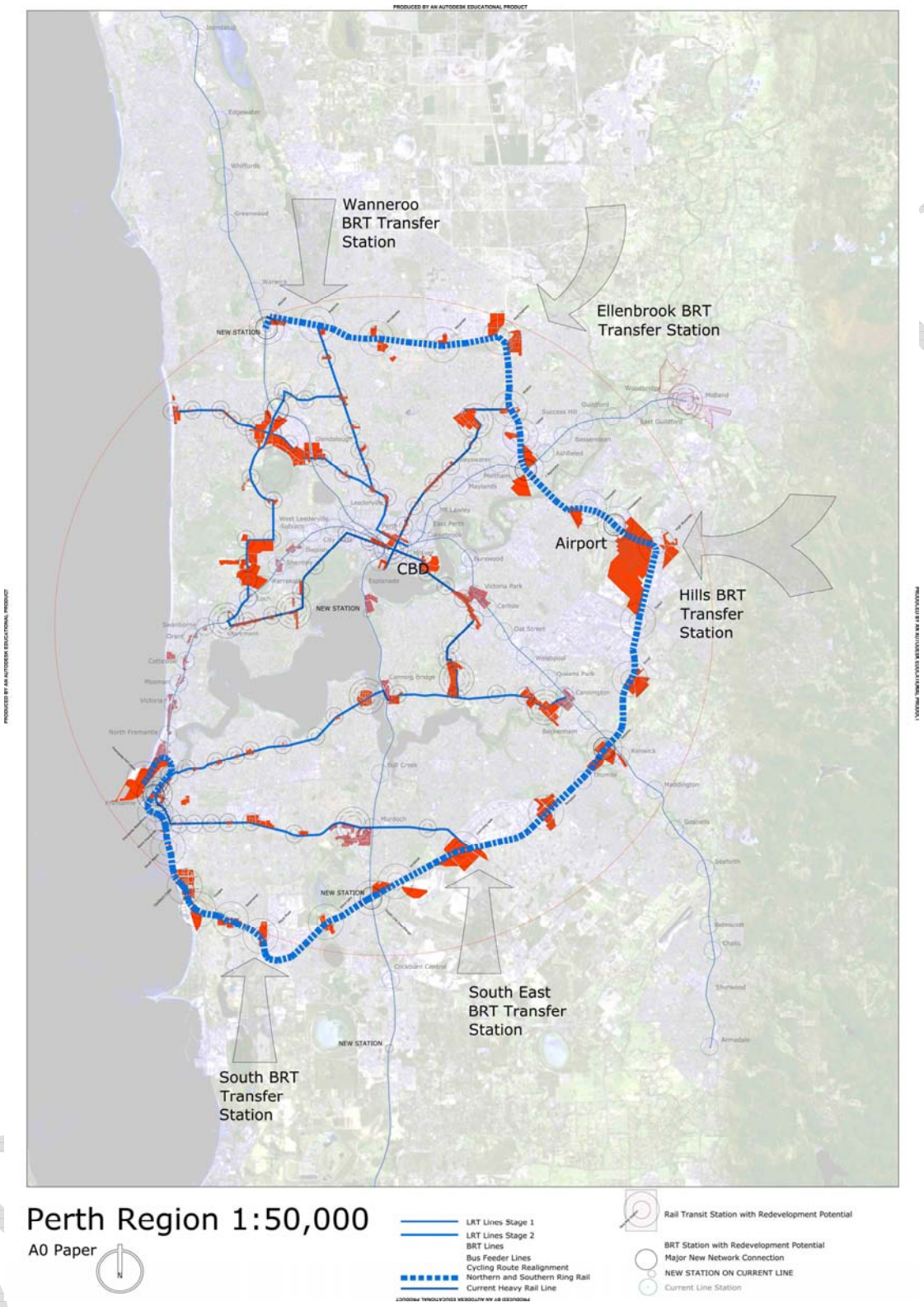


Figure 4 Ring Rail and the conceptual locations of Bus Rapid Transit transfer stations and redevelopment sites

SCL and NCL are shown in dashed blue, while existing lines are shown in light blue. Development pods at stations as discussed are shown in red.

4. Ring Rail and LRT designs

There will be some designs of LRT and Heavy rail operating in the alignments here.

5. What kind of urban form is needed?

The kind of urban form required is one which is flexible and able to accommodate the growing population base of Perth is walkable, mixed use, amenity rich and transit served neighbourhoods.

5.1. Targets and opportunities

5.1.1. Questions to answer: If we do this, what does it achieve?

We started with space as a fundamental question: how much space is available where we need it? Then we ask: what might this space - land - provide in terms of housing and jobs, parks and shopping? Who will it be for? Some indications from the state government have been forthcoming during the last few years to help guide the region.

Directions 2031, a long-range planning policy from the Western Australian State Government, has set the aspirational goal of 47 % infill developments (Western Australia Department of Planning 2011) to provide housing for the projected population growth from the Australian Bureau of Statistics (ABS 2011a). The ABS projections in series B, the median between conservative and more generous outlooks, suggest that 1.8 million more persons will move to Perth over the next 50 years. This means, using the Directions 2031 goal of 47% infill, that 848,000 more persons need to be found homes and work sites and places to shop and play within the existing urban fabric of Central Metropolitan Perth by 2056.

Three issues with this scenario which serve to illustrate the necessity of our study are:

1. Where is the land available for infill?
2. How will the people access the services of their neighbourhood and find the mobility to move about their region?
3. At 47% redevelopment, this does slow greenfield expansion into productive farm and forest land, but does it provide reason enough to indeed build better urban spaces with greater all-round amenity?

5.1.2. Answers to questions: We get a great deal.

To answer the first: Where is the land available for infill?

The land is all around the metro region in all forms, if one takes a moment to look for it. The following lists the array of places to look for infill opportunities. They are copied here from Table 3, below:

- empty lots along highway arterials;
- other lots along arterials which are oriented to the corridors, rather than backing onto it as most dendritic street layouts most often do;
- used and new car lots and other land uses that are possible to shift to less important sites;
- buildings set back with parking in front, as we see especially at fast-food restaurants, national grocers and others;

- urban decay areas, which are usually old building stock either not maintained and losing value or from an era when poor workmanship and a poor orientation to the street and its neighbourhood has never led to success;
- brownfield, being ex-industrial lands;
- greyfield, being older housing stock reaching its lifespan and calculated to be due to rebuilding (Newton et al, 2012); and

- high valued land adjacent to highly prized amenities, such as a beach, but which remain locked in its current zoning for a variety of local political reasons.

There are likely to be other subcategories not fully explored, but undoubtedly there are plenty of spaces for infill once they are looked for and mapped. These types of lands are especially prevalent across North America and Australia where automobile planning has dominated, leaving behind great swathes of disfigured urban lands as vehicle speed, parking and turning radii have triumphed over 'urbanity'.

To answer the second: How will the people access the services of their neighbourhood and find the mobility to move about their region?

Rail, as the highest order public transit, will be the lead amenity in these new precincts. But to get people in Perth to use the new trains, it may be necessary to use the 'carrots and sticks' approach to delivering the train service. If Perth, or any city, is to dedicate capital budgets towards infrastructure projects such as trains there will have to be an expectation of a return in the medium to long term. If any city is expecting returns, it is well served to make equally hard and equally far-sighted decisions regarding land use minimums and SOV infrastructure maximums:

- minimum residential density thresholds everywhere but especially at train stations (Newman and Kenworthy, 2009);
- minimum ranges of mixed use including street fronted retail, commercial office, commercial light industrial, institutional and appropriate parks and (Jacobs 1961);
- maximum parking ratios (Shoup 1999).

Although it is possible to make patronage levels that are quite reasonable by bus integration and ticket integration as with the Southern Rail, global evidence would support expanding the network and enabling much bigger returns on the rail infrastructure investment by bringing more people and activity closer to train stations and by making it harder for cars to access such areas. The approach adopted in this paper is to estimate the quantum of activity accommodated in the spaces around the stations. The rationale for this is well supported by the people quoted below who recognise the value in developing high amenity activity nodes for people around rail stations without providing high amenity for cars:

> *Density of people alone will account for the presence or absence of certain uses and services we find important to urban life. We suspect, for example, that the number and diversity of small stores and services-for instance, groceries, bars, bakeries, laundries and cleaners, coffee shops, secondhand stores, and the like-to be found in a city or area is in part a function of*

density. That is, that such businesses are more likely to exist, and in greater variety, in an area where people live in greater proximity to each other ("higher" density). The viability of mass transit, we know, depends partly on the density of residential areas and partly on the size and intensity of activity at commercial and service destinations. And more use of transit, in turn, reduces parking demands and permits increases in density. There must be a critical mass of people, and they must spend a lot of their time in reasonably close proximity to each other, including when they are at home, if there is to be an urban life (Jacobs and Appleyard 1987).

"…the total value of all parking spaces probably exceeds the total value of all vehicles." *(Shoup 1999 p.557)*

Pricing curb parking rather than requiring off-street parking will improve urban design, reduce traffic congestion, restrain urban sprawl, conserve natural resources, and produce neighbourhood public revenue. Eliminating parking requirements will also reduce the cost of housing and of many other goods and services. In conclusion, deregulating the quantity and increasing the quality of parking will improve transportation, land use, and the environment (Shoup 1999 p.570).

Parking lots can undermine a CBD's success. A downtown surface lot often has a very high and very visible opportunity cost. Instead of a building teeming with people, there is an expanse of asphalt with a single employee manning a booth; where there could be something there is instead not much. …Because land tends to be most expensive in the CBD, off-street parking is also most expensive there, and constructing it uses up capital that could otherwise be invested more productively. More important, if zoning requires off-street parking, as it does in many cities, then it becomes rational for firms to locate in places where land is less expensive. (Manville and Shoup 2005).

To realistically increase the level of walking and biking, it will be essential to reintroduce development practices that make it easier to engage in such activities during the course of one's daily activities. This may mean not only the introduction of the types of urban design features advocated by neo-traditionalists into developments located at a region's periphery but also the retrofitting of existing urban areas. For example, the provision of non-motorized linkages between residential, commercial and employment areas reduces the time required for travel on foot while holding the time requirements for auto access constant. In accordance with microeconomic theory, this should render a relative increase in the utility of walking and biking versus driving and promote physical activity while reducing auto dependence. (Frank and Engelke 2001 p.215).

Also see 5.2.1 below regrading Parking.

To answer the third: At 47% redevelopment, this does slow greenfield expansion into productive farm and forest land, but does it provide reason enough to build better urban spaces with greater all-round amenity?

Rail based public transit will be one of many amenities along with other provisions such as libraries, swimming pools and recreation centres, parks, and a sufficient level of commercial work spaces and

retail destinations, such as grocers, to make the communities genuinely 'complete'(Smart Growth BC 2012). These places need to be affordable, clean, walkable, be attractively well appointed with street trees and other design elements. They must also have a sense of belonging to the site by preserving what is good, like views and water-bodies, while sharing what is great through distinctive architecture or use of materials which are honest about the history of the region. While aesthetics and amenities are very important, there are many other targets and goals the region must achieve to be a part of national and global goals. Messenger and Reid discuss this issue in a well described article on the topic relating how the 40 odd TOD manuals that they have reviewed fail to deliver anything other than subjective intuition and:

> *"Where the manuals go beyond generalities to establish numerical standards or targets, there is no consensus among them on which to draw."(Messenger and Ewing 1996)*

That aside, a few of the targets for TODs discussed for this paper are:

- transit mode split increased;
- lowered Greenhouse Gas (GHG) emissions;
- lowered VKT;
- lowered infrastructure costs to build and to maintain;
- improvements in healthy lifestyles;
- increased affordable housing either as a set program or as a function of a greater quantum of housing available (scarcity of any product has never created equitable distribution);
- increased value of land near stations to then be 'value captured' and used to pay-down the construction costs of the rail and other utility costs.

One special note from the Housing Industry Forecast Group 2012 report, accessed from the Western Australian Department of Planning, regarding the quantum of housing required states:

> *While no overall land shortage exists in Perth, HIFG's estimate of future dwelling commencements will require land supply of around 17,000 lots per annum, some of which will be sourced from demolitions and vacant land listings.(HIFG 2012)*

This will be represented in the charts below demonstrating the years of housing supply available by each rail line or series of lines.

5.2. Land Use and Transport Characteristics

The transport and land use mix in this assumed future scenario will be one in which persons will live in higher-density, mixed-use neighbourhoods which are oriented through safe and comfortable walking and cycling paths towards the rail transit stations. The transit and the walking and cycling will extend beyond to other destinations in the nearby vicinity, such as large parks and beaches and shopping destinations. Within the bounds of the new walkable transit-served neighbourhood will with a high standard of government services, such as libraries and swimming pools, and private amenities such as cafes, grocers, medical clinics and bookstores to name a few. There will be sufficient, but perhaps not expansive, open space to provide for active recreation, public gathering places and for some of the ecological services rendered when soils support vegetal growth to cleanse both water and air.

For this to happen, though, there will have to be two things happen with a subsequent activity for each:

- Construct and deliver the rail transit
    - Build in enough frequency and priority that the rail transit has reliable and imageable presence (Vuchic 2007).
- Alter the land-use zoning to permit much higher intensity of land use and a much wider mix of uses
    - Control the look and feel of the neighbourhood though regulations for such things as pedestrian scale frontages, built-to lines, openings per block, minimum street tree, minimum density per lot, maximum parking among several others (Parolek, Parolek et al. 2008).

In short, to achieve the goals of lowered GHG, VKT, improved Health and so forth, the rail must be built and the permitted development must be encouraged. Finding the right reasons for this in the face of economic and social resistance will be paramount to achieving the economic (costs avoided, value capture), social (demographics shift to urban living) and environmental (GHG and sprawl reduction) benefits. Finding the right reasons to make a compelling argument to quantitatively counter the current bias towards dispersed car based culture Business as Usual (BAU). A new and better way of living in Perth as a citizen adjacent to a train reached under a line of arching street trees is not far away, it only takes the understanding of the benefits and cost in real terms. This will place Perth in an enviable position vis-à-vis other Australian cities and even world cities as it becomes an urbane and delightful place living in closer accord with the limits of its natural surroundings.

The other factor that will be much more difficult to implement is the use of Value Capture (Schiller, Bruun et al. 2010; McIntosh, Newman et al. 2011) to help pay down the expense of the rail infrastructure.

5.2.1.Parking

As a word of caution on the parking ratio; in this paper we have used the industry standard Roads and Traffic Authority of New South Wales “Guide to Traffic Generating Developments Issue 2.2, October 2002” as it was felt to best reflect the state of the art for trip and parking ratios for developments and is referred to by Main Roads of Western Australia as the default guide. The parking ratios the RTA of NSW has published are a reflection of a preference for automobile dominated landscapes. It should be imagined what sort of urbanism will be created with over 35 % (See Results) of a city as car parking. This parking will have to be either urban surface parking, structured above ground parking set apart or of underground building fabric each with their confounding problems (Table 2 below). The first creates huge dead-zones in the wall of the street, adds to stormwater run-off and contributes to heat island effect; the second is expensive and often hard to make an appealing part of the urban environment, and; the third adds greatly to the expense of building an apartment or townhouse block which erodes the affordability aspect of denser housing types. All of these, in addition, contribute to an ever expanding inducement to drive more which must be slowed if Perth, or any city, wishes to become genuinely transit-oriented and achieve the list of 21st century goals. These parking ratios must be examined in light of the expense of

continued automobile-oriented lifestyle over a walking, cycling and transit accessibility oriented lifestyle.

Parking Issues by type:

- Parking issues general: availability of generous parking induces demand for driving and an overall automobile-oriented lifestyle
- Surface parking: Often creates gaps in the fabric of street walls and deadens the ability of an area to be a great walking street; cause extensive storm-water runoff which moves surface pollutions into the watercourse and cause higher rates of erosion in stream beds; add to the heat island effect greatly; occupy land area of potentially much higher value if shifted to residential or commercial purposes especially if near transit stations
- Parking structures: hard to make appealing and hard to make work as a part of urban fabric however these can be done successfully; will always be paid-parking to private or public entities
- Underground parking: the expense to build is offset by higher rates to purchase units in associated apartments which erodes affordability; high ratios induce automobile ownership and driving
- Optimal solution: reduce parking ratios for new developments; be sure to charge appropriately rates to make persons consider using other modes of transport; use money raised to offset costs to improved local transit, pedestrian footpaths and cycle routes.

Table 2 Parking issues and urban form

5.3. Multi-directional Network

Building on the very successful Northern and Southern Suburbs Rail stretching between Clarkson and Mandurah, Perth's next generation of heavy rail can serve to connect the five lines of existing heavy rail into a cohesive whole, providing many more people with access to fast rail and also making a much more resilient system. As a diagram, this ring-rail might be described as creating a web, as in a spider web, which is inherently strong because of the lateral supports to the diagonal mains. A ring-rail will have flow on effects of opening a multi-directional network providing yet more options of travel across the region to more destinations as suggested by Thomson and Brown:

> *A dispersed transit network is one structured to serve an array of major destinations throughout the entire metropolitan area, as opposed to one in which service is concentrated on a single major destination (usually the CBD) and/or constrained to serve merely a portion of the metropolitan area. (Thompson and Brown 2012)*

While this does imply that a series of transfers will be required to reach potential destinations, Perth has already shown that this can work and Portland Oregon shows how a well-functioning bus-rail web delivers:

> *"..relatively quick travel between the metropolitan area's activity centres, and this makes transit more attractive to prospective riders. … Portland relies on easy transfers between its bus and rail systems, as well as bus-to-bus transfers, to connect more destinations than would be possible with a system based on one-seat rides. (Thompson and Brown 2012)*

This is an example of the convenient uptake of a unified and regional approach to planning transit routing to future and present activity centres. Despite transfers, and the apparent unwillingness of transit planners to understand that it can be so, people will transfer when the time and speed are maintained, destinations are worthwhile and travel by car is reduced.

It is envisaged that Perth will create many more sub centre destinations (Western Australia Department of Planning 2011; Western Australia Department of Planning 2012a), over the medium to long term. With planning focused on this ring rail, land values will rise in proximity to the stations, making the viability of higher density residential land with clustered office, commercial and retail all the more achievable.

This paper will discuss the role Public Transit can play as a surface-running, high capacity network operating in Perth and what this can do to help generate new sub centre destinations across the network. Developers are much more likely to be attracted to sites where rail is built due to its fixed nature and the increased value that rail generates (over 20% for residential and over 50% for commercial)(McIntosh, Newman et al. 2011). Many people will certainly choose single seat or transfer linked-trips to achieve their destination if the mode delivers them on time and in comfort. The key is to provide a transport option that is faster than traffic, providing mobility, while also creating land use patterns planned to be walkable, mixed use and ultimately produce less traffic, providing accessibility. As Perth's traffic congestion has increased, the need for a train and bus option is now needed into the long term future.

5.4. Population Growth

If the Perth region, through the agency of local governments and State government, were to be serious about shifting its land use and transport orientation towards the development opportunities along current and potential transit lines, such as in Figure 1, there would be a cascade of benefits to be accrued. In addition to the ones shown below there would be the more intangible benefits of being a well renowned city which invests in its future in a very positive pro-urban manner or being a city which is immensely liveable as it provides multi-layered amenities in a highly polycentric and non-hierarchical way reinforcing its best benefits of smaller neighbourhoods and town-centres. We need to house the current and future residents of the Perth region in high quality housing, in areas rich with amenities and open space and with high quality public transit which takes them to numerous possible destinations.

The kind of region Perth can aspire to is comprised of high-quality and high-density urban areas served by fast and reliable transit services. The transit services will be able to transport the residents to shops, to jobs, to schools and to open spaces such as beaches and parks. In this way an array of benefits can be accrued regarding health, transport costs, greenhouse gas emissions, and economic productivity all of which are outlined below.

6. Methodology

6.1. Rationale

The methodology has many steps to be explained, suffice it to say that this paper responds to Robert Cervero's (2003) call for clear accounting on the social costs and benefits associated with any infrastructure project. These are now mainstreamed requirements in all major projects by Infrastructure Australia:

> *The proposal will be assessed against how well it contributes to Infrastructure Australia's strategic priorities, first identified the 2008 Report to the Council of Australian Governments.*
> *….*
>
> - *Expanding Australia's productive capacity;*
> - *Increasing Australia's productivity;*
> - *Diversifying Australia's economic capabilities;*
> - *Building on Australia's global competitive advantages;*
> - *Developing Australia's cities and regions;*
> - *Reducing greenhouse emissions; and*
> - *Improving social equity and quality of life in our cities and regions. (Infrastructure Australia 2012 p.11)*

The benefits and costs analysed here will be based on the approach outlined in Trubka et al (2009) based on the method developed in the monograph 'Sustainability and Cities' (Newman and Kenworthy 1999).

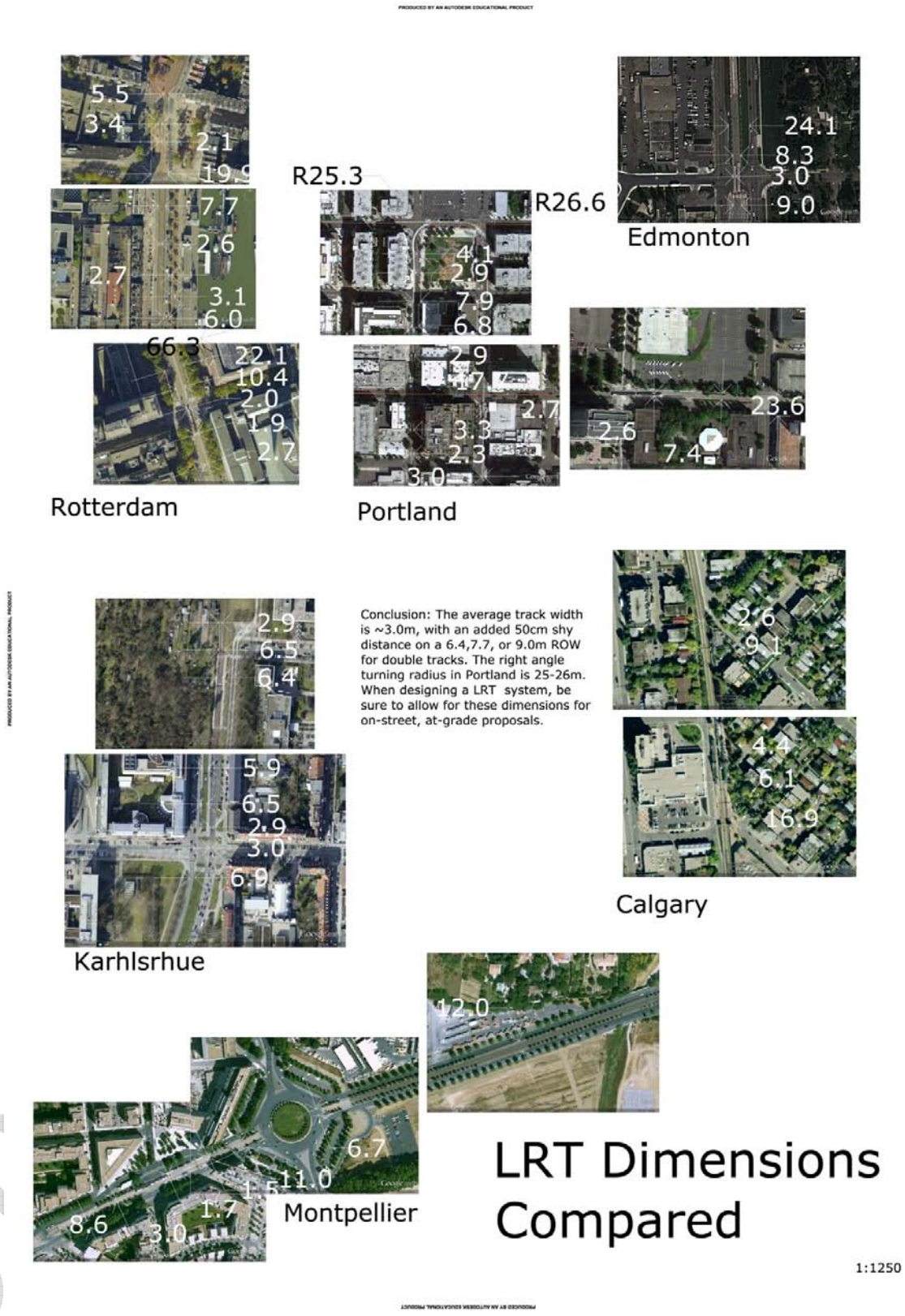


Figure 5 LRT dimensions compared from selected cities.

Figure 6 Right of Way Dimensions and the LRT in the street

6.2. Process

The method developed for this paper aims to locate ideal transit served development plots, ascribe a land use mix and floor heights and to produce population and employment results by station precinct, transit line and for the entire metropolitan region. This is a very daunting task. We start with space as a fundamental question: how much is available where we need it? Then we must ask: what might this space, land, provide in terms of housing and jobs, parks and shopping? Then, we might wonder about what are the benefits or creating new neighbourhoods around the transit stations which are walkable, mixed use, amenity rich and desirable place to live.

