Curtin University Sustainability Policy Institute

Department of Humanities

Towards the Transit-Oriented Region:

Polycentric Urbanism to Transform Automobile Dependent Cities

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature:

Date: March 24, 2015

ABSTRACT

This research asks the question: Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions? After a reading of the literature and existing strategies, the research approaches this question by a detailed study of public transportation options and associated Transit Oriented Developments in Perth, Australia, a highly automobile-dependent metropolitan region. The research aims to uncover the capacity for redevelopment, both possible and necessary, to achieve a long-ranged transformation from an Automobile-Dependent City to a Transit-Oriented Region. It will prepare a replicable methodology based in available data to more clearly see the pay-offs and trade-offs of policy levers of sustainable transport and land-use planning. The results show that depending on the building heights, mixes of land-use, transportation mode capacity and other factors, it is possible to build the next generations' requirements of parks, housing, commercial and retail spaces along high-capacity rail public transit corridors. The results demonstrate that this may be accomplished while managing road congestion, housing the expected growth in population, improving social equity and ecological function, and positively underwriting the fiscal position of governments. The results reveal a methodology to understand metropolitan growth as a science, to better inform the art of human-scaled urban design.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF NOTES

LIST OF ABBREVIATIONS

VKT	VEHICLE KILOMETERS TRAVELLED
GHG	GREENHOUSE GAS
CO_2	CARBON DIOXIDE
POS	PUBLIC OPEN SPACE
TOD	TRANSIT ORIENTED DEVELOPMENT
TOR	TRANSIT ORIENTED REGION
OECD	ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT
LUTI	LAND USE AND TRANSPORT INTEGRATION
GLUTI	GREEN LAND USE AND TRANSPORT INTEGRATION
BRT	BUS RAPID TRANSIT
LRT	LIGHT RAIL TRANSIT
SOV	SINGLE OCCUPANT VEHICLE

DEFINITIONS / GLOSSARY

Automobile Dependence	Cities and regions in which the ability to live, to travel to work, to access most of life's necessities is predicated on use of a private automobile. Prime examples of this are homes set at a long travel distance from schools, shops and place of work beyond what may be conveniently walked, necessitating an automobile. Examples exist in large swaths of suburban North American and Australian cities since the late 1940s as the availability of automobiles was matched by increases in highway capacity.
Multi-modal Transport	Transport scenarios in which many forms of transport are considered as equal in the right-of-way. Examples of this are ROWs with slow automobile speeds; bicycle lanes; safe crosswalks with pedestrian lights, curb-extensions and comfortable footpaths (sidewalks); bus lanes and/or bus stops with a strong image and a priority lane for arriving and departing; safe and clear foot-access to public transport facilities and amenities. This is the opposite of a single-mode (automobile) priority as is planned and constructed in most street and road cross sections.
High Capacity Public Transport	A mode of transport capable of moving a large percentage of hourly traffic generated from an intensively occupied urban area. Typically these may be either Bus Rapid Transport (BRT) or Light Rail Transport (LRT) so long as they operate at short (under 5 minute) headways and have the required seats and standing room for large flows of peak travel. More often High Capacity refers to commuter rail or metro rail which operates in dedicated lanes, has multiple carriages linked, and has less than half-hour headways.
Green Economy	The Green Economy Initiative, as a part of the United Nations Environment Programme, has a working definition as: "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive. " http://www.unep.org/greeneconomy/AboutGEI/WhatisGEI/tabid/29784/Default.aspx The aspects of the Green Economy touched on in this research overlap with many of the concerns for an economy based in low-carbon lifestyles of higher social equity in the most resource (land and dollars) efficient

	manner. This research will calculate the pay-offs and trade-offs of building urban density along public transport corridors as opposed to spreading automobile-dependent housing into farm and forest.
OECD	The Organisation for Economic Cooperation and Development is a group of the most economically powerful, resource-rich, free-market and well-governed countries (i.e. neither Saudi Arabia nor Russia are included, though Slovenia and Estonia are) to 'share experiences and seek solutions to common problems'. The terms 'OECD' and 'non-OECD' countries are used instead of wealthy/poor, North/South, Developed/Developing, First World/Third World as in other literature. This admits that some countries are more fortunate but that the others need not be limited permanently by current account balances, a changeable political system, language, or geography and may accede to the club as well.
Land Use and Transport Integration	Land Use and Transport Integration (LUTI) is an approach to ensuring the appropriate level of land-use development is staged to provide ridership on transport infrastructure (roads, rail and cycleways) and inversely, that the appropriate transport modes serve all land-use changes. Ideally, less capital and operational cost to provide transport options and maximum benefits from the rise in land values will accrue to residents, workers and governments. While TOD (see below) is fundamental to achieving the aims, it is but one strategy. Many other strategies are not necessarily physical land-use design solutions (i.e. master plan) but a Level of Service change to the transport options and or subtle changes to infill development programmes.
Monocentric Cities	Cities with one centre, one focus, which all or most transport networks lead to and away from.
Polycentric Cities	Cities with multiple centres, more than one centre. While not all the centres are equal, they each perform a specific set of tasks, specialising but still providing baseline services and amenities, while providing homes and jobs. Although a more complex transportation network is required to meet the different origin-destinations, there is more economic opportunity and decongestion of traffic movements.

Suburban	Though in Australia 'suburb' equates to borough or neighbourhood without the pejorative connotations, in this work suburban will be the descriptor for the automobile-dependent single family homes set in pods of single-use zones which have very poor public transport access. Largely phenomena of post-World War Two North American and Australian cities, they are now being observed around the world in more extreme examples (Chakrabarti, 2013) of social stratification, and automobile serviced and largely not-walkable localities.
Transit / Public Transport	Transport services which are motorised (i.e. not a bicycle) have a larger capacity than a private automobile's typical five passengers and run on a set route and a set schedule throughout the day and often night.
Transit