6.2.1.Current planned land redevelopement

Step 1: To help answer these and other sub questions the researcher and author, Cole Hendrigan, first began a search through the available planning documents and social media sources to trace where preferred lands redevelopments and rail alignments are across the Perth Region. There are decades of work by a cadre of professional planners and visionaries to work from. Their work will serve as a foundation and rationale to many proposed future land developments, but not all. The current planned areas of redevelopment, such as Curtin Town, Stirling, East Perth, Fremantle, Cockburn Coast, South Perth and many others were traced over as well, giving more coherence to where rail might want to serve. (see below) AutoCAD was used to insert the image files into a properly scaled base plan of the Perth region made available through the Western Australia Department of Planning and the Australian Urban Design Research Centre. Area figures were recovered by querying drawn polygons.

6.2.2.Preferred rail transit alignments

Step 2: It was then important to check the various proposed rail alignments for sufficient dimensions in the cross-section to support a low-floor Light Rail or conventional heavy rail carriages, see Figure 6 above. A 500 meter buffer was placed alongside these lines to then delineate the areas for discussion. Only the land areas within or reasonably adjacent to this buffer were under consideration, not the entirety of all of Perth. AutoCAD was able to dimension the RoWs as presented in the base plan.

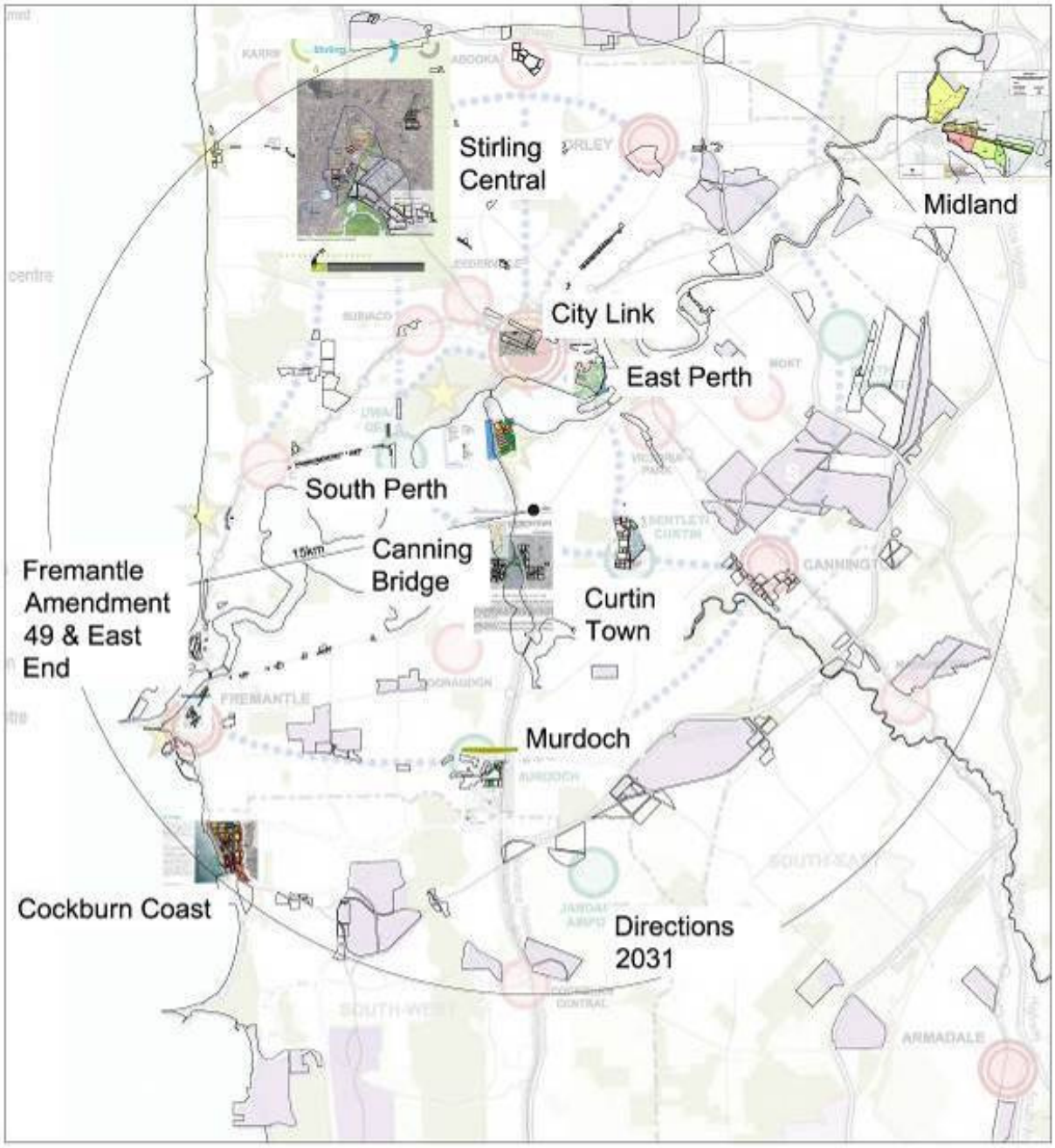


Figure 7 Planned areas of expansion

6.2.3.Current zoning

Step 3: The third step was to see how large areas across the region were already zoned for use (see below) and for density along the R-Coded (Residential Codes) (see below) to give shape to what has already been discussed and agreed on at the local and state levels.

Figure 8 Local Planning Scheme

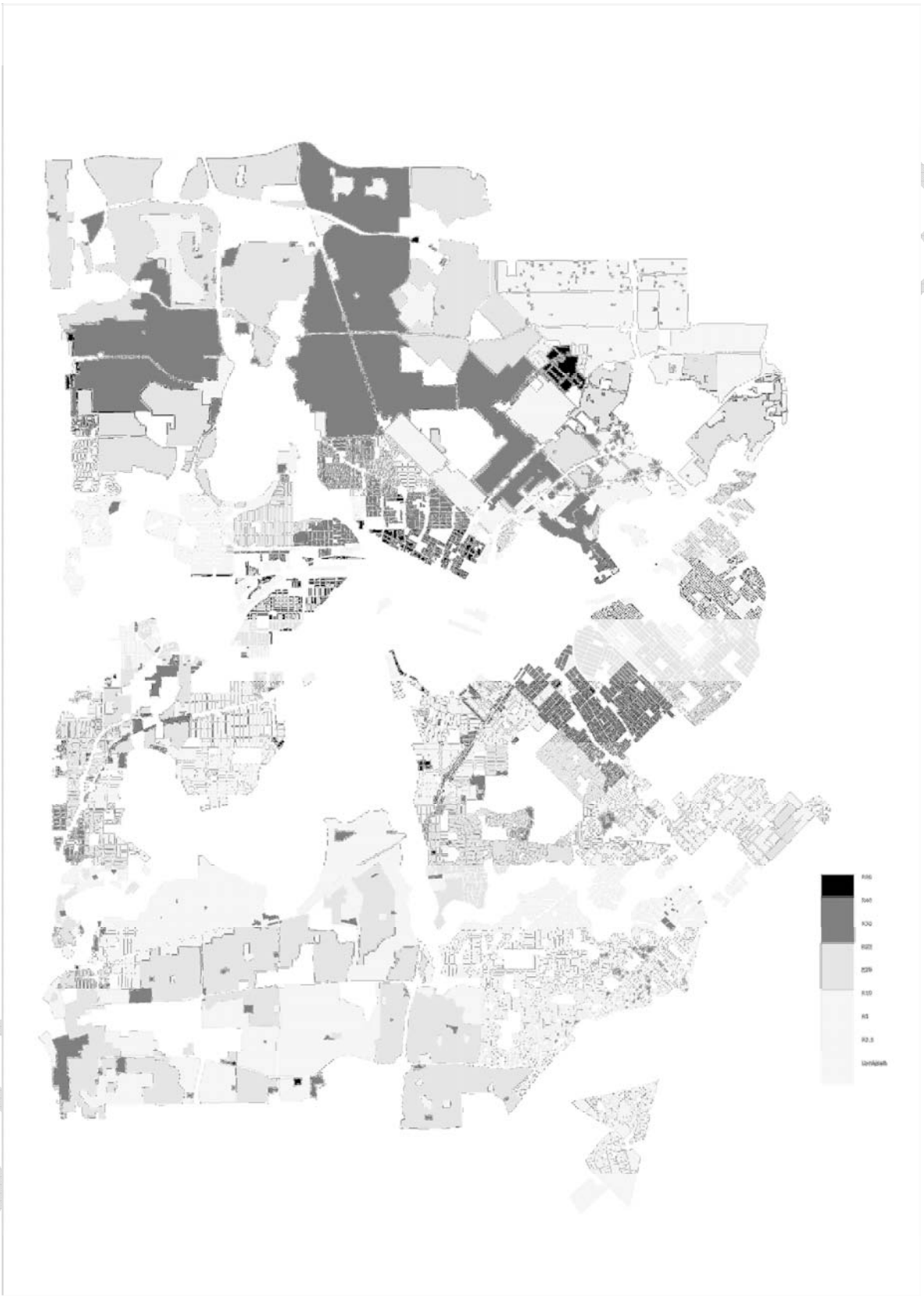


Figure 9 Residential Codes (R-Codes)

6.2.4.Places for infill developments

Step 4: There was lastly an 'objectively subjective' process to look for brownfield (ex-industry), urban decayed (car yards), underused (wide open campus-like settings) and opportune (lots arranged facing towards corridor) sites to redevelop within the buffered areas surrounding the proposed rail lines. These were added to the list of redevelopment polygons alongside the existing official plans (see table 3). All these sites, as traced, were given a potential station location within their bounds, a name and a place on a list in which the re-developable areas were to be scrutinised. The areas ripe for redevelopment were measured and listed, and a type of development selected which might best suit the adjacent characteristics of the site. This process examined lot by lot, site by site, by station precinct and transit line to come to the totals presented in the results.

The types of places ideally suited to infill developments:

- empty lots along highway arterials;
- other lots along arterials which are oriented to the corridors, rather than backing onto it as most dendritic street layouts most often do;
- used and new car lots and other land uses that are possible to shift to less important sites;
- buildings set back with parking in front, as we see especially at fast-food restaurants, national grocers and others;
- urban decay areas, which are usually old building stock either not maintained and losing value or from an era when poor workmanship and a poor orientation to the street and its neighbourhood has never led to success;
- brownfield, being ex-industrial lands;
- greyfield, being older housing stock reaching its lifespan and calculated to be due to rebuilding (Newton et al, 2012); and
- high valued land adjacent to highly prized amenities, such as a beach, but which remain locked in its current zoning for a variety of local political reasons.

Table 3 List of available land types for urban infill

6.2.5.Gross and net developable land

Step 5: The land, which was both close to rail current or future and likely to be redeveloped, was measured to the nearest square meter, lot by lot. Land area was removed from the gross land total at 10% for Public Open Space (plaza, beach, park, ecological reserve, waterfront) and 15% for utility and road Rights of Way as well as for any building set-backs. These numbers for POS and RoW can be lessened in practice depending on specific local interactions of adjacent park land or combined utility and road corridors, but as a first step of due diligence, this is assumed to be a correct course of action. This was done to all the land parcels discussed.

6.2.6.Building height

Step 6: The land parcels were also given a graduated zoned height (see Table 4) so that precincts with small redevelopable lot areas were not overburdened with out-of-scale buildings (Shoup 2009).

- a station precinct site was less than 40,000 M^2 in size, or 4 Hectares, the maximum height allowed ion that size was 5 stories;
- for building sites over 40,000 M^2 but less than 100,000 M^2 the maximum height was set at 6 stories; and
- a station precinct's redevelopable area over 100,000 M^2 was permitted a maximum of 10 stories.

Table 4 Maximum heights for rail transit serviced urban land redevelopments

This was conceived as a method to limit relatively small station area precinct's impact on the surrounding urban fabric so that one small site might not have a single towering built form far outside of the local context in which it sits. If there was only a small area available, this speaks to an existing tight urban fabric of notable character or a limiting factor such as water, both of which should be brought into a careful orchestration of individual and collective building masses. In this way the large precincts can grow very high, taking the bulk of the load for space provisions, while the smaller precincts ones may still contribute to the regional growth but stay proportional to their extant urban form.

6.2.7.Land use mixes

Step 7: A mixing of uses was aspired to with the remainder of the land. As almost universally agreed on in current literature, and aspired to in current planning practice, that to achieve higher-order sustainability a high-degree of mixed land uses are desirable. Ostensibly, this is to bring more destinations closer to more people and shorten the trip to and from a destination. Ideally, then, more trips become a walk or bike trip within one's own neighbourhood as well as support a higher density of persons which then further the case for higher-order transit service provisions. (see Tables 5 & 6)

Principle type of buildings discussed in this paper:

- Residential =assumed to be townhouses, stacked town homes or apartments
- Commercial = Office, Institutional, light Industrial;
- Retail = Ground floor both street-oriented and large-format.

Each of these has unique layouts, stairwells, elevator, water and sewer service provisioning, parking requirements and traffic generation.

Table 5 Three Principle building types used in this paper

Name	Resi	Comm	Retail	1.00
University Precinct	0.50	0.40	0.10	1.00
Residential Mixed	0.60	0.25	0.15	1.00
Residential + Mixed	0.75	0.15	0.10	1.00
Residential	0.90	0.00	0.10	1.00
Commercial	0.20	0.60	0.20	1.00
Commercial-	0.20	0.40	0.40	1.00

Table 6 Land use mix by development types

6.2.8.Person Activity

Step 8: The Land-Use Mixes with floor heights on parcels of land which might be well served by rail transit formed the basis for the results. The results took the form of floors of buildings which then gave floor areas which in turn related the numbers of people (ABS 2012c), jobs, shops, traffic generation and parking requirements (RTA 2002). Once the land area was established after a percentage removal for POS and RoW, the land use mix and maximum building heights were assigned and this produced floor areas which were accorded a number of 1 (one) persons per $50M^2$ for residential (ABS 2012c), $25M^2$ for retail, or $20M^2$ for Commercial space (Hillier 2001; Western Australia Department of Commerce 2012). (See Appendix 3). The numbers for retail and commercial were, however, averaged upwards to $40M^2$ and $50M^2$ to take into account the varying types of educational and large format workspaces being developed. These numbers of people then formed the basis for the calculating the benefits and costs which may be accrued over the next 50 years.

6.2.9.Traffic Generation and Parking

Step 9: Traffic and parking rates were derived from the Roads and Traffic Authority of New South Wales multiplied against per meter of per 100 M^2 units of land use in the ultimate build out scenario. For example, each dwelling was expected to produce 5 trips per day and have .9 parking stalls, each commercial $100M^2$ was to produce 10 trips per day and have 2.5 parking stalls per unit while Retail units of $100M^2$ were expected to produce 50 trips per day with 5.1 parking places per unit. (RTA 2002 p. 3-3, 5-4)

6.2.10. Cost Avoided

Step 10: The total Cost Avoided was calculated by calculating the number of dwellings possible in all residential floor space (520,645 dwellings) (100 M^2 units for 2 people are assumed to be the average dwelling) multiplied by the findings derived as per dwellings costs avoided by Trubka et al. in 2009 ($378,553). (Trubka et al. nominated a per 1,000 dwelling figure below)

Figures are per 1000 dwellings	Inner	Outer	Difference
Infrastructure Costs			
Roads	$5,086,560	$30,378,880	$25,292,320
Water and Sewerage	$14,747,620	$22,377,460	$7,629,840
Telecommunications	$2,576,110	$3,711,850	$1,135,740
Electricity	$4,082,120	$9,696,510	$5,614,390
Gas		$3,690,840	$3,690,840
Fire and Ambulance		$302,510	$302,510
Police		$388,420	$388,420
Education	$3,895,460	$33,147,270	$29,251,810
Health (Hospitals, etc.)	$20,114,870	$32,347,330	$12,232,460
Total Infrastructure	$50,502,740	$136,041,070	$85,538,330
Transport Costs			
Transport and Travel Time	$206,542,060	$342,598,100	$136,056,040
Roads and Parking	$46,937,540	$154,826,100	$107,888,560
Externalities	$2,219,880	$9,705,380	$7,485,500
Total Transport	$255,699,480	$507,129,580	$251,430,100
Greenhouse Gas Cost			
Offset Cost ($25/t)	$2,500,000	$5,400,000	$2,900,000
Social Cost ($215/t) (NB. not included in total)	$21,500,000	$46,440,000	$24,940,000
Total Greenhouse	$2,500,000	$5,400,000	$2,900,000
Physical Activity Costs			
Healthcare Cost		$4,229,950	$4,229,950
Productivity Loss		$34,454,900	$34,454,900
Total Activity Costs		$38,684,850	$38,684,850
Total (excluding social cost)	$308,702,220	$687,255,500	$378,553,280

Table 2: Estimated development costs for an urban redevelopment compared to a fringe development

Figure 10 Table of Cost Avoided in Trubka et al.

The dwellings numbers were calculated after a lot by lot search for space in new and current rail station precinct along the proposed and current rail transit lines. The dwelling numbers are the result of the net land available divided into land use types which best suit its context (Table 6) multiplied by the maximum number of floors (Table 4) for each type of built form.

Tubka et al. counted all the costs, including the loss of productivity due to traffic congestion and the expenses of building new schools and hospitals per thousand dwellings in a report published in 2010. This report deals primarily with the costs associated with constructing urban areas in Perth, Western Australia showing there are clear savings to be accrued by making the infrastructure already in place work harder to support the increase in population[5,6].

[5] The current capacity of the underground services is upgraded on a regular half to full century schedule.

[6] Infrastructure costs can vary widely depending on what is counted and costs change from year to year as between states and cities. For a complete understanding of Trubka's methodology, please view the papers as per the works cited.

6.2.11. Value Capture

Step 11: With the next generation of transport projects we need the land and parking to be zoned to take best advantage of the demographic changes happening in Perth (or any city). The real estate market needs to function freely in this regards, but with a series of simple to implement and 'nothing hidden' charges to help pay down the expense of the PT infrastructure. Some of these fees, charges, rates or taxes exist in a format which can be 'ring-fenced' to this end. All new land rezoned along these transit lines will contribute at the price they can bear on the open market. The results demonstrated in this model are therefore highly indicative and to be taken as an illustration only of the Value Capture concept.

The Value Capture numbers derive from using the several possible funding streams. Many of these streams exist already (MRIF, Land Tax, Parking Levy) (McIntosh, Newman et al. 2011) and can be amended to suit the purposes of building the next generation of rail transit. The streams discussed below only apply to the new transit served developments; however, if these streams were applied more broadly to the existing properties the Value Capture fund could be even larger. These numbers are hence conservative as they only calculate the development occurring in up-zoned land adjacent to rail transit. None of these funds will begin deliver the estimated result until the land is rezoned, the real-estate market takes up the opportunities and the units are under construction.

- Using the same dwelling numbers as found for the Costs Avoided (520,645 dwellings) , multiplied by the possible average housing value rounded to $500,000 (Realestate.com.au 2013), multiplied by a 10% premium (the premium can be as high as 20%) for being near or in rail station precinct and multiplied by a 10% 'rate' applied to the increase in the properties values: (520,645X$500,000x.1X.1). This is equal to 1% of the dwelling units' value being applied towards a Value Capture ring-fenced fund. If this were applied just one time, at sale, on each dwelling this fund could raise $2.6 billion dollars. This stream could be applied each time the dwelling is sold, capturing the resale of dwellings between 'off plan' speculators and the ultimate homeowners. Were this stream applied as a special rate per year at a lower rate, it could raise multiples of billions per decade. This is contingent on at least these two factors:
    - that there is a hedonic price rise for these units due to being adjacent to public transit service; and
    - that the property market is active and moving upwards in value.

- If the same 1% were applied to the rise in Commercial properties, valued at a conservative average of $300 per M^2 (Realcommercail.com.au 2013), as a one-time fee this could ring-fence another $60 million. Similarly this stream could be applied at a lower rate per year and generate funds for decades to help pay down the expense of transit infrastructure. This is contingent on at least these two factors:
    - that there is a hedonic price rise for these units due to being adjacent to public transit service; and
    - that the property market is active and moving upwards

- A $5 per working day charge on all new Commercial parking spaces could raise $627 million per year. Pricing parking reduces induced driving demand. Calculated on 250 working days per year. This number does not reflect existing parking and could therefore produce a many fold increase contribution to the fund. Applied to the owners of parking to be recouped through daily paid parking, yearly fees or absorbed by the owners of the properties. It is preferred this volume of parking is not built, see 5.2.1 above.

- A $5 per day charge on all new Retail parking spaces could raise $297 million per year. Pricing parking reduces induced driving demand. Calculated on 365 days per year. This number does not reflect existing parking already available and could therefore produce many folds increase contribution to the fund. Applied to the owners of parking and to be recouped through paid parking, by yearly fees or absorbed by the owners of the properties. It is preferred this volume of parking is not built, see 5.2.1 above.

- A 1% tax per meter on the sale of land, valued at a conservative $200 per meter, in these transit-served lands could bring in approximately $61 million in one-time fees. These extra fees would be clearly evident to the purchaser/developers by the zoning in effect which allows their development. This stream could be applied each time the land is sold thereby capturing the resale of land between developers. If the land were valued higher, it would bring in more to the ring-fenced fund. A 1000 M^2 lot (1/4 acre) is more likely to be valued, conservatively, at between $250 and $500 per M^2 in Perth currently.

These totals were added together to give the potential Value Capture of $3.6 billion once the real-estate with parking is constructed and occupied.

The Value Capture mechanisms above have been very simply estimated and conservatively create almost enough money to pay for the overall infrastructure just from the new TODs. Building the rail will benefit all of Perth and defining the areas that would benefit most can provide a value capture fund that could easily pay for the new rail system in its entirety. This will need further work.

6.2.12. Capital costs

Step 12: Martin in 2011 described the costs to construct major transit projects in "Reviewing the last decade of public transport infrastructure projects in Australasia". It is described that per kilometre the average to build heavy rail projects in Australia with no tunnelling, grade separation, inner city costs or bridges, has an "average construction cost ….(of) $17M per-kilometre." (Martin 2011 p.11)

The Southern Rail in Perth cost $17 million/km to build.

Light Rail: "Based on the sample of projects, the average per-km construction cost for a light rail project in Australia based on actual costs from the previous decade is $11.9M." (Martin 2011 p.9)

To be conservative, the dollar figure used in the calculations was $28 and $24 million per kilometre respectively. The kilometres were derived by reading the length of each transit line segment from the scaled region wide base plan in AutoCAD.

6.2.13. Floor Area Ratio

Step 13: Floor Area ratio is an indication of the gross area to be built on and the relation to the ultimate volume of building on that footprint. In the instances modelled in these scenarios the FAR will vary between 1 and 5 Floor Area Ratio (FAR), which is modest in global terms.[7] The Floor Area Ratios (FAR), or Plot Ratios, were recovered as well this methodology. An FAR is a widely used figure to have frank and open dialogues with communities and developers about what may be permitted on a given site.

6.2.14. Significance:

Other results followed similar paths of relating a known impact or benefit and multiplying it across the resultant M^2 of floor space, per dwelling or by person.

What this model, or rather a "scenario analysis, informed by a sophisticated understanding" (Dr Garry Glazebrooke 2013, personal communications, January 16, 2013) comes around to find is:

Were Perth to strategically aim for the outlined 47% infill Policy in Directions 2031 it could house all the new residents along current and new transit lines in a chain of nodal developments[8]. These developments would occur only in the red polygons on the Figure 1 and not in the established suburbs. Likewise these developments will be happening where urban development ought to go, near rail transit lines and rich in amenities rather than as dispersed car-dependent Greenfield developments.

[7] For example, The Beasley building in Yaletown, Vancouver, Canada is a mixed use, mixed income, heritage conserving, street-front retail building of over 30 floors and comes in at 7.22 FAR, which will not be even noticeable within its urban context: http://forum.skyscraperpage.com/showthread.php?t=147928 . While Floor Area Ratios of 16.4 are achieved in Manhattan, one might think that all tall buildings have high FAR, but this is not so; the Brasilia Superblocks are only FAR 1.1 due primarily to the great areas of anti-urban, not even ecological, 'open space' left between the buildings. In other words, if all the floors of any one of these buildings in Brasilia were laid out across the lot in which they sit, they would only just cover the entire lot with building mass whereas the building in Manhattan would cover the site 16.4 times. http://densityatlas.org/casestudies/

[8] These nodes will have building masses of a maximum 10 storeys, some 5 or 6 storeys depending on site redevelopment size.

7. Results

7.1. Outcomes of the Southern Circumferential Line

7.1.1.Transport and Land Use Characteristics

The envisioned transport and land use surrounding the new train stations along the SCL will have significant changes in densities of residents, jobs in commercial spaces and street-fronting retail. The significant benefit to extending the reach of the very popular heavy rail system will be to make car use less of an optimal transport mode which has multiple flow on effects including reduction in GHG, VKT, and health outcomes, while creating the walkable compact and complete communities.

This paper will use the SCL as the first example as the changes along the route reflect the breadth of opportunities and options to change. It will provide the first case study but also best reflect the methodology. See Appendix 1 for a breakdown of the methodology.

7.1.2.Total Net Area

The best way to read the bars in the chart below is to understand that each of these three main types of building floor-plate products are:

- representing each type of designated built form land use with the last line representing the total floor area in M^2 of the site; and
- trending larger the further to the edge of the current conurbation the rail lines travel as a function of the line reaching the much wider open areas of Coogee, Spearwood, Jandakot, Canning Vale and other which are currently significantly active industrial, underused urban and/or brownfield ex-industrial lands

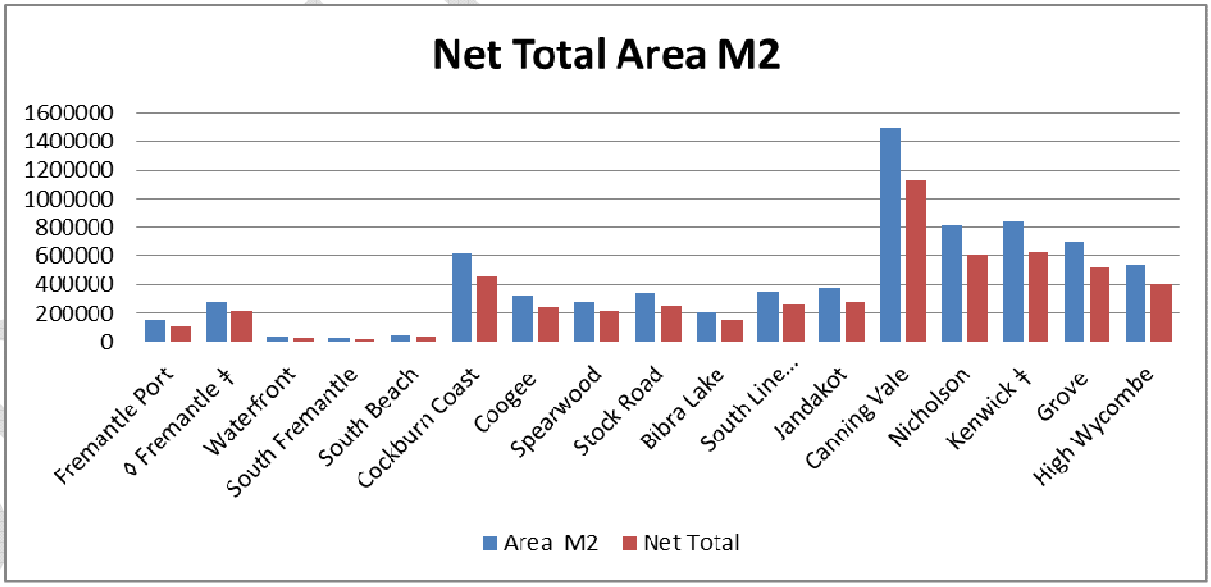


Figure 11 Redevelopment Opportunities by land use mix in M^2, SCL

One may find there is more land available than what is listed here at these stations as these are the immediately redevelopable lots, not counting those that might yet change from current uses due to changing real estate markets in the long term. The reasons why the stations of Fremantle and East End do not show in this line as having opportunities is because they are counted as benefiting more directly from one of the Light Rail Transit Lines included in the overall results discussion below; indeed one might consider that Amendment 49 and Knutsford Site be equally best placed in the LRT accounting.

7.1.3.Mix of land use

Figure 6 describes the mix of uses at each station. Visible by the coloured bars are the mixes and also the dominance of certain uses, such as residential or commercial. It also reflects the designating of height limits on buildings based on the precincts available land. See table 5 below.

The land available has been analysed in terms of the best possible uses for those areas and the results for the SCL are set out below. Figure 6, show a significant difference in the retail sector from the other two indicators. This is due to the majority of the retail being near the Fremantle Waterfront and South Beach, which are small station redevelopment precincts and hence the retail proportion, at 25% at those stations, is equally small. The other sites, such as Jandakot and Spearwood, are better suited to a 5 to 10% retail as a part of a mixed-use redevelopment in this way bringing enough small scale shops closer to residents so that they may walk, not drive, to convenient services in their own neighbourhood.

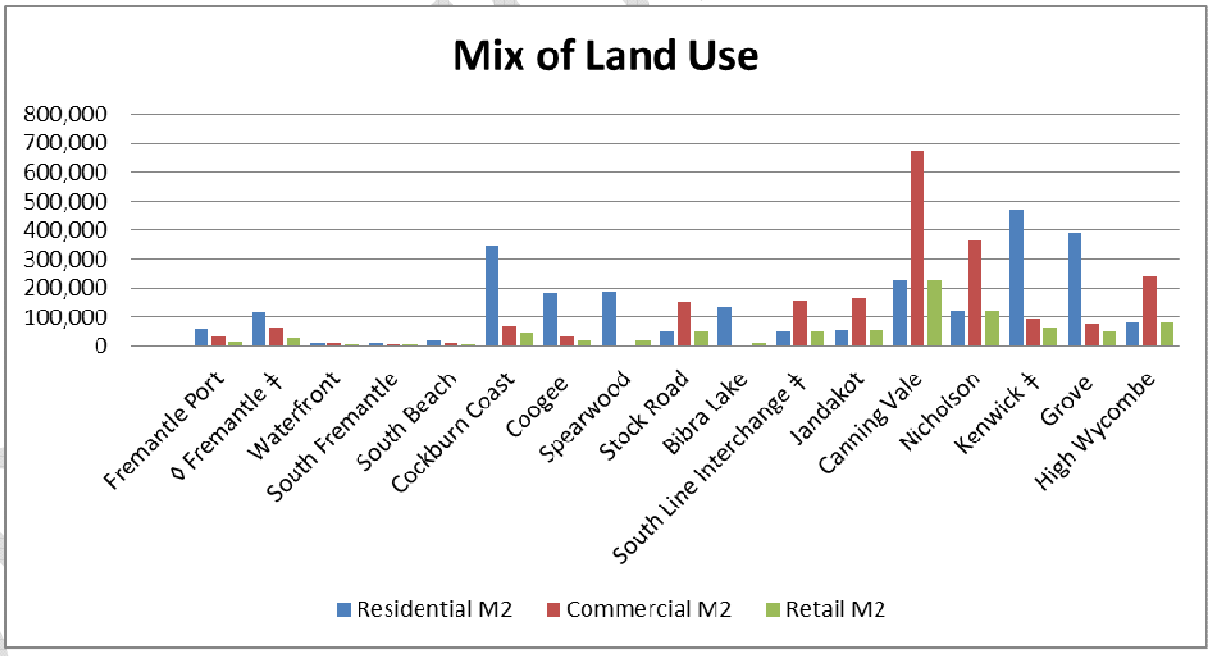


Figure 12 Mix of Land Uses in M^2, SCL

7.1.4.Area by land use

Figure 7 relays the mix of land use overall along the SCL. It will be reasonably split between residential housing and commercial spaces. The housing will be comprised of higher density multi-family units and the commercial space for office for back office managerial and technical, professional, light industrial. There will be a strong component of retail space as well, as shown, and in an effort to finding the correct balance has been kept to approximately a sixth of the overall M^2 available.

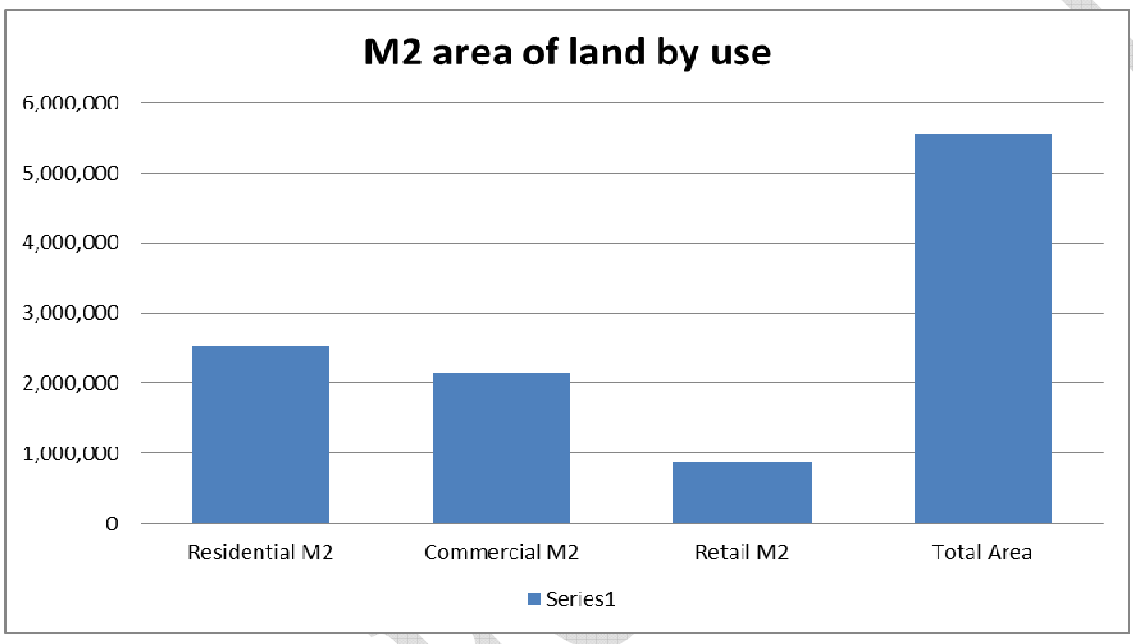


Figure 13 Residents, Jobs and Shopping in M^2, SCL

7.1.5.Person activity

Person activity relates the numbers of persons who may reasonably find housing or work in the precincts surrounding the rail stations along this SC Line. While Fremantle and Cockburn will grow, we can see that a great deal more persons will be able to find either or both work and home in the middle suburb sections of the line from Spearwood to High Wycombe.

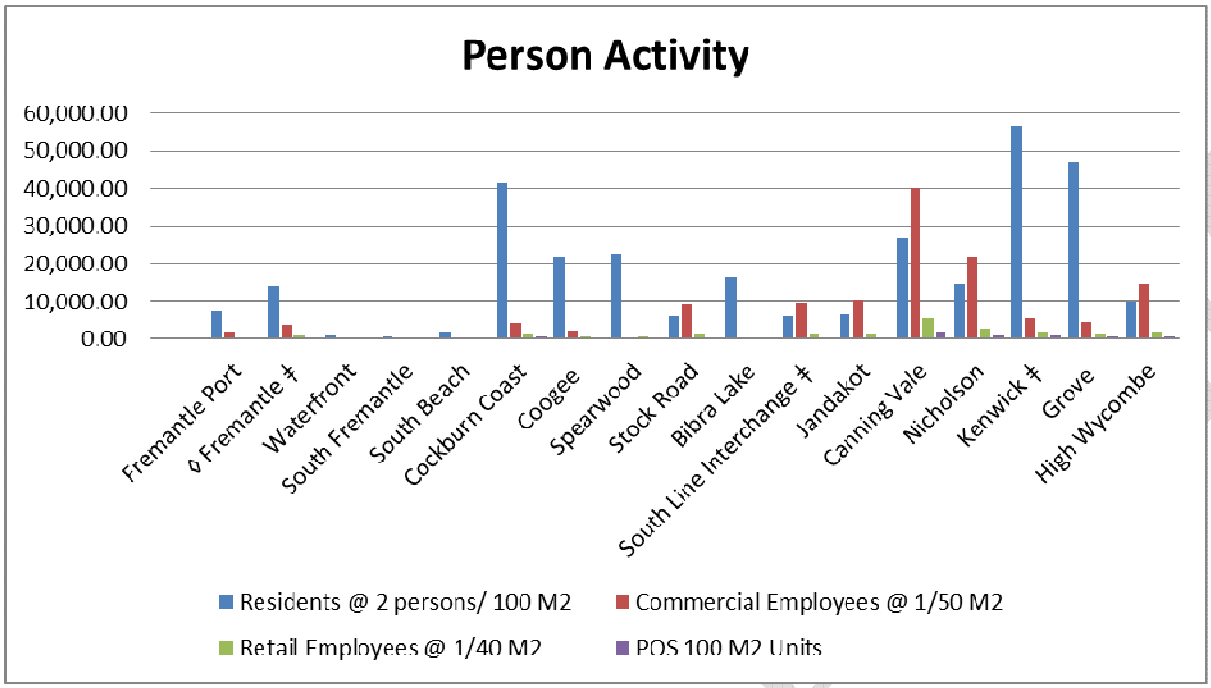


Figure 14 Residents, Jobs and Shopping by persons, SCL

7.1.6.Trip generation and parking

Figures 9 and 10 shows the relationship between the standard Roads and Transport Authority (RTA 2002)of New South Wales recommended parking provisions and trips generation to the increase in population, commercial activity and retail stores as a result of either type or square meters of land use. One can see that there are a very great number of trips; back and forth to homes, to shops, to schools, to friends, to eat or otherwise which will comprise the comings and goings of an active and prosperous citizens in a network of urban precincts along the Southern Circumferential Line. This number is a per day figure for the residents and workers along this line. What one can also see along the lower line is that there will need to be more car parking bays than people living along this line if the RTA standards are to be followed by land use. Despite retail contributing little to the overall numbers of employees, with a per day trip generation factor from the RTA being factored in Retail alone contributes as much as each of the other types of land use, Residential and Commercial. What is also shown on this chart is the rate at which Public Open Space, as recreation facilities primarily or as mere open parkland, contributes to the trip generation numbers. Recreation Facilities contribute almost as much as Retail to both parking requirements and trip generation numbers. See section 4.4.1 above for a discussion on parking.

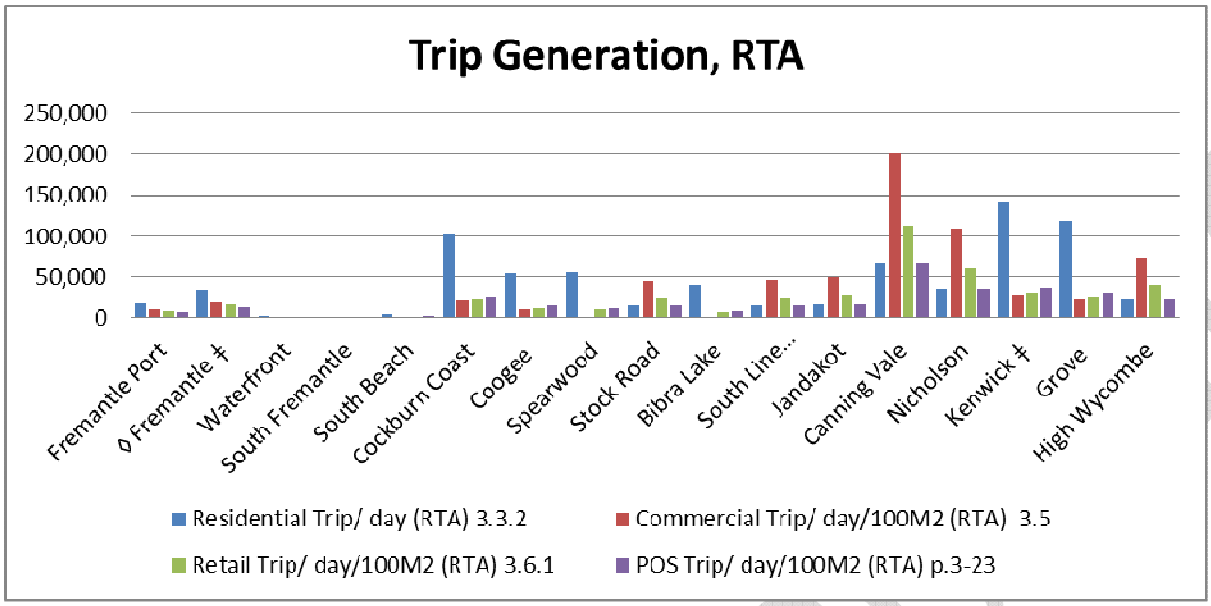


Figure 15 Daily Trip Generation according to RTA standards, , SCL

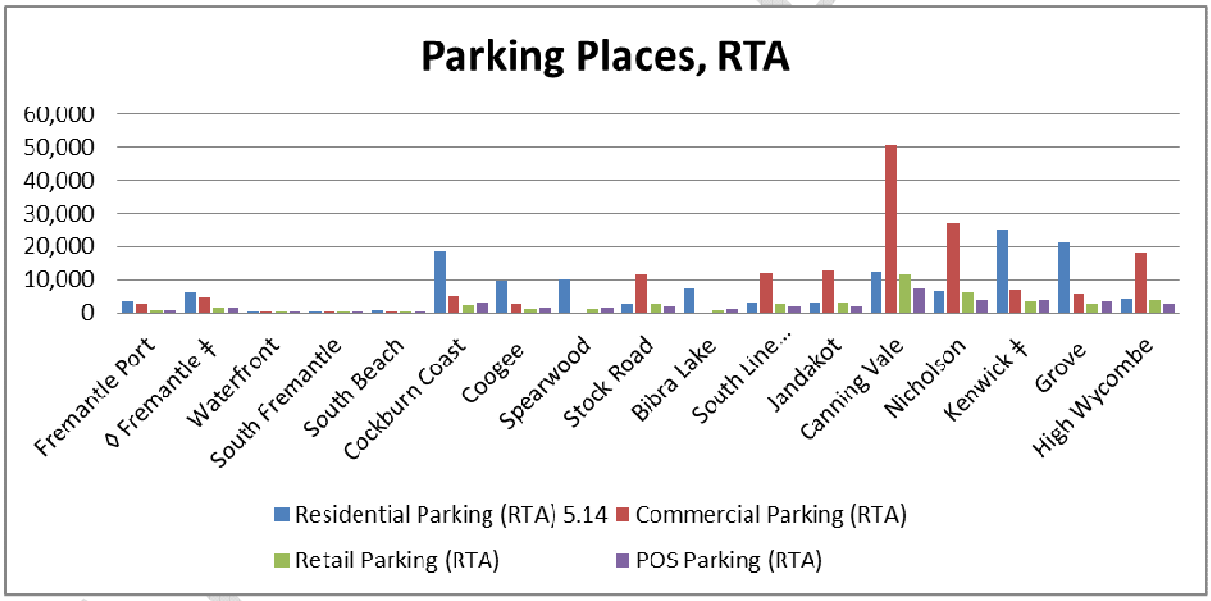


Figure 16 Parking Places according to RTA standards, , SCL

7.1.7.Years of housing supply

According to the population projection from this building fabric of maximum 10 storeys on the redevelopment precincts over 40,000 m^2 that 33.4% of the population could be housed along this SCL line alone if Perth made a concerted effort to achieving the Green economic goals. This is equivalent to over 8 years of housing supply according the latest data on Perth's housing supply(HIFG 2012).

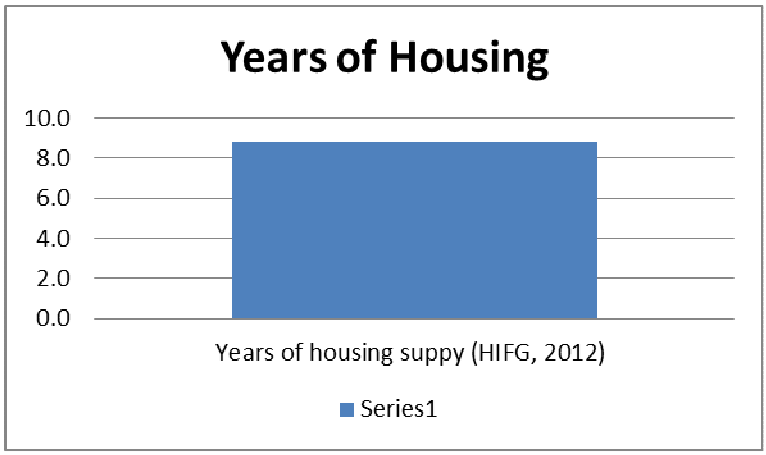


Figure 17 Years of Housing , SCL

7.1.8.Greenfield area saved, Sprawl reduced

The redeveloped built form for living and working within the urban footprint is equivalent to the same amount of land preserved from low density car-dependent, greenfield, single- family housing. In this instance the SCL preserves the ecosystem services of 21,231,000 M^2 or 2,123 hectares, being near to the size of John Forrest National Park in size at 2,678 hectares. This is not including the housing redevelopment opportunities coming from the northern half of the ring-rail or the LRT and BRT contributions to urban redevelopment.

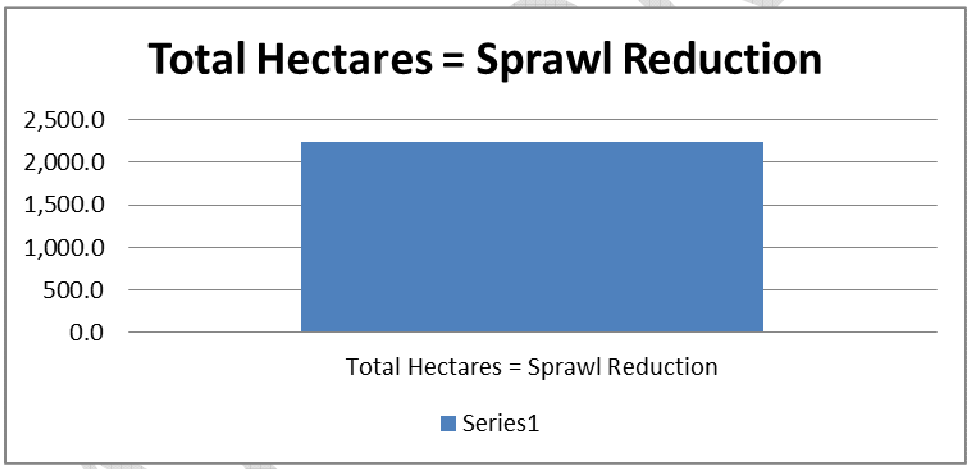


Figure 18 Sprawl Reduction, SCL

7.1.9.Infrastructure Costs avoided

In Trubka et al, the contrasting urban forms are Highly Walkable Urban Environments, or HWUE and Low Walkable Urban Environments, LWUE (Trubka, Newman et al. 2010) . Figure 13 demonstrates how much money might be saved by retrofitting and upgrading the infrastructure which already exists versus undertaking the same plus installing the entire new infrastructural components to dispersed new settlements.

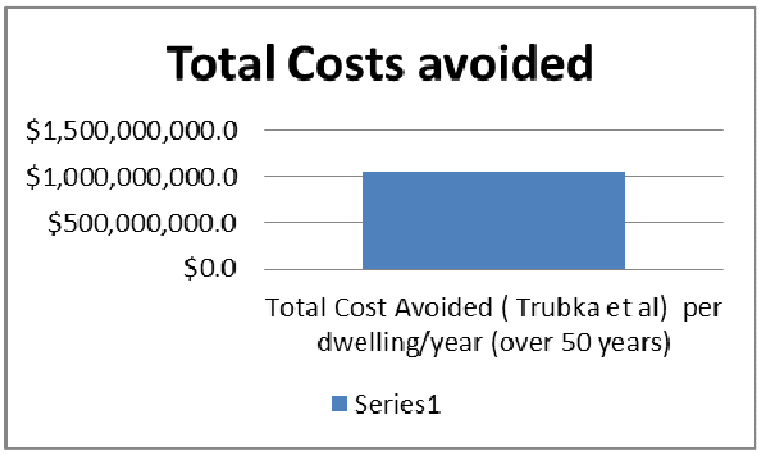


Figure 19 Total Costs avoided for all dwellings at all stations, SCL

7.1.10. Transport costs

The scale of the monies saved to be used for other things is evidently borne out in real life. Persons living in Central Business Districts, or other types of inner city neighbourhoods, replete with plentiful shopping and employment destinations and with safe walking routes may attest that one doesn't need a personal car (SOV) very often for daily or weekly tasks and transport costs are perforce lessened. Transportation Costs as prepared by Trubka et al is comprised of these indicators: capital cost of cars; fuel Costs; other operating car costs; time costs differences between private and public transport; road costs; parking; externalities including fatalities, injuries, property damage, air pollution and noise pollution; and transit costs.

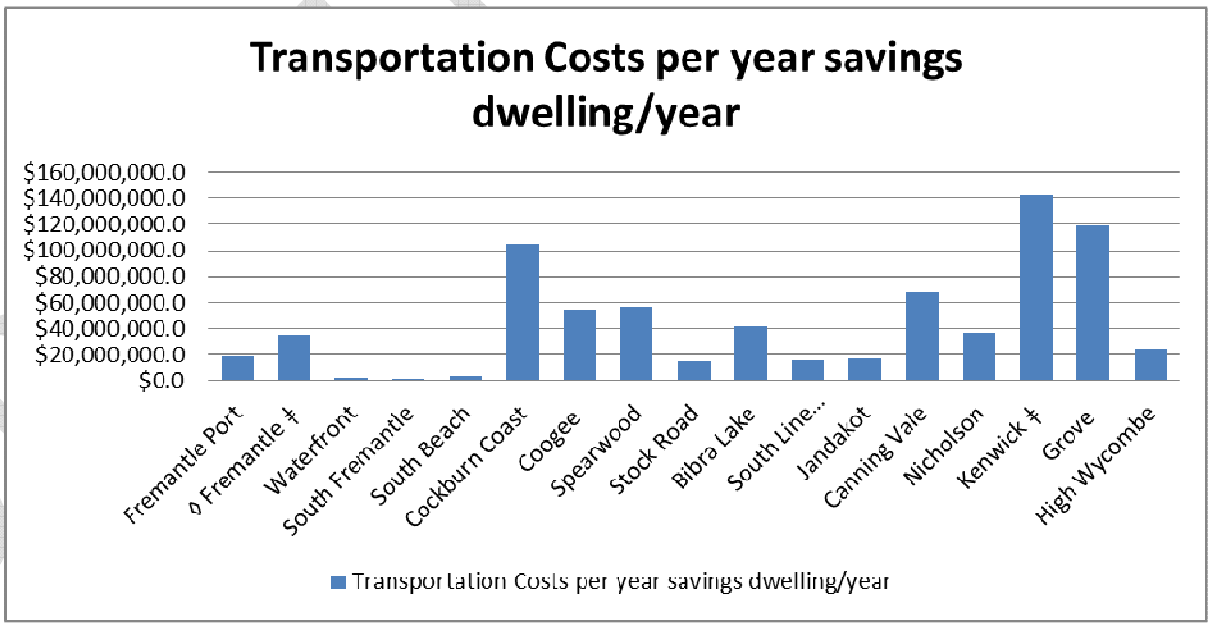


Figure 20 Transport Costs (saving of 5028$ per dwelling per year), SCL

Vehicle Kilometres Travelled is a universal means of calculating the extent to the rate at which individuals on the aggregate as a census tract, neighbourhood, city or region use the Single Occupant Vehicle for their daily or weekly needs. It shows the rate at which persons are dedicated to their personal vehicles as opposed to complimentary transit modes such as rail, bus, walking and cycling. VKT is a very useful proxy for a host of other important , as not only does it correlate to transit mode splits, but also reflects negatively on the road capacity, air quality, and rates of diabetes, heart disease and obesity. It also shows, indirectly, where the priority has been, politically, for transit in any given city.

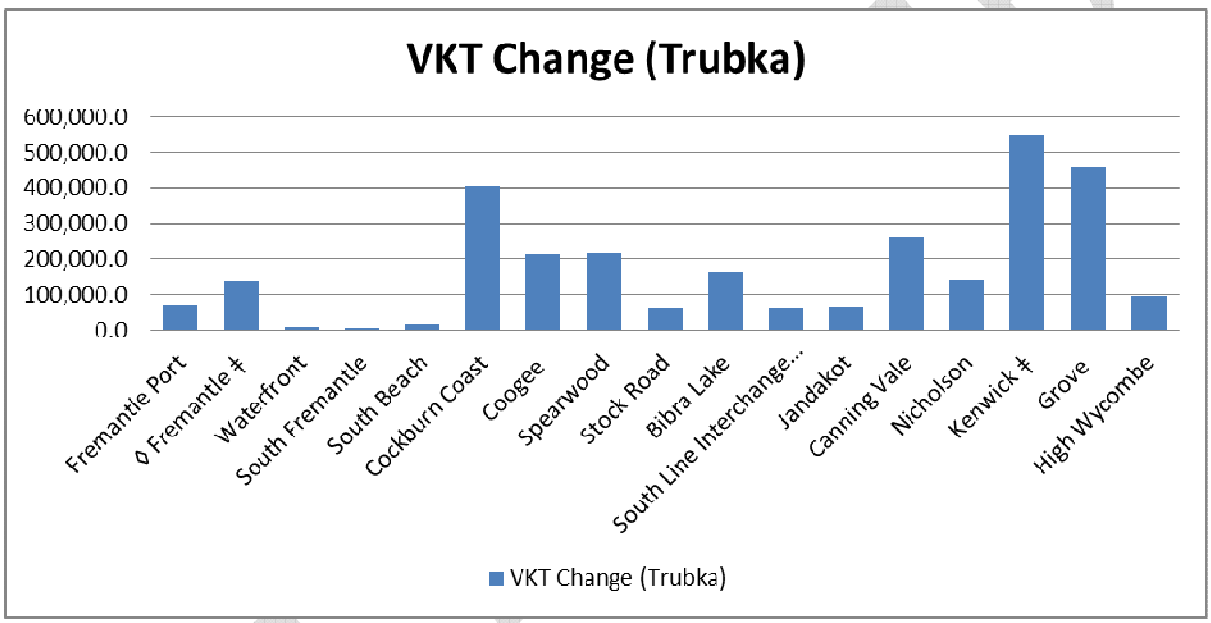


Figure 21 Vehicle Kilometre Travel reductions, SCL

Greenhouse gases, or GHG, is comprised of several chemical compounds elements not least of which is dealt with in the Clean Energy Futures (Australian Government 2012a) program which designates $23 a tonne be charged for carbon emissions. The totals for below represent where some of the saving might be achieved in a higher density, transit oriented future.

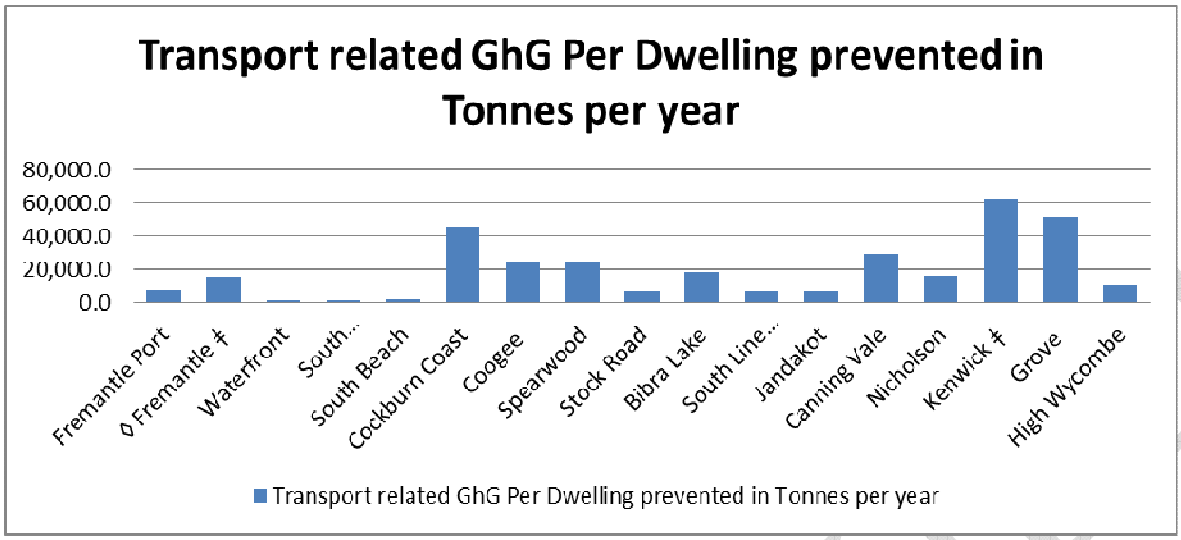


Figure 22 Transport related GHG, SCL

7.1.11. Physical activity benefits

Physical activity accounts here for the likelihood that one living in a walkable neighbourhood will more often walk or cycle to the closer destinations provided by the mixed use aspect of their locality. This includes active transportation to work and back, to school, to shops and so forth. There is a quantifiable cost and benefit to this 'extra activity' (only when compared to BAU, not historical activity levels) and the results are indicated below. The dollar benefits will be most keenly felt in unnecessary doctor visits or less premature hospitalisation due to illnesses attributable to lack of exercise namely; heart conditions, obesity, diabetes and others.

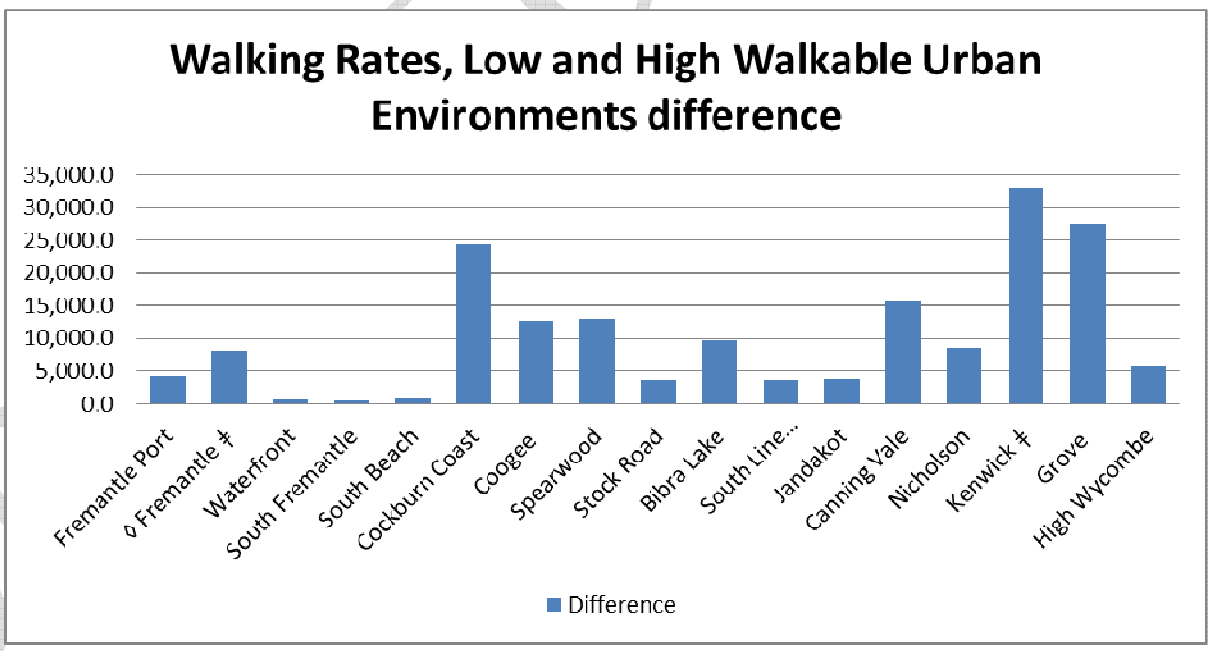


Figure 23 Walking Kilometres per day improvement on the SCL

Productivity is related to good health. When we sleep and eat and exercise well we feel better and produce more value in the place of work or at home. The dollar benefits for all the residents living

along this SCL in regards to health, as related directly above are great, but the dollar amount benefit to society and the economy is even greater for being a more productive member of the workforce in in the economy. The combined benefits to the economy of persons living in walkable neighbourhoods, increasing health and increasing productivity, is indicatively $116,000,000 per year according to the study by Trubka, Newman, et al.

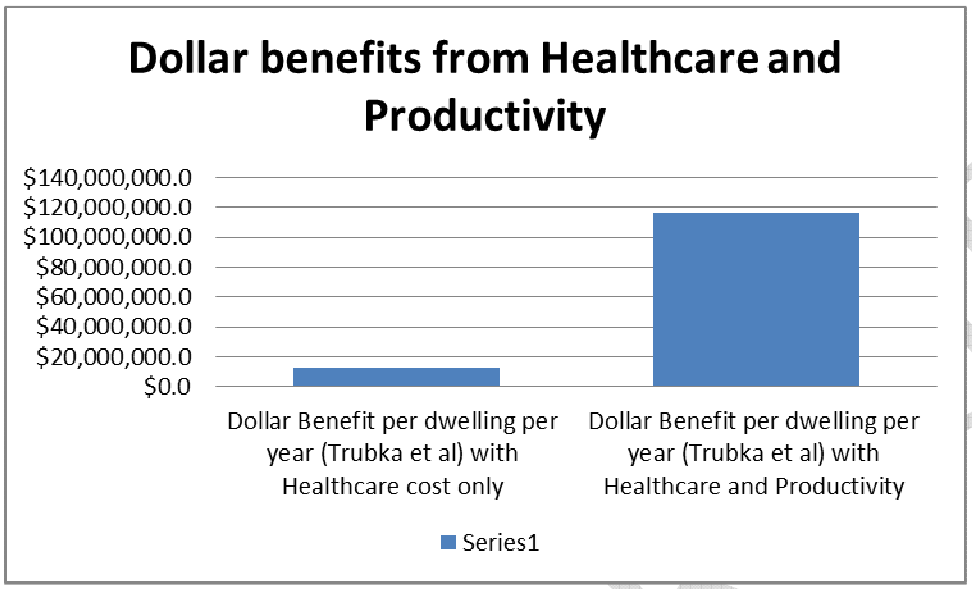


Figure 24 Dollar Health and productivity benefits in dollars in a Walkable Environment on the SCL

If persons live in an area which has few destinations of sufficient quality and type to attract walkers, unsafe and unclear pedestrian connectivity to the areas beyond their community and little opportunity to walk due to stress and time spent in their automobiles commuting due to the distances travelled to find affordable housing, there is an strong disincentive to be active. These modelled numbers as presented are due to the connective and safe and destination rich urban environment which Transit Oriented Developments can bring to a city if the projects are implemented as pedestrian realms first, transit realms second and private SOV zones last. At almost $13 million, the decrease in expense from just the two hundred odd thousand persons along the SCL alone, should interest policy writers and funders of health care greatly.

However, all the benefits from living in these amenity-rich walkable urban areas as beneficial to healthcare costs pale in comparison to the calculated overall cost attributed to poor worksite productivity when persons are not being able to exercise as a regular part of their daily routines due to the types of urban form purposefully constructed over the last 50 years to service the automobile. The $116 million which might contribute to the overall productivity of the economy due to per person rates of “absenteeism, presenteeism, stress levels, job satisfaction, and job turnover” (Trubka et al) should be viewed even more positively for policies for and funding of the ring-rail. If people are able to achieve activity thresholds easily they are more likely to be more productive members of society. Perth requires these sorts of reasons to underline the huge range of benefits as

a part of the program in articulately developing high-order transit and Transit Oriented Developments.

7.1.12. Costs Ratio:

The ratio of costs avoided to capital costs for this line of 37 KM of Heavy Rail (though the project could be a Light Rail Project as well) (Martin 2011 p.11) of this SCL project is, in millions: $1,339:$1,036. This is roughly a 1:1 savings to capital expenditure. Furthermore, if compared with a highway extension, which will cost in health VKT, GHG, sprawl's new infrastructure to build and maintain, and be equally costly to build, the optimal infrastructure to invest in for the healthiest and wealthiest society is evidently in projects such as the Ring Rail.

7.2. Outcomes of the Northern Circumferential Line

This section will describe the benefits of the Northern Ring Rail. The benefits will be much the same with an overall total of costs avoided and other, currently more intangible benefits of lowered GHG, VKT, and healthcare costs with an increase in walking rates but with a similar distribution of trip generation and parking requirements according to the RTA of NSW. The biggest difference is there are fewer stations, fewer large areas for redevelopment strictly along this lines 500 meter buffer (there will be many opportunities for feeder bus network further afield), and the types of development are less supportive of high residential population mixes. This does have an impact on the results as fewer people will 'live' in these station precincts as opposed to working in these grey and brownfield sites. The effect of this is that the model does not respond well to compact working environments as most of the literature has been written in response to primarily dwelling close to work and overall making distances shorter from the home, rather than from the worksite. This fact drives down such numbers at GHG reduction, health and productivity benefits and others which cumulatively add to a reduced cost avoided sum. Therefore, the totals for this section of the ring rail, the NCL, may be less impressive than they might be were the land supply better located to accommodate residential type developments[9].

The one area which will stand out in the result is the enormous impact the Perth International airport lands could have, with the appropriate variances regarding height and intensity, so that they might become part of what John Kasarda describes as "Aerotroplis".

> *The aerotropolis …contains the full set of commercial facilities that support such firms and the millions of air travelers who pass through the airport annually. Included here, among others, are office, hotel, convention and exhibition complexes, shopping, dining, and recreation venues, and logistics and distribution facilities. As increasing numbers of firms cluster around airports and outward along their highway corridors, the aerotropolis emerges where air travelers and locals alike work, shop, meet exchange knowledge, conduct business, eat, sleep, and are entertained without going more than 15 minutes from the airport."(Kasarda 2011)*
>
> *"The U.S. and Western Europe often view airports as nuisances and environmental threats rather than as critical infrastructure to compete and prosper. This has resulted in their*

[9] For an explanation on why these lands are not as well suited for residents see Vukhic 2007 for a description on the impact highway median RoW transit services being suboptimal for populated redevelopment.

maligning and neglecting airports while Asia and the Middle East invest heavily to leverage them. Such malign neglect comes at the long-term economic peril of the West." (Kasarda 2012)

Airports are also closely associated with key characteristics of knowledge-based or post-industrial economies. Both the number of flights and passengers are correlated with the percent of adults that are college grads, the share of the workforce employed in knowledge-based, professional, and creative class jobs, and even more so with concentrations of high-tech industry. Again, we found little association between such factors and the amount of cargo that passes through metro airports. (Florida 2012)

The case can certainly be made that Perth's airport land bank, so critical to Perth's economic well-being and for maintaining global connections, could certainly be upgraded from its current low intensity status. With vastly improved rail connections such an uplift of uses might just be the reason and a result for the airport's improved status in the coming years.

7.2.1.Transport and land use characteristics

The transport and land use characteristics of the Northern Circumferential Line will be one of predominately commercial lands with a moderate amount of residential areas where appropriate. The case can be made that living beside a train line may be convenient with a high frequency services with many destinations from ones origin, but that living beside highway right of ways might not for the reasons that there are often high levels of pollution, air borne particulates, neighbourhood services split by lengthy distances traversing to the other side on foot, low levels of walkability and excessive noise. These may, however be useful places to develop commercial areas, with retail and other services fronting the highway with residential towards the back of the precincts. These types of highway median accessed rail services are also ideal feeder bus termini, with services extending the reach of high quality public transport deep into the adjacent neighbourhoods.

7.2.2.Total net area

The gross area available along this line is in the order of 809 hectares, but net area after reductions for POS and RoWs (setbacks, underground services, internal roads and so forth) being 621 hectares. High Wycombe is counted in the SCL.

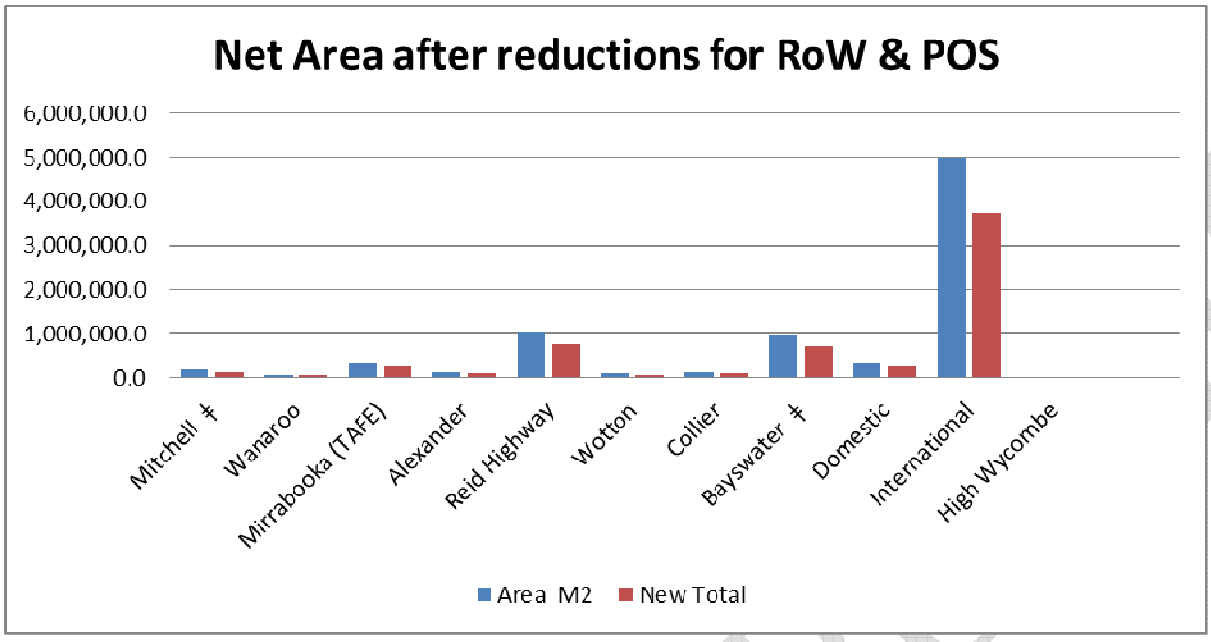


Figure 25 Net area, NCL

7.2.3.Mix of land use

The land use mix results in a leading area best suited for commercial uses, as one can see in the red bar below. These are not to be misread as separate zoning on the ground plane but more an indication of primary uses at the ground plane in a very mixed use regime.

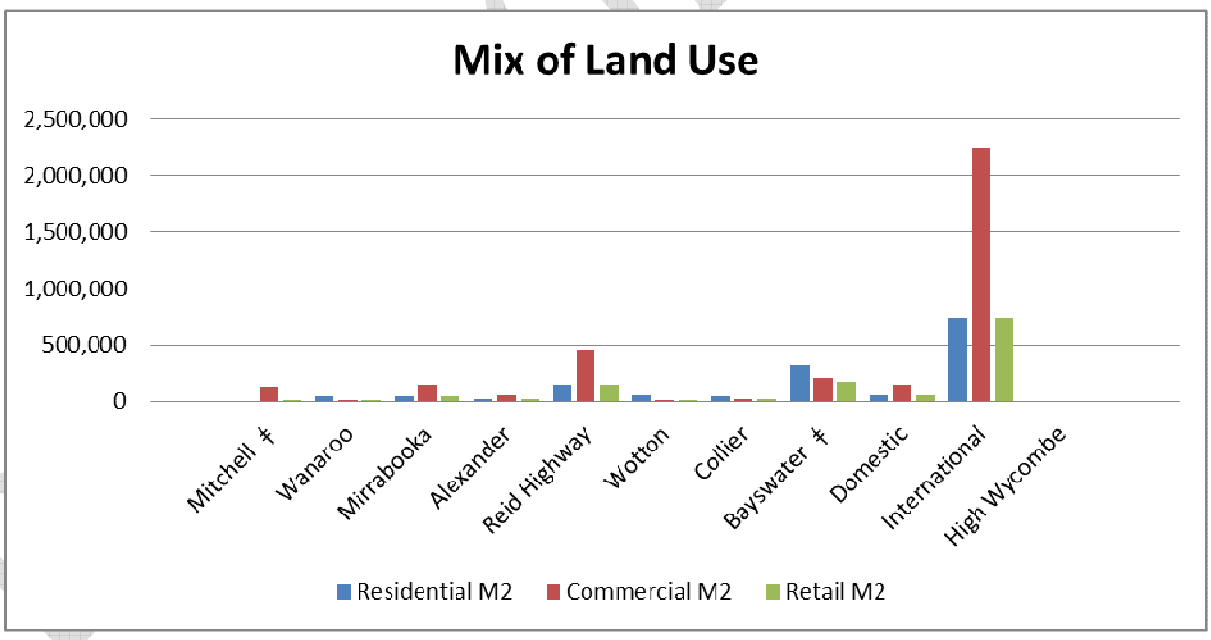


Figure 26 Mix of land use, NCL

7.2.4.Area by land use

The totals for each land use are roughly 150 hectares for residential, 346 hectares for commercial and 125 hectares for retail.

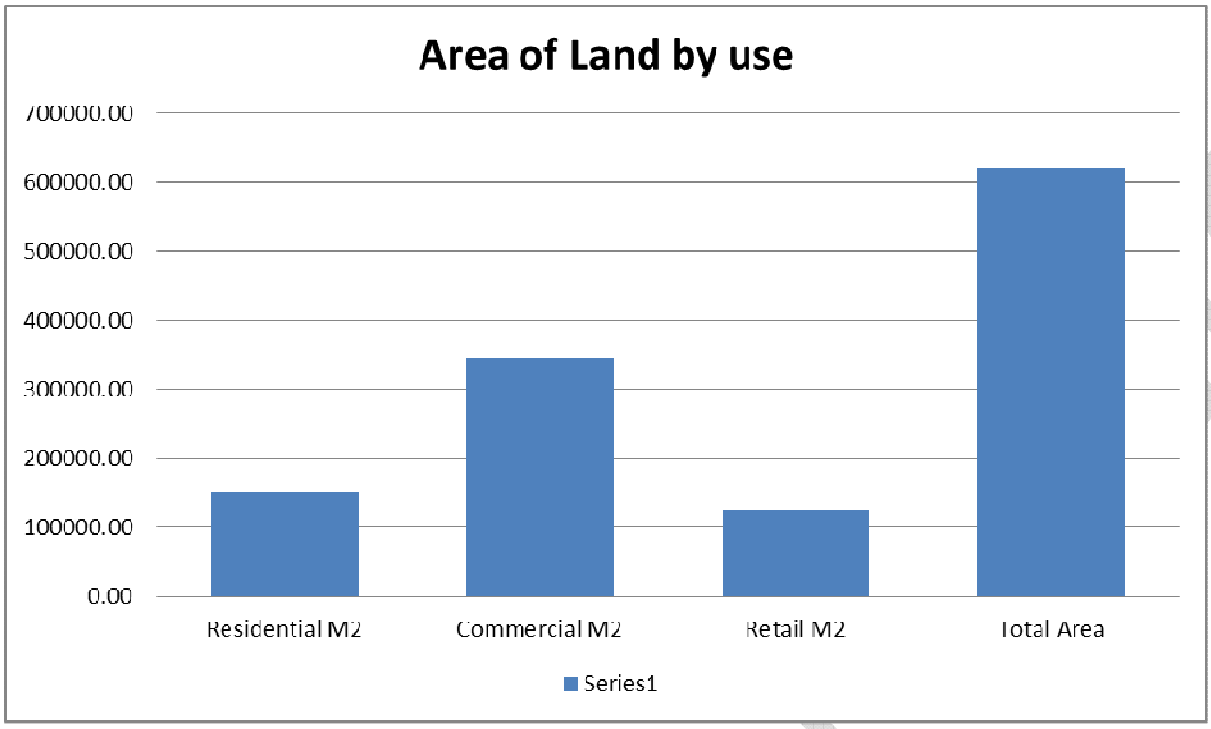


Figure 27 Area of land by use, NCL

7.2.5.Person activity

While there could be room for 177,000 new residents, more significantly there could be in the range of 207,480 commercial office and light industrial spaces along this NCL corridor, thanks in no small part to the fantastic opportunities available at the Perth International Airport which responds directly to the visionary forecast of John Kasarda's Aerotropolis concept (see above).

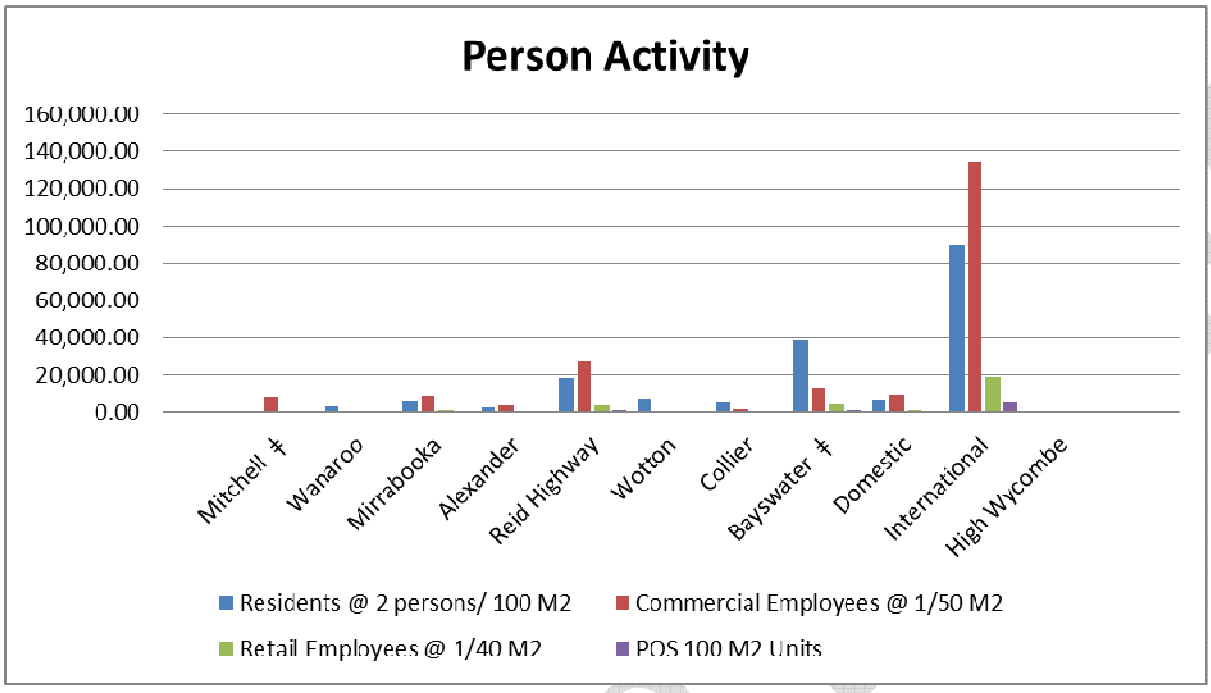


Figure 28 Person activity, NCL

7.2.6.Trip generation and parking

The potential for the Perth airport to be a major source of transport requirements, in addition to the existing workers and passenger traffic, is evidenced in this chart. The Airport, using the RTA ratios of trip generation, could produce almost 700,000 commercial trips per day and 373,000 retail trips per day. The parking chart again shows massive needs for parking without having taken into account that many trips will be taken by public transport or through active transport, thereby lowering the requirement for large areas of parking. Please see 5.2.1 for a discussion on parking.

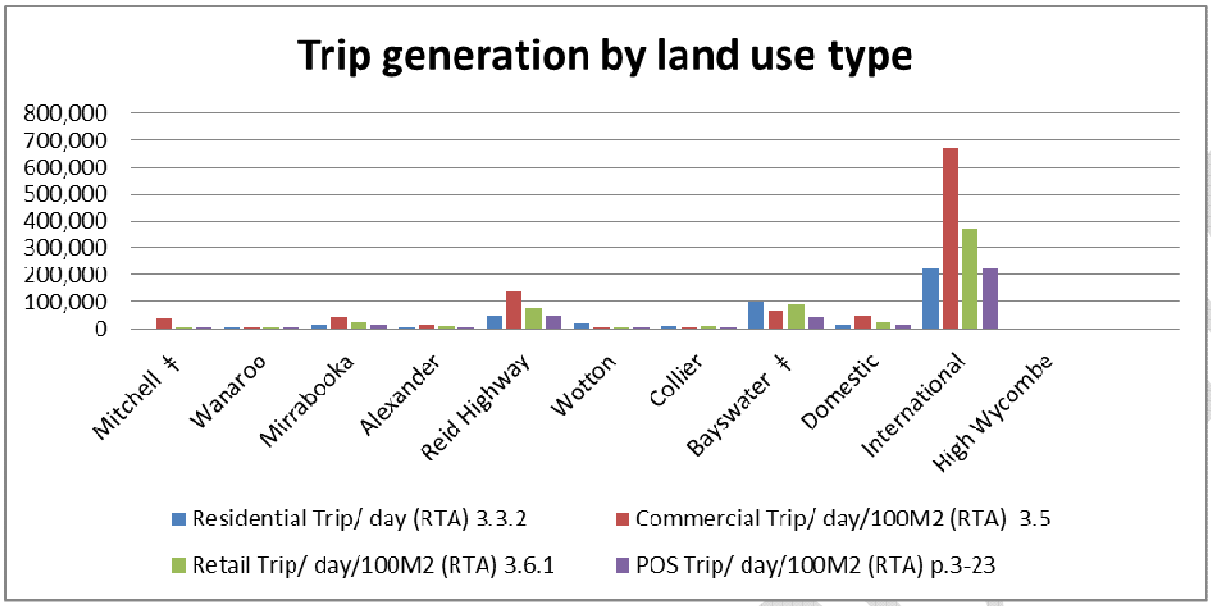


Figure 29 Trip generation, NCL

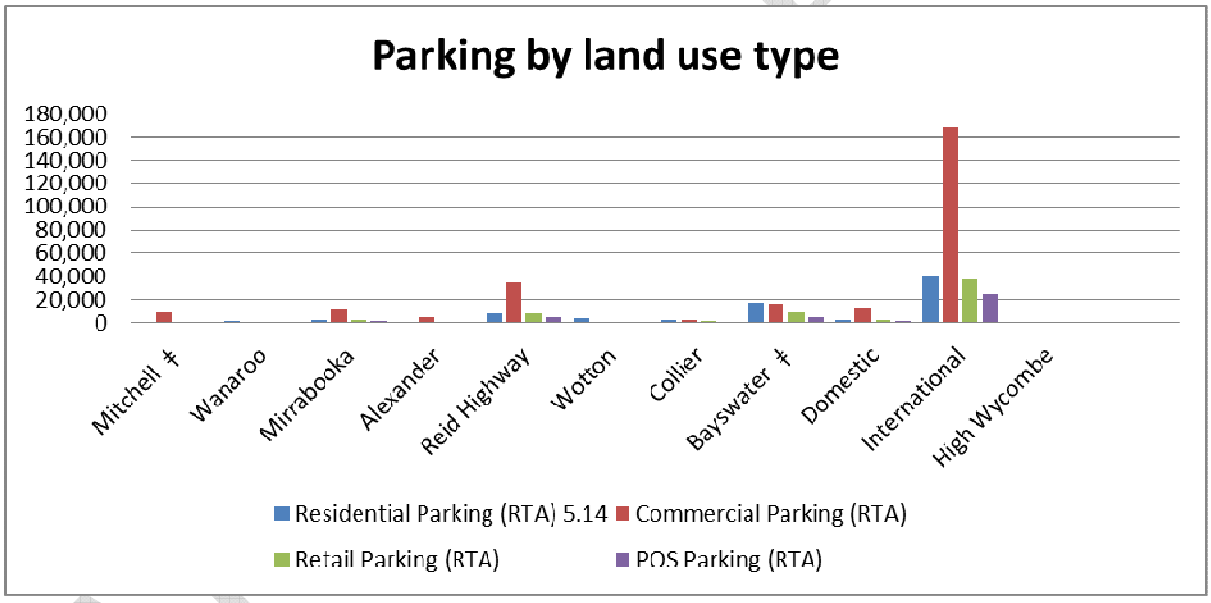


Figure 30 Parking by land use, NCL

7.2.7.Years of housing supply

The 5 year housing supply along the NCL is low compared to the SCL's 8 years, however this as due to the commercial and retail character of the station precincts.

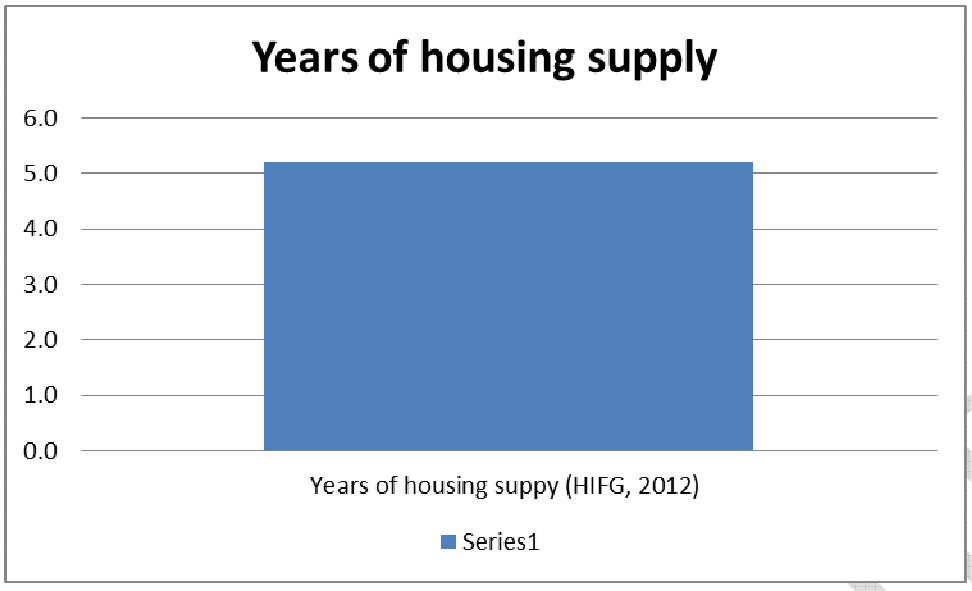


Figure 31 Years of Housing supply; NCL

7.2.8.Greenfield area saved, Sprawl reduced

By clustering more development on a smaller footprint of land and by building upwards along the NCL, not outwards, Perth could effectively save over 2000 hectares of forest and farmland form car dependent suburban development.

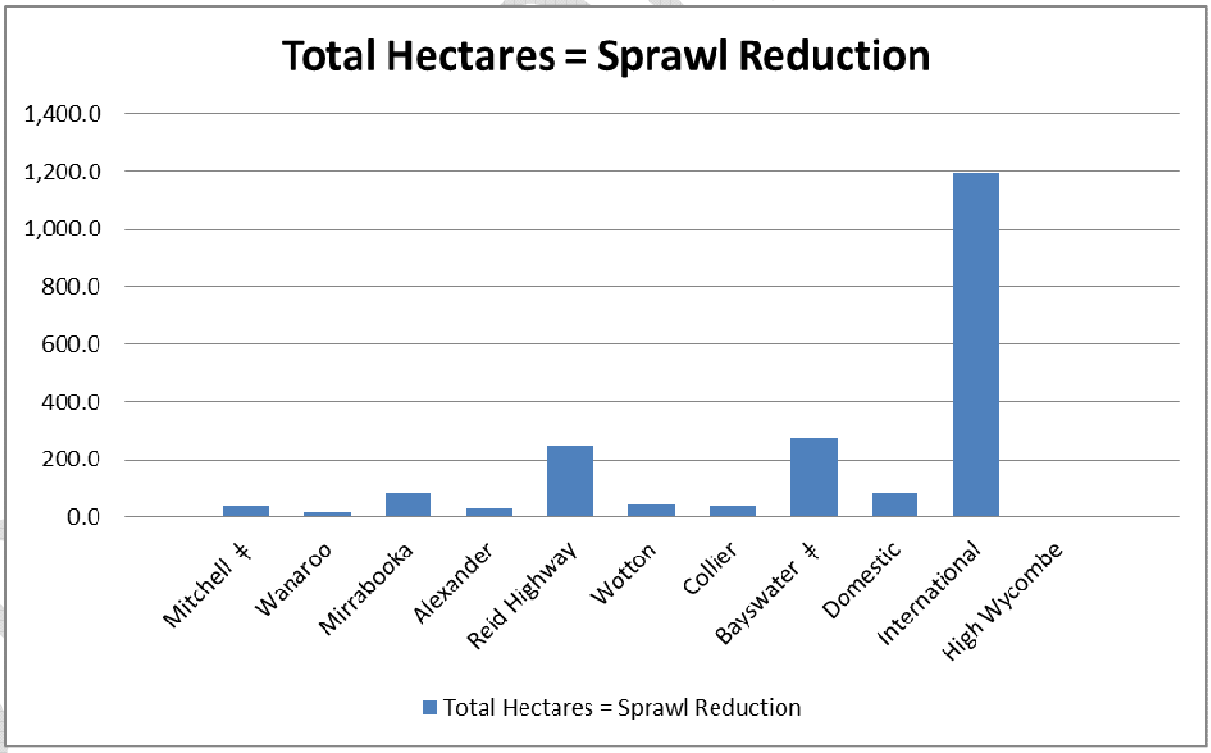


Figure 32 Sprawl reduction, NCL

7.2.9. Infrastructure Cost Avoided

The costs of undertaking such a large capital work project will be daunting. However, there is a great deal of money which will be saved by the fact of tying into existing infrastructure for the redevelopment of the lands for housing, commercial office and retail activity centres. One can see, for example, that at Bayswater alone there could be a savings of $800 million over the lifespan of redevelopment.

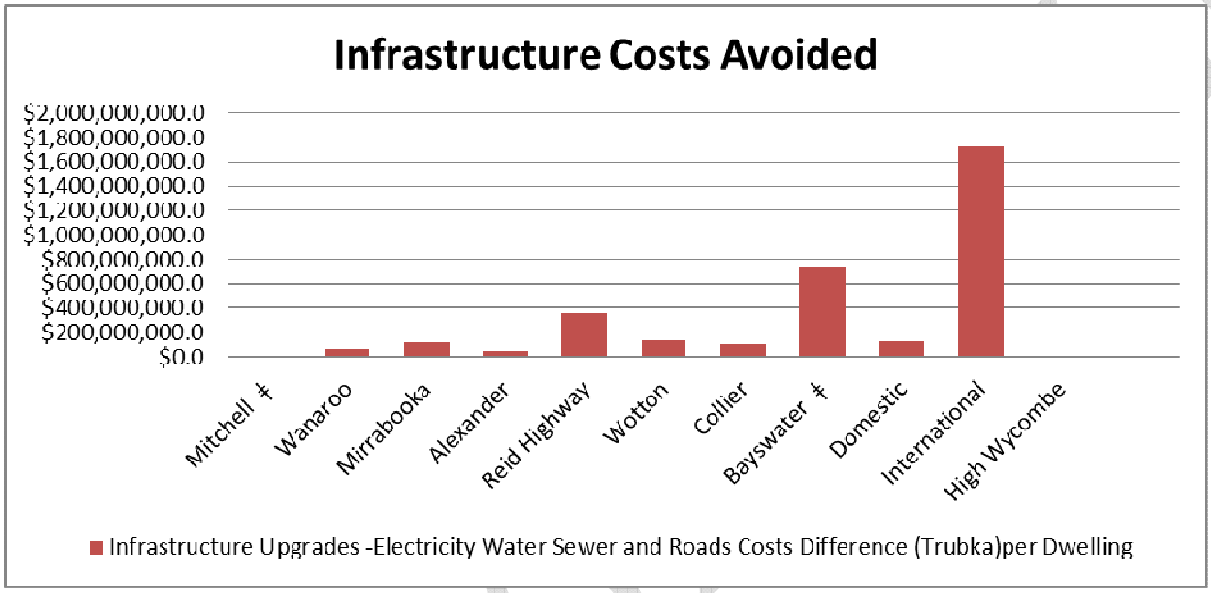


Figure 33 Infrastructure upgrade costs avoided overall on NCL

7.2.10. Transport costs

Vehicle Kilometres Travelled will certainly be reduced along the NC as the highly networked transport system will improve on the delivery of high quality transit service to a multi-destination region. The NCL will result in an estimated reduction in VKT of over 1 million fewer kilometres travelled by private vehicles per day.

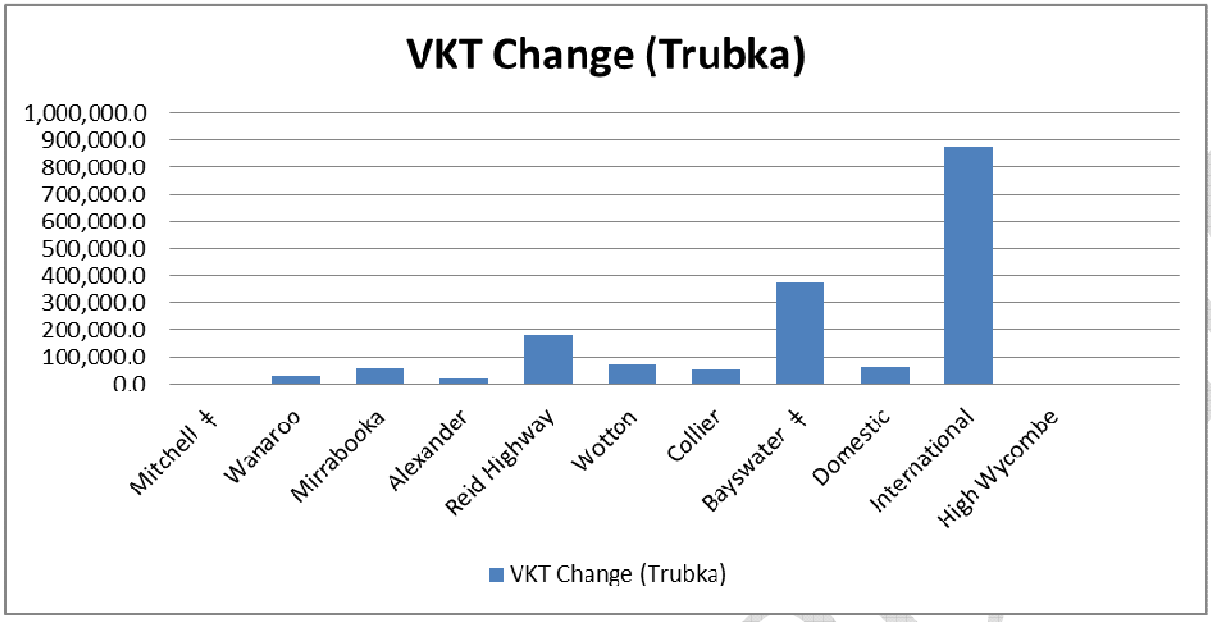


Figure 34 Vehicle Kilometre Travel change due to living in clustered communities along NCL

The costs of transportation will be primarily borne by the residents and households, but the flow on effect of the dollars remaining in the region, as opposed to car-makers and petroleum companies based out of state or even country, is very large indeed. In the order of $446 million will be saved per year by residents living along in the transit served and highly walkable NCL alone.

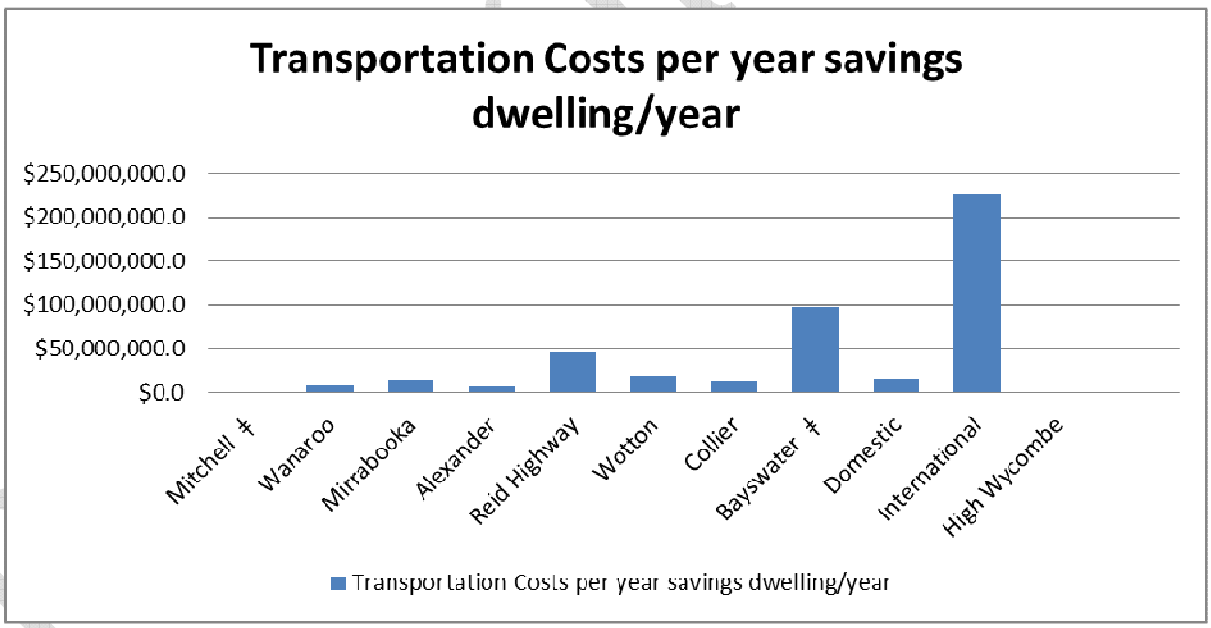


Figure 35 Transportation Costs avoided to persons living in the walkable transit served communities of the NCL

Greenhouse gas reductions due to transport could foreseeably be quite great due to the ability of residents and workers being able to use trains as a major means to travel around the region on this proposed highly networked system.

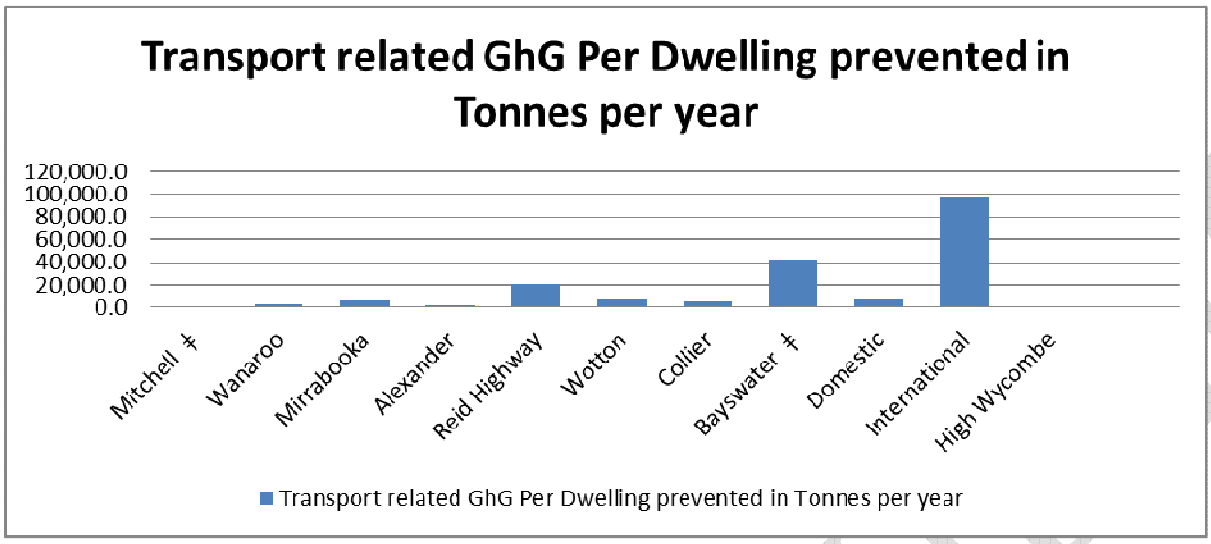


Figure 36 GHG reduction on the NCL

7.2.11. Physical activity benefits

The daily walking rates could be vastly improved along the NCL's redevelopment lands. Whether or not the Perth Airport will become a 'walker's paradise' remains to be imagined though it is quite possible to imagine the predicted quantum of trips per year from office to a lunch counter, or from plane to hotel, being made on foot.

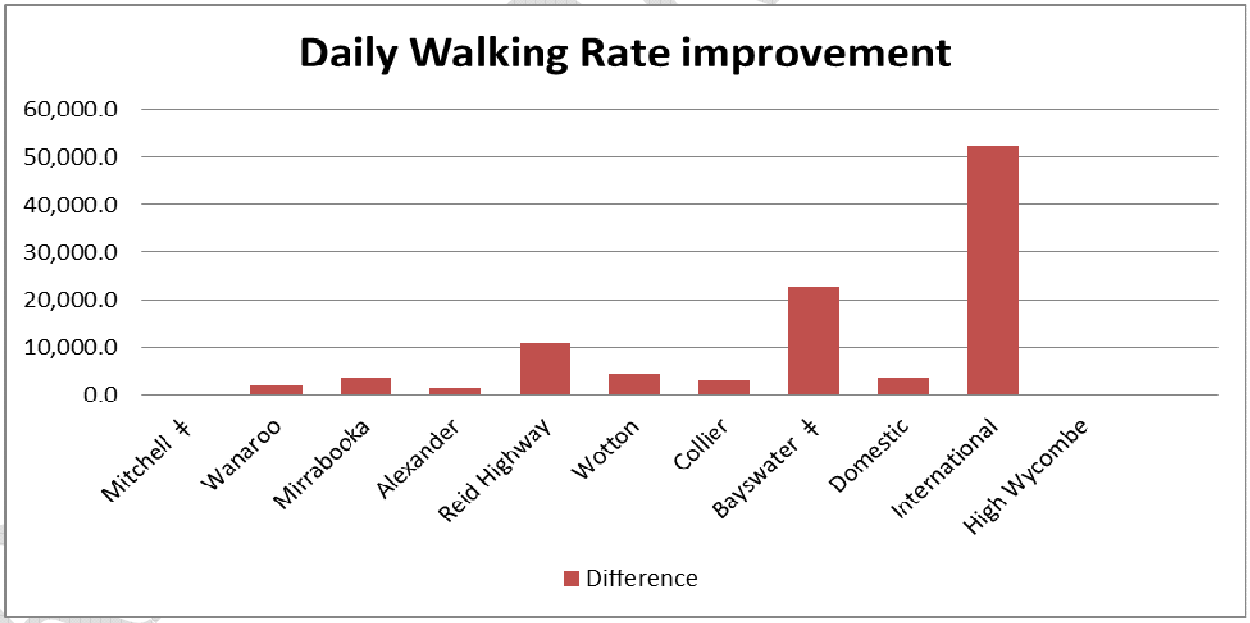


Figure 37 Daily walking rates from living in more walkable communities based along the NCL

The productivity dollar value due to improved health and ability to walk or cycle to work comes in as a fairly modest rate across this line, but this is due to the lower rate of residences along this line. However, the total for the NCL still delivers 68 million in benefits due to increased productivity alone.

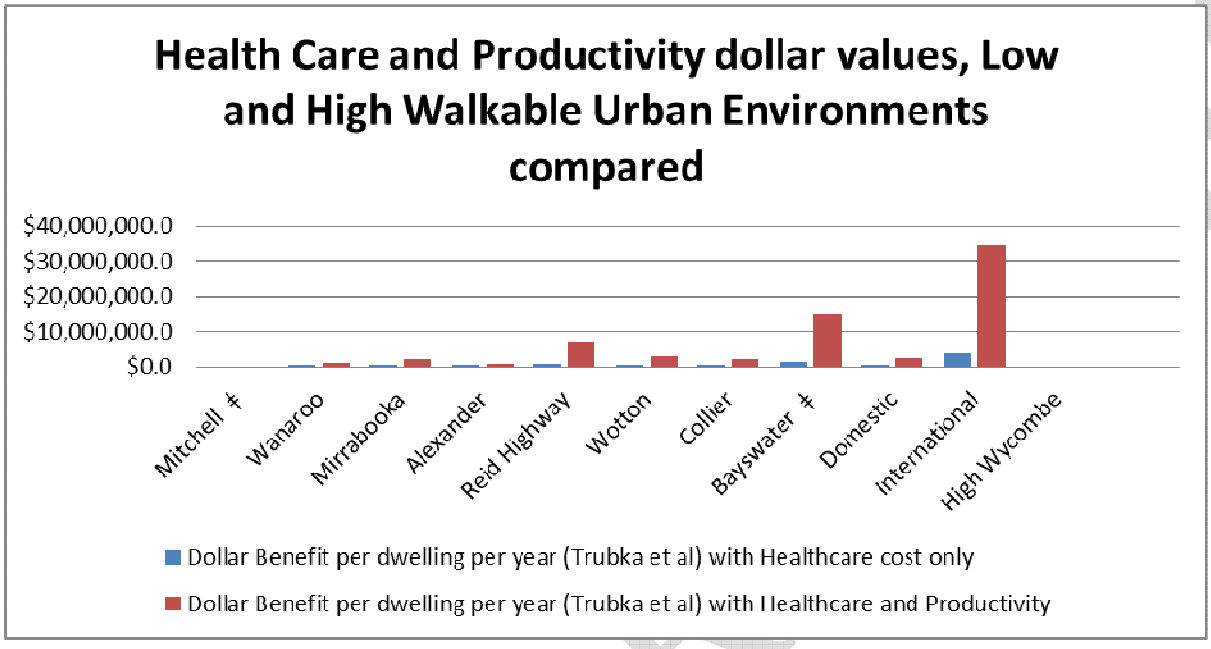


Figure 38 Dollar benefits to healthcare and to productivity from living in a healthy walkable community

7.2.12. Costs Ratio:

The ratio of costs avoided to capital costs of this NCL project is, in dollars: $1.1:$0.8. This ratio may indeed be conservative on the capital cost side as the cost to construct does not reflect the tunnelling and bridging need to move the train over Guildford Road, the Swan River, and under the airport which will push the cost ratio higher. However, as the ratio for construction is for the Average cost in $M per km (2010 dollars) (Martin 2011 p.11) across Australian cities it does not figure in the inexpensive nature of building in Perth's sandy soils. For example, the Perth to Mandurah Line was $17 million per kilometre, with the average per/km cost being raised due to "the last few kilometres of the line into Perth represent(ing) complex engineering challenges" of bridging and tunnelling (Martin 2011 p.14). While in Perth the most recent construction figures may be in the range of $17 million per kilometre, the national average is in the high $30 million dollar mark per kilometre and so to err on the side of caution, the national average was used despite this being nearly twice the Perth average.

7.3. Outcomes of all proposed transit improvements

This section will make a very large assumption. It will assume that Perth will accomplish not only the ring rail's SCL and NCL but also a portion of other Light Rail Transit lines running through the inner and middle suburbs. These will link not only a great proportion of the existing population to higher-order public transit, but also the 47% of 1.8 million, or 848,000 persons (Western Australia Department of Planning 2011), who will arrive or be born in the Perth region over the next fifty years. They will be the ones living in infill developments within this large transit served region. Please see 5.2 above for a list of all the types of redevelopment places.

To view a plan map of all the redevelopment areas, in red, along the current and proposed rail lines, please see the map on the following page.

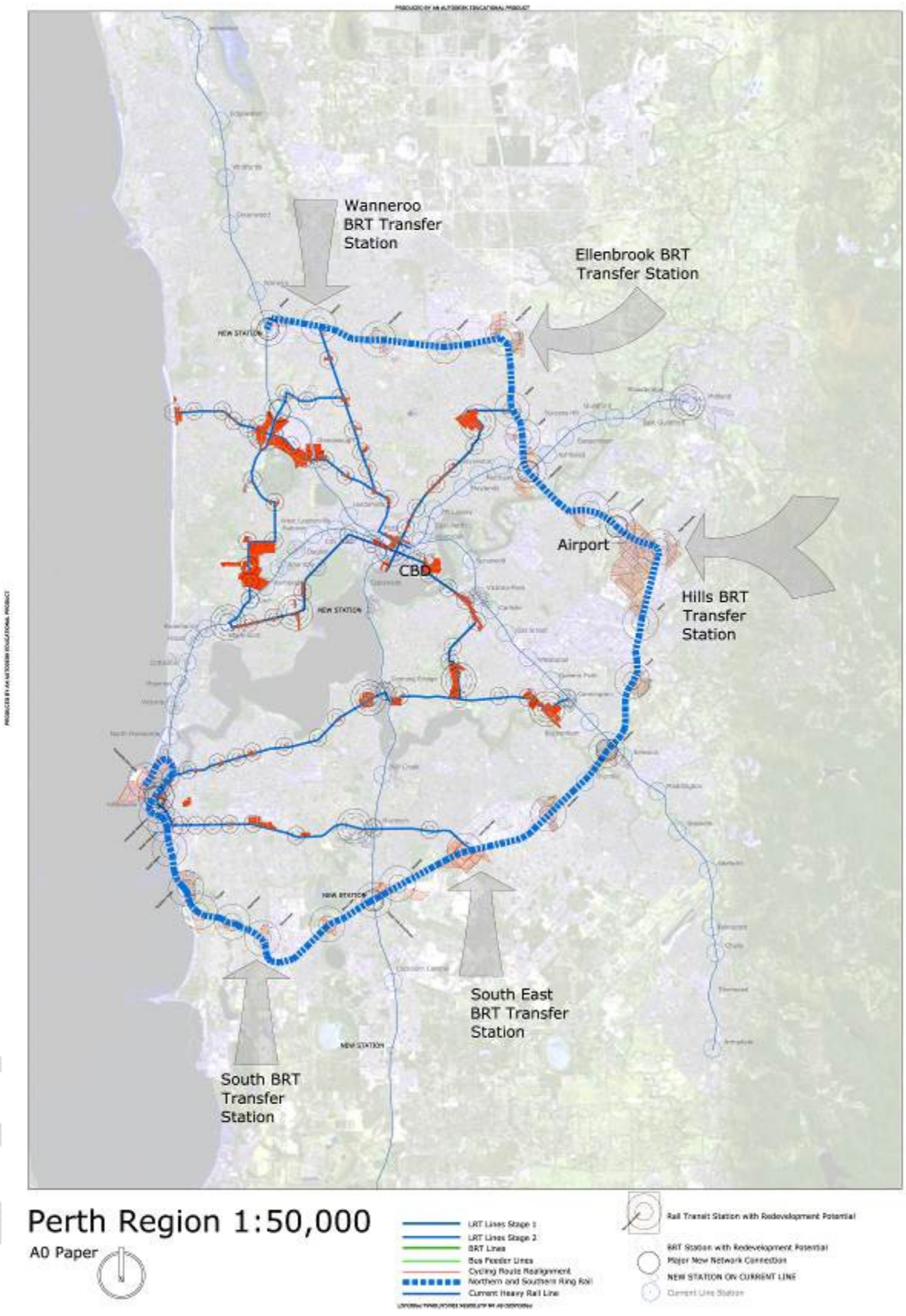


Figure 39 LRT network (solid blue) with SCL, NCL (dashed blue) with existing lines in light blue. Development pods are in red.

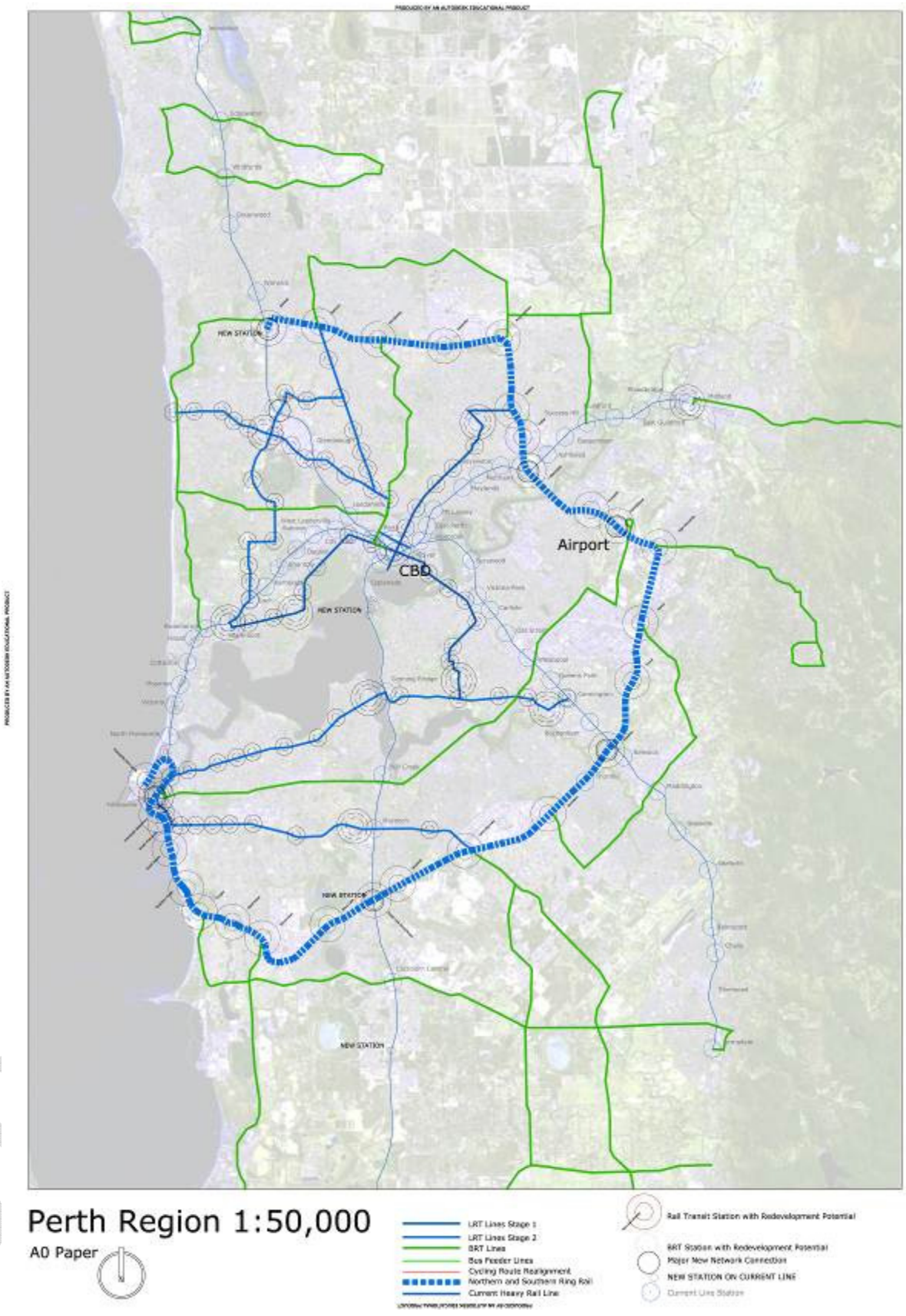


Figure 40 BRT lines in green and Heavy rail line in dashed blue

7.3.1. Transport and land use Characteristics

The envisioned transport and land use surrounding the new train stations of this network will have significant changes in densities of residents, jobs in commercial spaces and street-fronting retail. This will house at least the targeted population growth for residential infill development while also offering space for work, shopping and play. The significant benefit to extending the reach of the rail system will be to make car less of an optimal transport mode which has multiple flow on effects including reduction in GHG, VKT, and health outcomes, while creating the walkable compact and complete communities.

7.3.2.Total area by modes of transit and separate lines

The total net area, in the red columns, represent the land available after subtracting a portion of land for Public Open Space, POS, at a rate of 10% and Infrastructure for underground services, internal roads, building set-backs as so forth. The gross area is represented by the blue columns. Two notable things present themselves in these two joined charts: one; the larger volumes of land on the NCL, SCL and on the Current heavy rail lines as these lines pass through areas of grey and brownfield land ready for redevelopment while the LRT lines must be more discerning about the lands to be redeveloped inside the exiting urban fabric and two; there large increase in land available along the BRT lines which is due to the envisaged large areas of land amalgamation possible in the outer fringe, greenfield and agricultural rural areas. Combined, the rail lines can provide 3064 hectares of land and the BRT lines 11,770 hectare of land for developing walkable transit served communities.

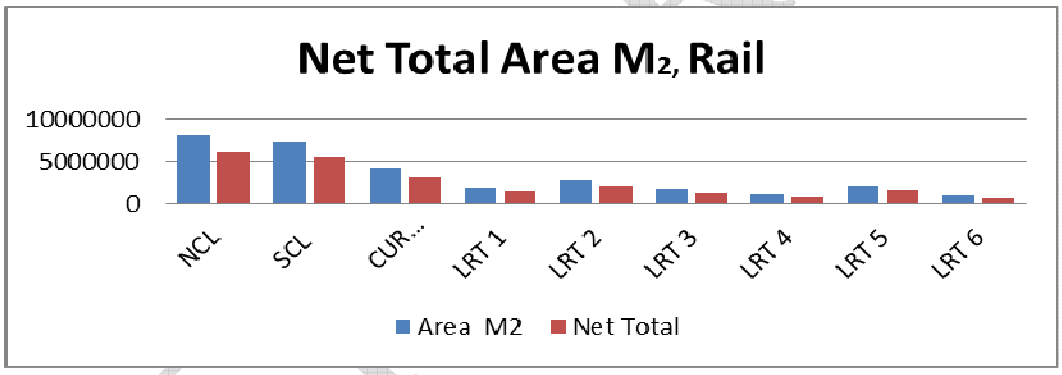
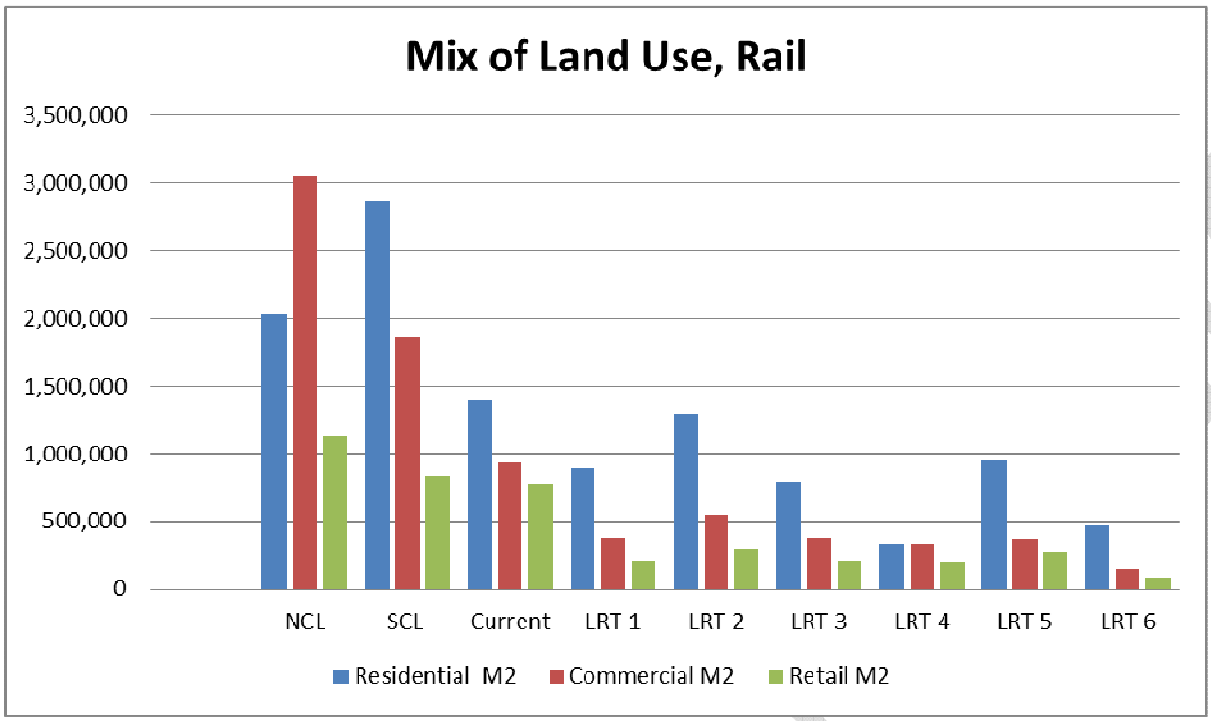


Figure 41 Developable land across the Perth region near future transport lines

7.3.3. Mix of land use

The coloured bars reflect the discussion above regarding how the NCL will be more commercially focused and the SCL will be, as well the rest of the Light Rail Lines, more residential in character. The commercial aspect of the NCL will be most noticeable on the ground, first and second floors of buildings at most stations.



7.3.4.Land use on the yields by mode and separate lines

The land use yields, once factored against the maximum allowable heights (see table four in the SCL section above), reveal totals of floor area from the various stories assigned to each use, lot by lot, station by station, line by line. It becomes apparent that the NCL and SCL outstrip the LRT lines in terms of net floor area for the same reason as outlined above.

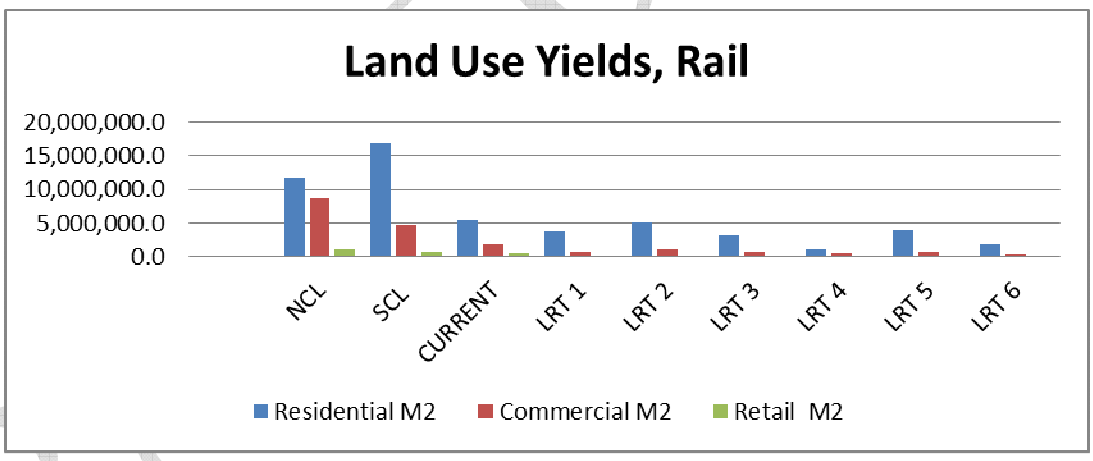


Figure 42 Floor plate areas of vertical and horizontal mixed use scenarios

7.3.5.Person activity by modes and lines

The NCL is envisaged to be much more a worker-oriented line and this shows in the person activity chart. The red bar denotes numbers of commercial employees while the blue bar denotes residents. That the residents will also be workers does not confound the chart as what is actually being shown is the M^2 available for each. Therefore, as a person needs a space to live in and a space to work, this

chart reflects the balance of each along each proposed transit line. The SCL, for example, demonstrates a preferred balance in which approximately one thirds of the population may possibly find commercial office space or light industrial work along the same line while it is predicted the other third might be children or seniors. The other lines are similarly balanced while the Current, or exiting heavy rail lines, being almost evenly split between new residences and new office spaces as the resident population may prefer to find work in one of the new offices in their neighbourhood. These numbers reflect thirty years of housing and just over fifty years of employment in commercial, light industrial, tertiary educational and retail work site supply.

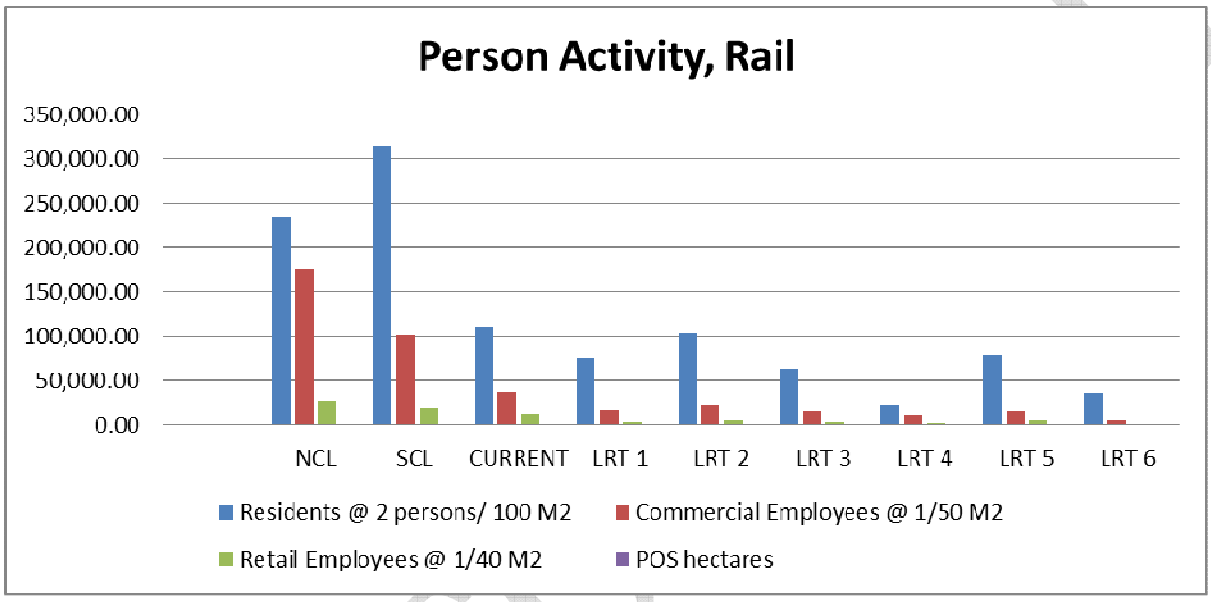
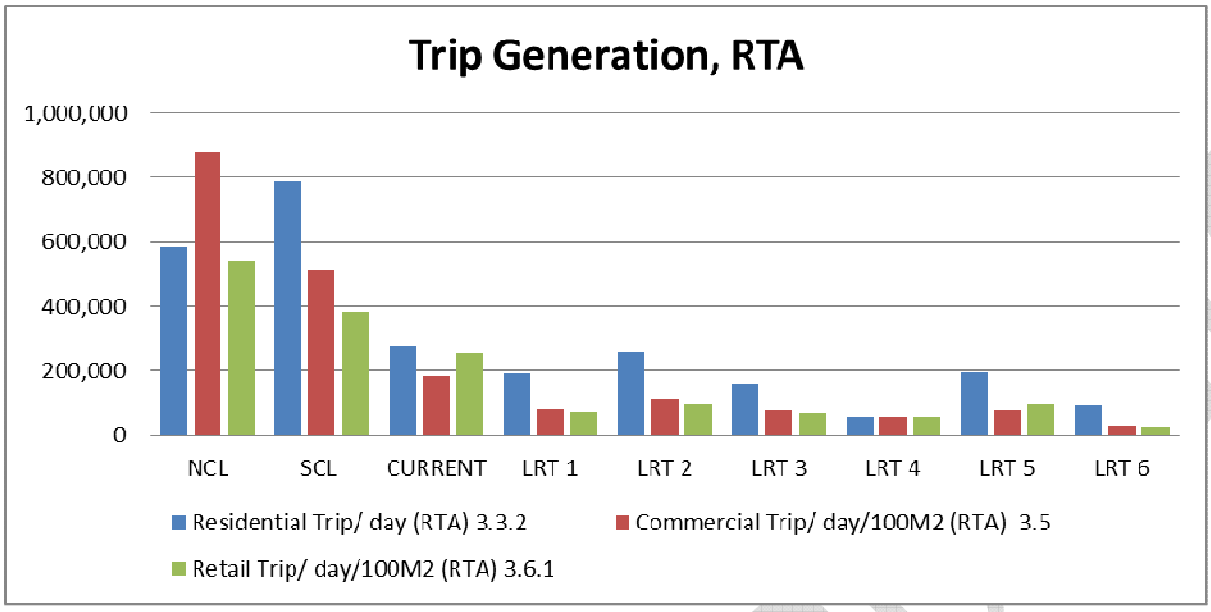


Figure 43 Numbers of persons activity

7.3.6.Trip generation and parking requirements

Using the RTA of NSW (RTA 2002) ratios for trip generation we can see clearly that there may be a great deal of trips being made in the region. If only 15 percent of these were made on public transit this would equate to over 94,000 trips on rail or bus per hour.

The parking ratios ought to be alarming. If we followed the RTA's recommendations the urban fabric along these rail lines would actually have to be in the order of 34 % of all space would have to be devoted to parking the car. In straight numbers the area required would be 25,717,876M^2 which is much more than the original amount set aside, 4,596,622M^2 for Right of Ways from the gross land area. At 34% this will lead to unabated induced driving with consequences regarding transit use, walking rates and the ability to effectively and affordably redevelop many of these areas as envisaged.



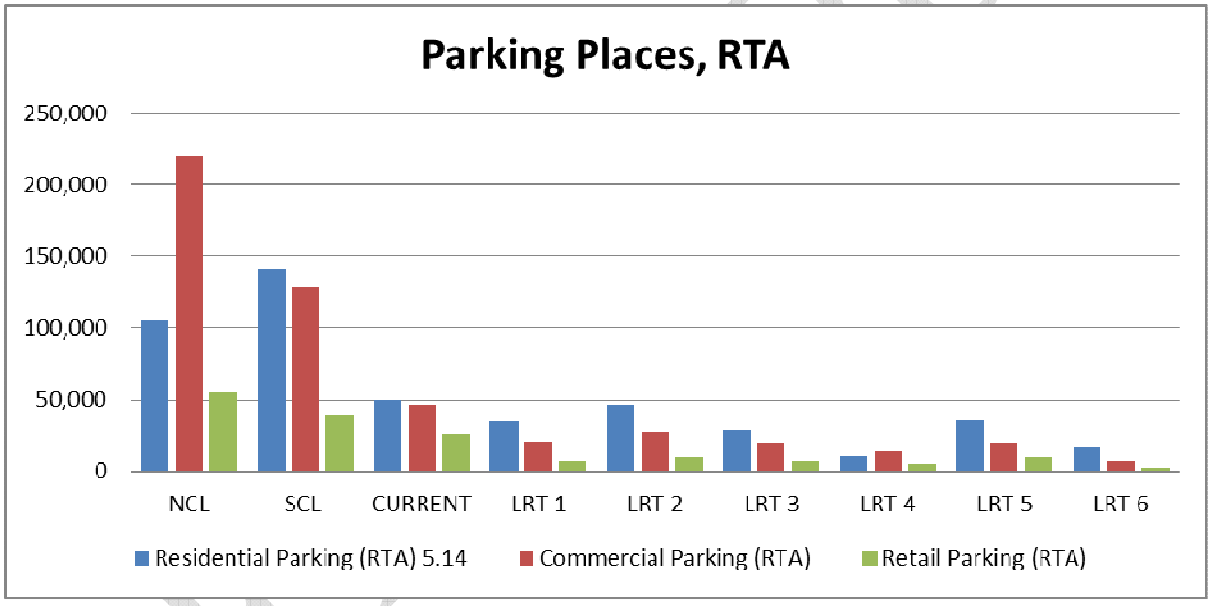


Figure 44 Trip generation and parking numbers

7.3.7.Years of housing supply

The entire proposes rail network of the NCL, SCl and the 6 lines of Light Rail will open up land for infill redevelopment on greyfield, brownfield, urban decayed and other (see table 2) which, in addition to the latent land available along the current heavy rail lines will be able to support 31 years of housing supply. All of this growth be to a maximum 10 storey height, but only in precinct which can accommodate that height (see table 4). The average Floor Area Ratio (see methodology below) for rail based transit-oriented precincts is 2.3.

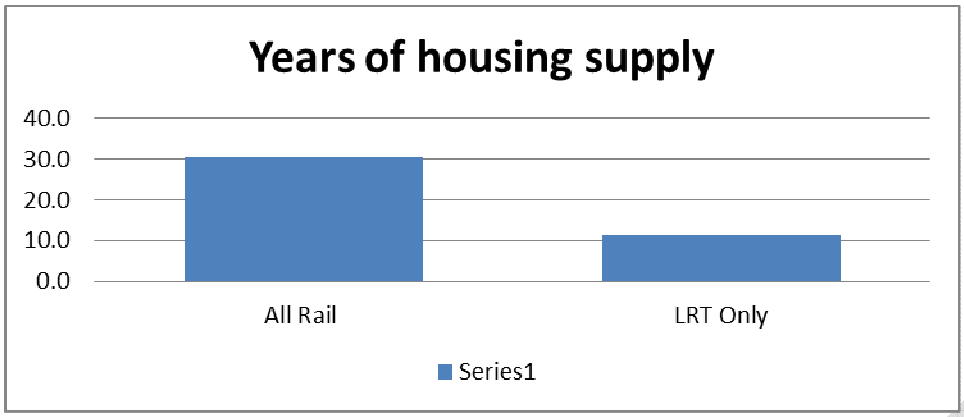


Figure 45 Years of Housing Supply on all rail and BRT land redevelopment

The policy regarding new residential developments in Directions 2031 states 47% of new growth should be directed towards infill. By running through the scenarios it is calculated that over 100 % of this infill target is achievable in rail based transit oriented developments[10].

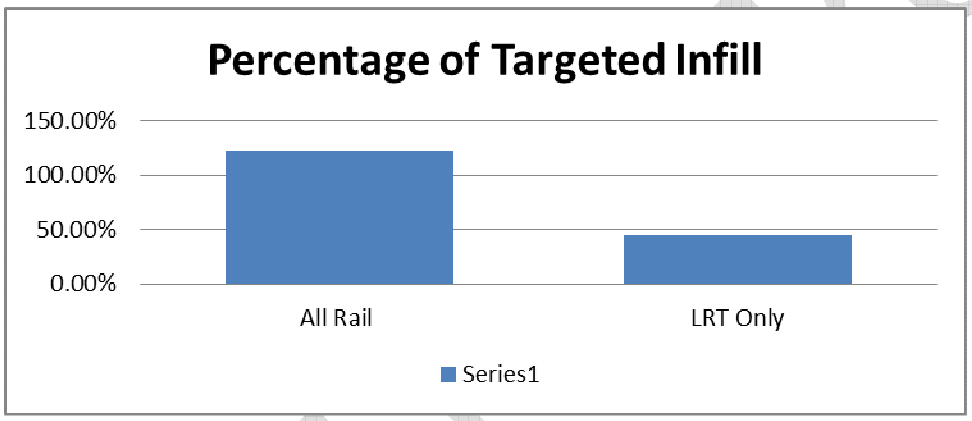


Figure 46 Percentage of targeted infill (Directions 2031) achieved

[10] However, it must be cautioned that this does include large tracts of land (including the Fremantle Port, waterfront areas, the International Airport and parts of the Western Suburbs) which may not be evident in today's urban fabric as opportunities but rather very fixed in their current use. Perth, Fremantle and every city that has ever been have flourished by an every changing evolution of lands from one use to the next.

7.3.8.Greenfield area saved, Sprawl Reduced

The total hectares of all floor area of built form, with POS and Infrastructure already left to the side in each station precinct is equal to 7,591 hectare along rail based transit lines and 8,505 hectares from the fringe area BRT villages. The rail-based sprawl reduction numbers are equal to approximately 2.8 John Forrest National Parks (at 2,678 hectares), or almost 4 Rottnest Islands (at 1,900 hectares).

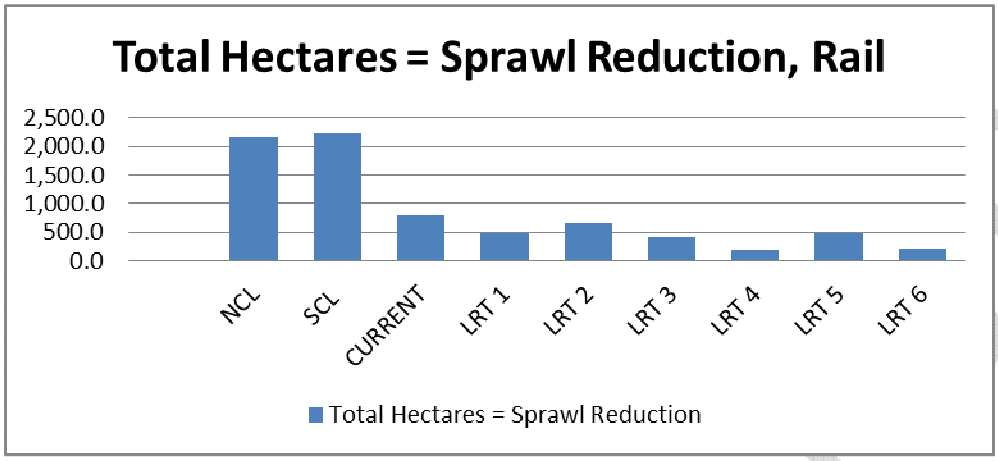


Figure 47 Sprawl Reduction from a region of Transit served communities

7.3.9.Infrastructure costs and costs avoided

The total infrastructure costs savings accrued from tying into and upgrading existing infrastructure as opposed to building new sewers, water, electricity and roads to dispersed car-based fringe developments could be in the order of almost 50 million dollars over the lifespan of redevelopment along these transit lines. This is not, alone, a significant amount in today's capital budgets. However, as most of these cost are eventually passed onto new homeowners, this figure of $50 million can be accurately placed as a benefit towards making home more affordable and broadening the quantity of homeownership or as money to be reinjected into the local economy by residents.

The total cost avoided could range into the order of $9 billion dollars. This will be $9 billion in costs avoided from transport, health, greenhouse gas and infrastructure including schools, hospitals, fire stations and police services (Trubka, Newman et al. 2010) which won't need to be constructed at the rate that Business as Usual, outer-fringe focused, car-based residential developments require at current costs.

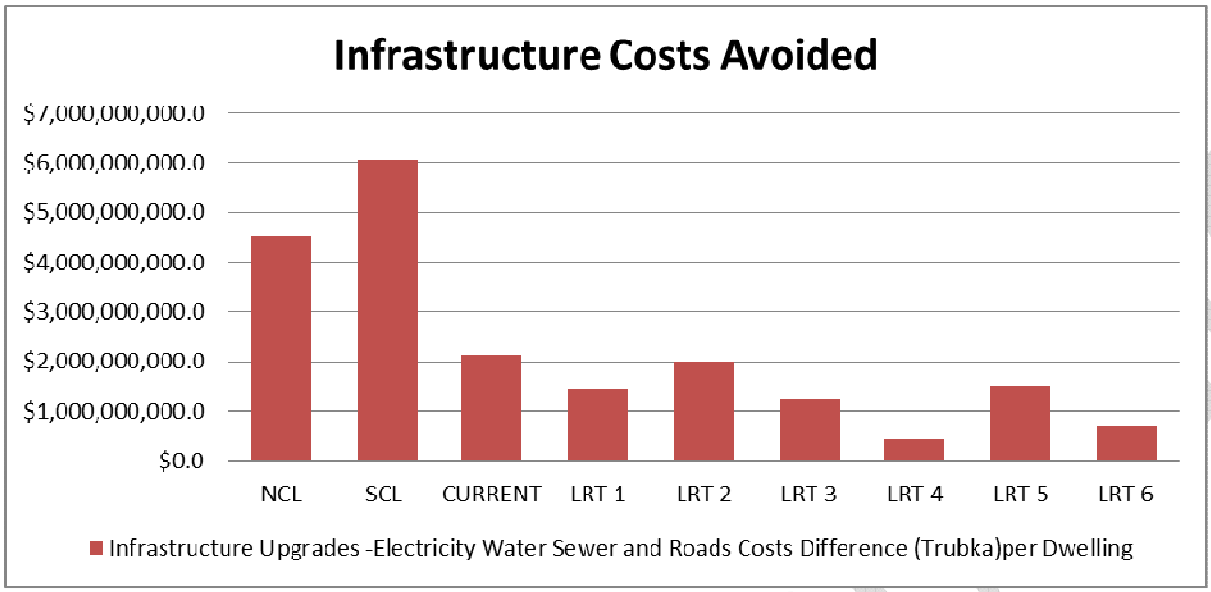


Figure 48 Dollar value of infrastructure costs avoided over 50 years

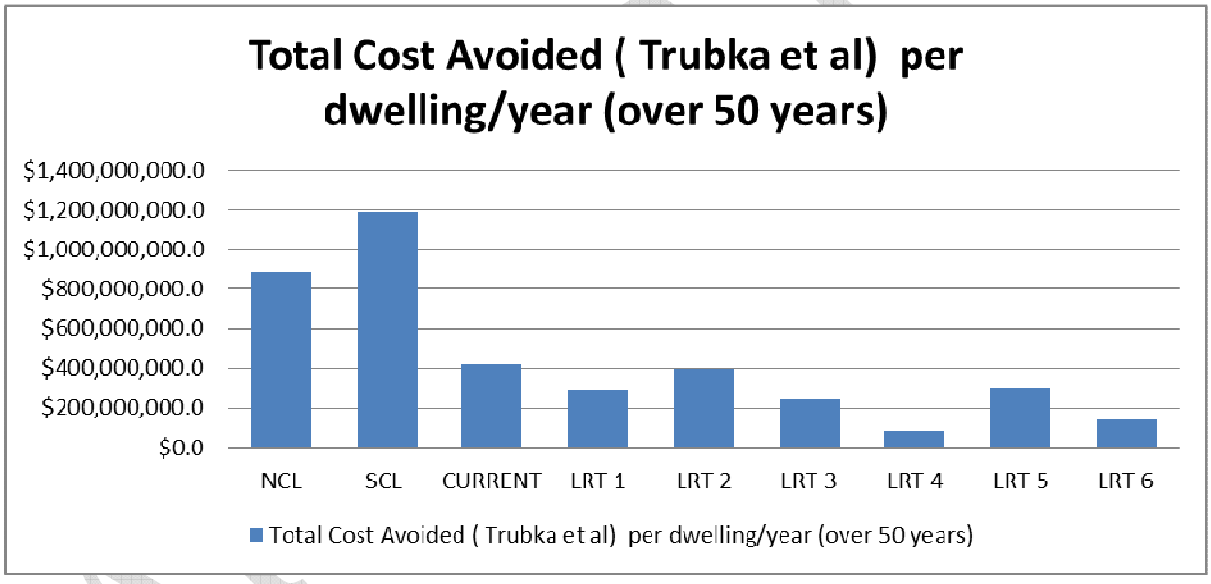


Figure 49 Total costs avoided per year

7.3.10. Transport Costs

To break down the total costs into the transport costs alone the first chart looks at Vehicle Kilometre Travel per person aggregated across all precincts along a transit line. From the rail-accessed transit lines redevelopments we can expect in the order of 10 million fewer kilometres driven per day by the 531,000 residents, or 18.8 kilometres less per day per person. This number is entirely reasonable if these residents have high quality and multi-destination transit within walking distance and live in a compact, complete, mixed use community where driving is rarely necessary.

The second chart shows the total costs saved by rail transit line. In total the value of costs saved from living close to rail transit oriented developments is in the order of $2.6 billion over 50 years.

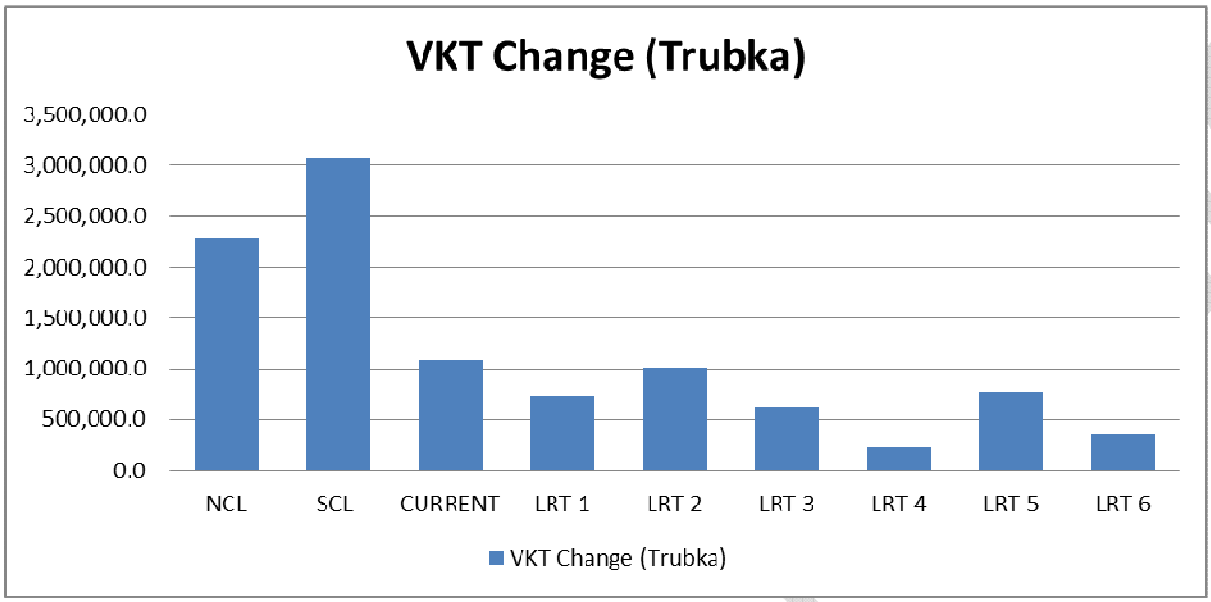


Figure 50 Vehicle Kilometre Travel change

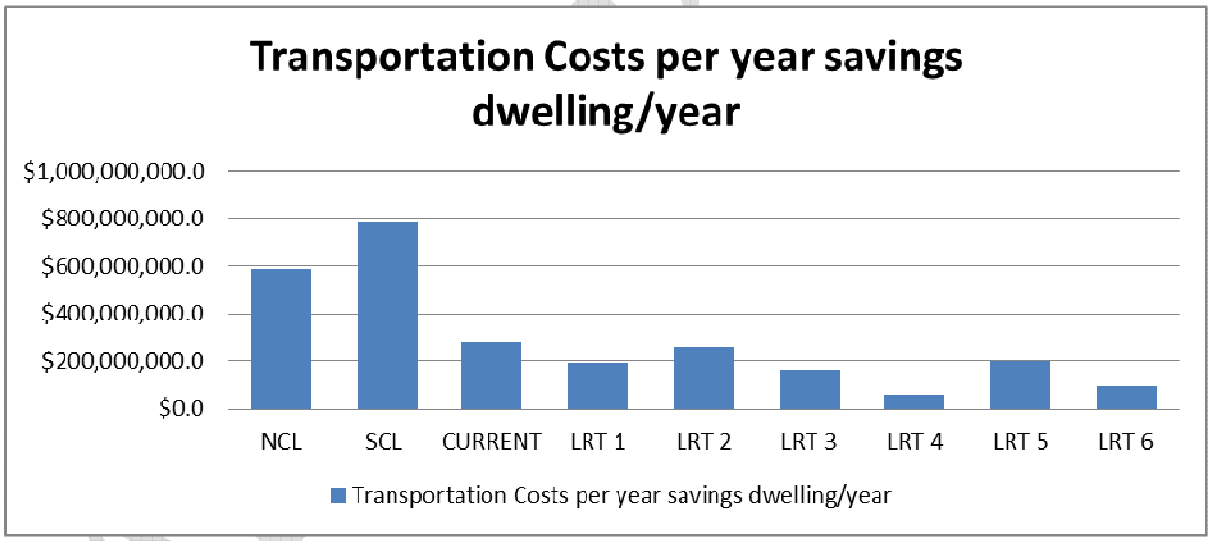


Figure 51 Transportation Costs across Perth Region

Green House Gas Emissions

If even a minority of persons are using public transit in the new transit oriented neighbourhoods and villages it can be estimated that 1.14 million tonnes of GHG could be reduced. At a rate of $23 dollars per tonne from the Australian Clean Energy Future this equates to almost $22.62million to be used to:

- *assist households with price impacts they face by cutting taxes and increasing payments*

- *support jobs and competitiveness*
- *build our new clean energy future.(Australian Government 2012a)*

How this may work out to underwrite the costs as a benefit in the accounting between the State of Western Australia and the Federal Government of Australia is yet to be understood, however in making application for federal funding this dollar value could be used to leverage extra consideration towards rail and bus transport projects.

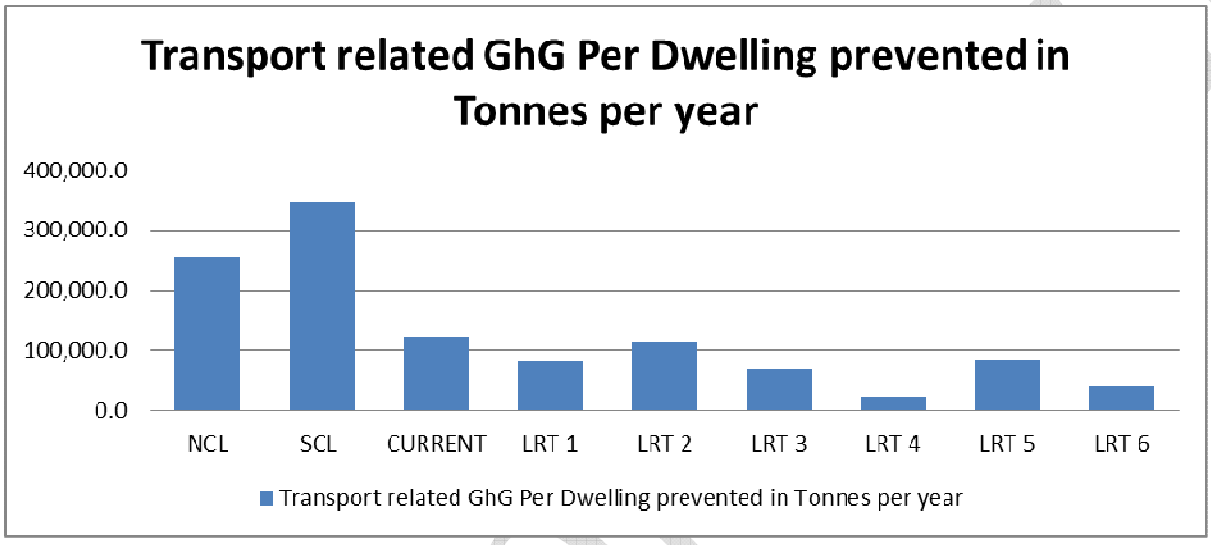


Figure 52 Greenhouse Gas reduction across Perth from TOD development

7.3.11. Physical Activity Costs

It can be estimated that the walking rates will increase to above BAU, but perhaps not reach historic pre-automobile levels of physical activity, by the act of living in closer proximity to daily needs within the walkable neighbourhoods and by walking to and from the transit stations at either end of a work, school or shopping trip. The total accounting potential for all the proposed transit lines across the Perth region is in the order of 609,000 more kilometres walked per day by the newly housed residents living in the Perth region's TODs in all these scenarios combined. This is equal to walking only an extra 0.6 kilometres per person per day which is entirely reasonable. The calculated direct benefit of this additional walking to the healthcare system over 50 years is approximately $44 million as it delays the onset of obesity, diabetes and other health illnesses related to inactivity.

The total benefit to the economy of having a much more active and healthy and therefore productive workforce from the entire new population of living in walkable urban environments is in the order of $402 million dollars over 50 years.

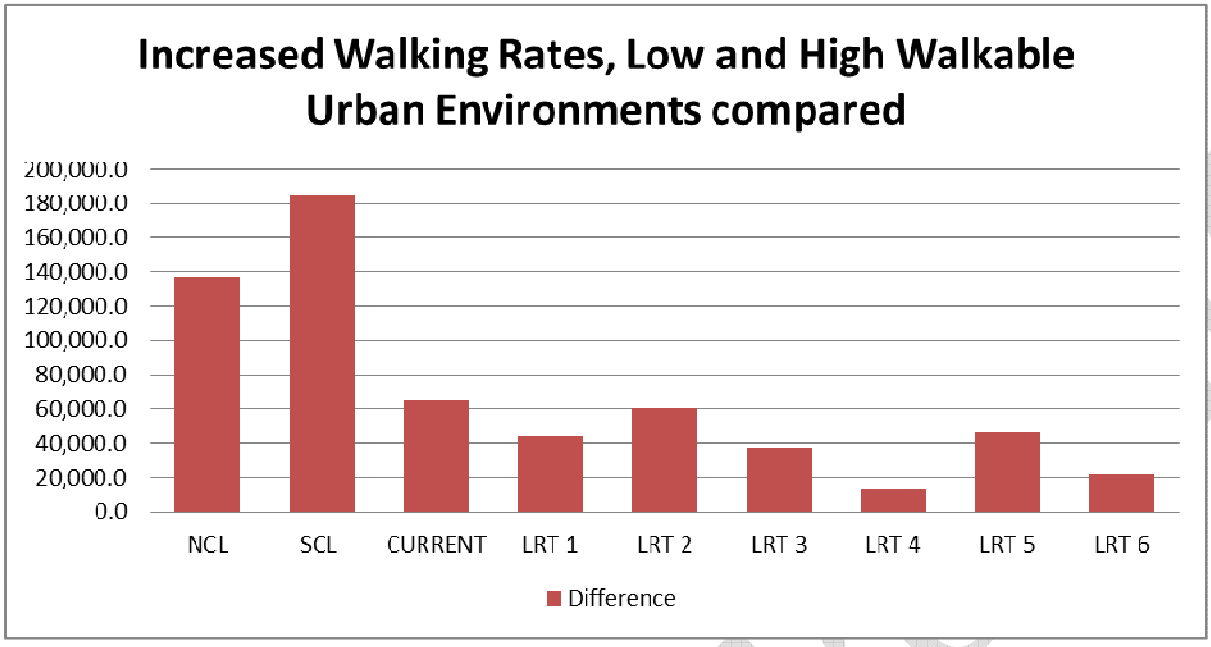


Figure 53 Daily Walking Rates in km per day

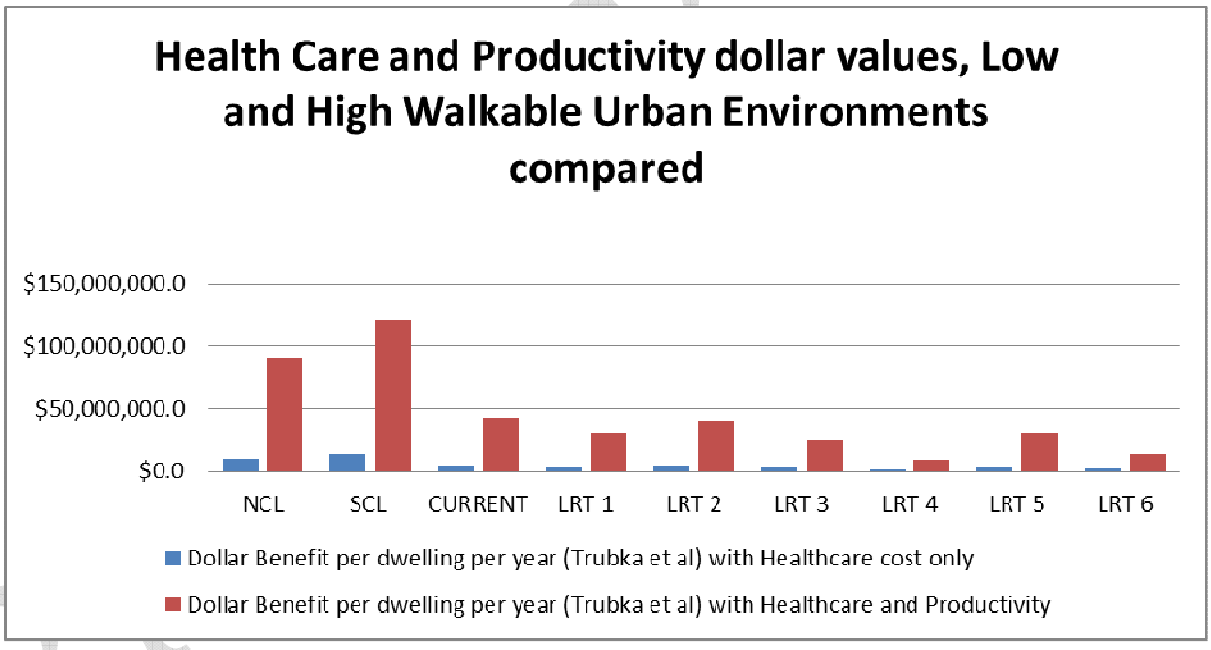


Figure 54 Healthcare and Productivity dollars

7.3.12. Cost Ratios for all modes and scenarios considered

In sum, the cost of building all these transit lines will be a significant dollar amount. However, as a total of over $7.5 billion in Cost Avoided contrasted with $4.4 billion to construct this same kilometres of rail transit once (Martin 2011 p.11) this does begin to makes the overall case for rail transit. However, it does not consider ongoing maintenance and operations of the transit network

which is a cost that is ongoing alongside the continued benefits of being a global city. The expected up-zoning along the transit lines into Transit Oriented Developments begin to make a very sound, long range and visionary investment for Governments to entertain.

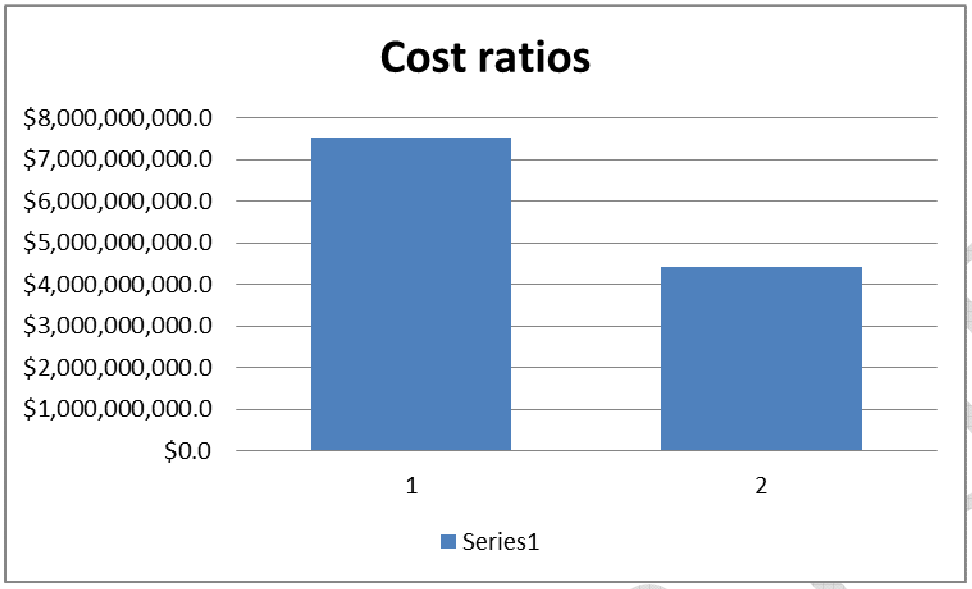


Figure 55 Costs avoided and Value Captured (column 1) to capital costs to construct (column 2)

These numbers reflect the best available data on costs avoided and value captured compared with a capital costs to construct in Australia.

8. Conclusion

As Robert Cervero is quoted above "only through a full accounting and weighing of social costs and benefits" (Cervero 2003) will we be able to say that the costs to construct the new network of proposed light rail and heavy rail multidirectional network may or may not be worth the investment. If Scott Martin's public transport infrastructure costs from 2011 are any indication, if the work by Trubka et al. are to carried forward into real time mixed-use developments adjacent to high order transit, if the likelihood that the urban form and fabric of Perth will change with market demand and active upzoning somewhat akin to the proposed scenario of this paper, then there is a strong case to be made for the rail and bus investments. These investments in the transport network will be for the next generation of residents with spaces to live, work, shop and play with a car reduced lifestyle. This paper demonstrates the benefits accrued for a region by following a comprehensive land-use and transport integration policy.

Perth can achieve at least the minimum of infill housing as the policy in Directions 2031 indicates. Perth can become a polycentric, multimodal, multi-family, shared infrastructure city of note which lives within its ecological bounds in the emerging Knowledge and Green Economic era.

This Plan enables Perth to choose to augment its rail transport network and thus achieve a major step forward in achieving regional and national 21st Century goals while remaining a competitive and liveable city.

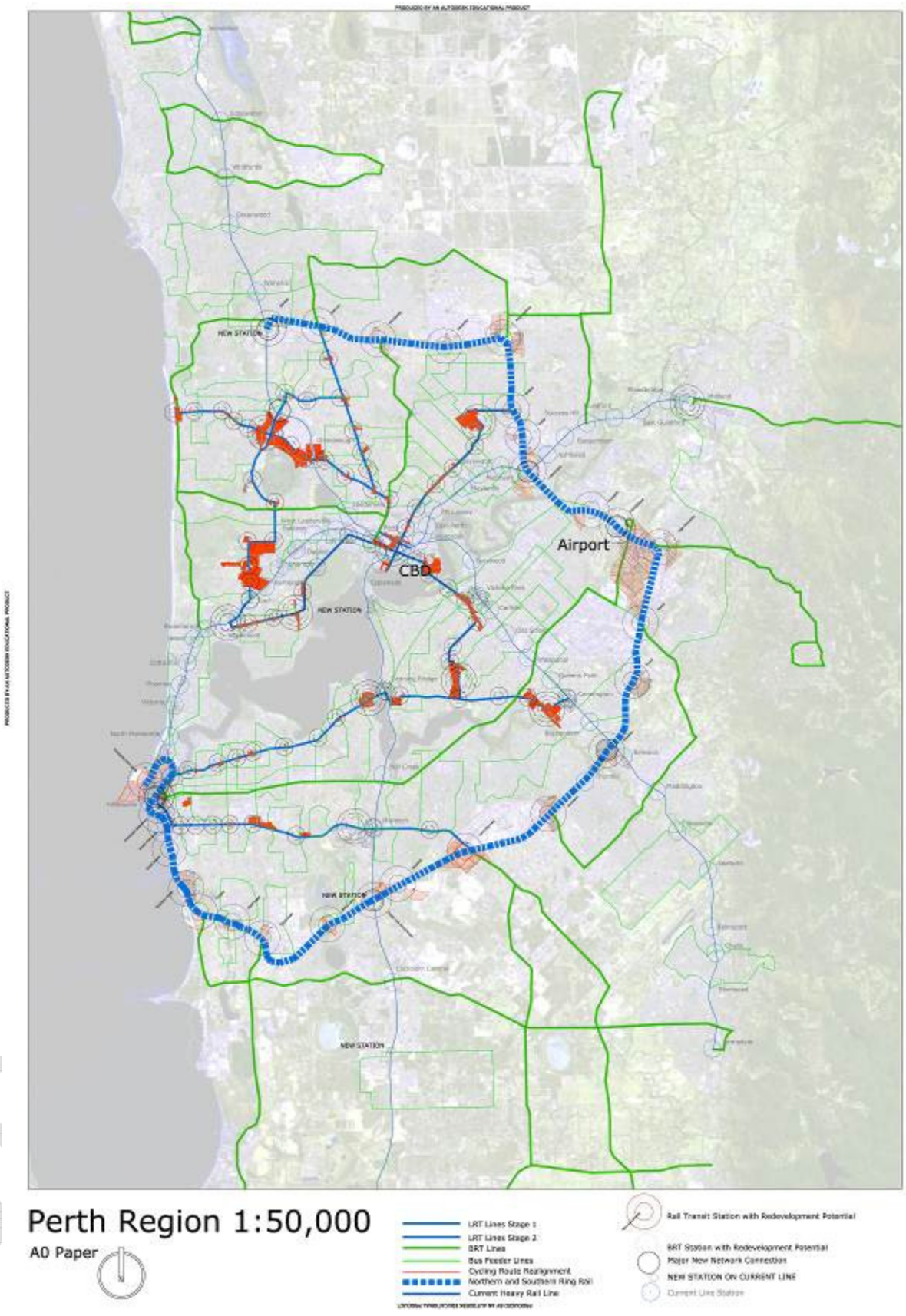


Figure 56 SCL, NCL, LRT, BRT Lines (dark green) and regular Bus (thin middle green) lines working optimally as a network feeding each other.

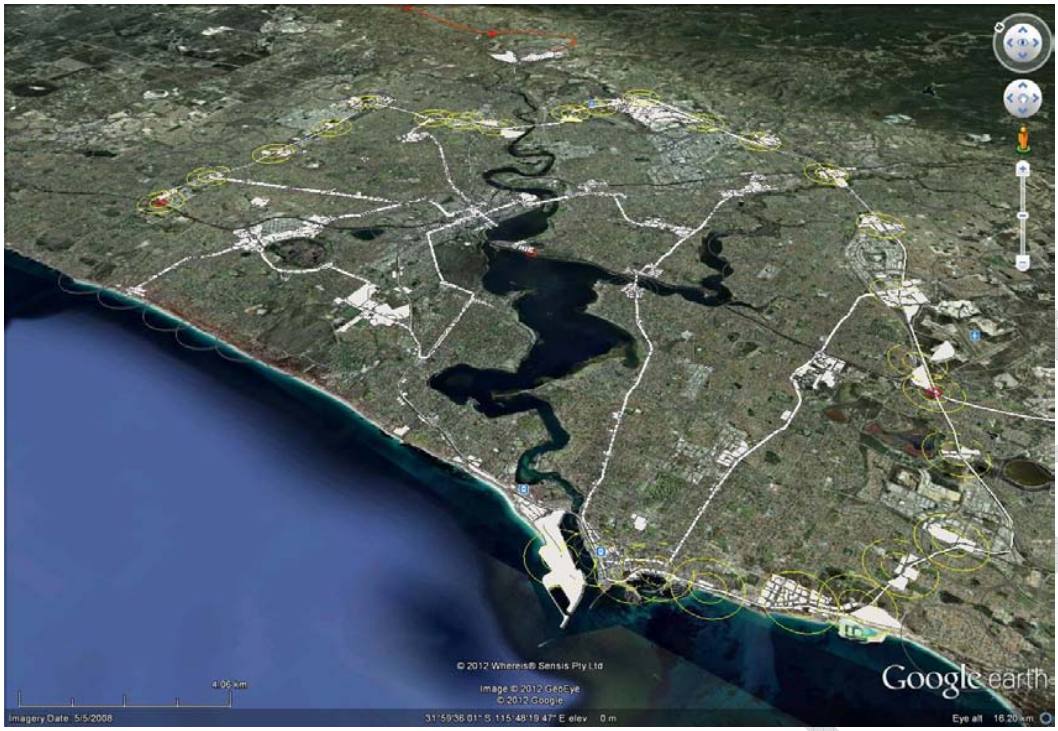


Figure 57 Perth from above

Redevelopment pods in white and rail lines in white

Figure 58 Fremantle from above

Redevelopment pods in white. The SCL runs along the marinas to the lower right on its way to Jandakot and High Wycombe.

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10. Appendix 1: Cost of Car per year

Car Cost Calculator

Do you know how much your car is costing you each year? Use the Car Cost Calculator to find out!

Your car costs you around $8115 per year

Insurance	$	1000
Petrol	$	665.6
Servicing	$	702.12
Parts Replacement	$	312
Registration	$	208
CTP	$	250.09
Stamp Duty	$	175
Other Rego Fees	$	50.66
Depreciation	$	2500
Parking	$	1040
Interest Expense	$	1263.44

Interesting Fact - If you used a taxi instead of your car it would cost you $5927.91 per year

Figure 59 Car Cost calculation based on 100 km per week with a new 25,000$ Asian car

From:(OzInsure 2012)

The $ 8,1154/year result is based on a 100km/week driving and 20$/week parking for a 25,000$ new 'Asian' car. Notice, the website form OzInsure.com.au also states the cost to use a taxi would be $ 5,927 but does not give a number for transit use, but would be certainly much less (OzInsure 2012). Public Transport for Perth 2031 (2012 p.31) indicates a 10 dollar per day as transit cost. At 250 working days per year this equates $2,500 per year for using public transit, or well less than half the cost of taxi fares.

11. Appendix 2: Stephenson & Hepburn's Rail Vision

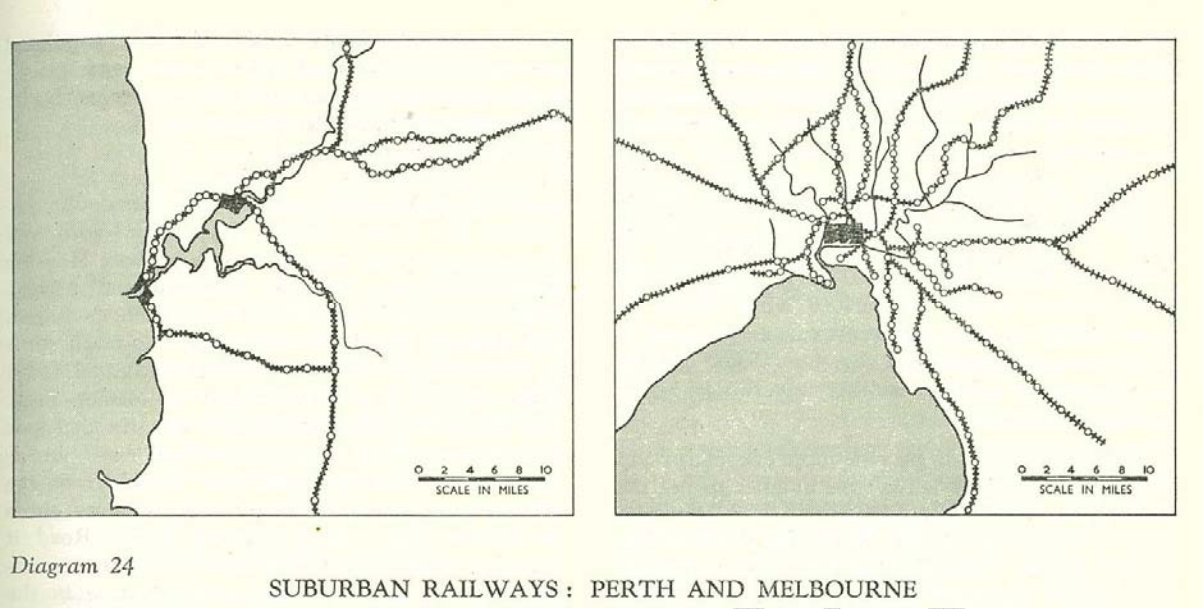

Figure 60 Stephenson & Hepburn's concept for Southern Rail

"It may be suggested that short distance suburban rail travel is not an economic proposition. On the other hand we have the example of Melbourne and other Australian cities where very large numbers are moved by train at peak hours. As the regional population and, consequently, road transport in its various forms increases, movement on the roads will become slower in the inner areas. With speedier rail services, using modern rolling-stock, the railways will attract more passengers, relieve the roads of some part of the increasing volume of traffic, and reduce the need for extensive, expensive and disturbing road improvement works. The road proposals in the Plan are based on the assumption that a remodelling and extended railway system will carry a large proportion of suburban passengers." (Stephenson and Hepburn 1955 p.130)

"If this form of mass movement were expected to materialise, the central city parking problem would be beyond solution and the congestion on the inner roads would be appalling. This forecast of what could happen in half a century must, therefore, lead to consideration of the contribution the railways must make to meet the transport situation, and to the proposals in the Plan which are designed to improve the movement of city workers during peak periods as the Region continues to expand. There are already promising signs that the railways will carry more passengers in the immediate future, through the use of new rolling stock, the creation of new stations, and the speeding up of the services. At the present time public road transport may be nearing its maximum in terms of proportion of passengers carried in relation to the railways."(Stephenson and Hepburn 1955 p.131)

Unfortunately, this was about all they had to say on the topic of railways for Perth and Fremantle in the wide ranging report of 1955.

12. Appendix 3: Space per person in residential, commercial and retail

Housing: ABS housing sizes indicate an upward trend towards the 250M^2 sized house in Australia. Such houses often have three to five bedrooms though they may house only 2 person.

> *"Over time the typical house in Australia has evolved from having three bedrooms, one bathroom and separate living areas into a more open plan, including a fourth bedroom and ensuite facilities. Popular extras, such as rumpus rooms, walk-in wardrobes, walk-in kitchen pantries and the like, may add to the overall size of modern homes. This has resulted in an increase in the size of new residential buildings." (ABS 2012c)*

Therefor if we were to remove the rumpus room from the total leaving four bedroom 200 M^2 homes, divided by the four bedrooms and we are left with 50 M^2 per person. This will include a bedroom, part of the kitchen, bathrooms and the like, but not parking space as parking will be discussed in a section above.

Much of the housing stock in the post-World War Two era was a modest 100 M^2 and such houses did suit the 4-5 person families of that era. In the relatively recent past Australians lived well with far less space per person in their residential units.

Commercial space per employee was assumed to be as written for the City of Sydney (Hillier 2001 p.33) at a ratio of 20.76M^2, however, due to not all jobs being alike and many of these listed will include tertiary educational spaces, the number used was 50M^2.

Retail space per employee was assumed to be as written for the City of Sydney (Hillier 2001 p.33) at a ratio of 22.78M^2 for shop/showroom or 23.93M^2 for a restaurant, however, to be sure that all spaces such as grocers and other large format shops were reflected a number of 40M^2 was used.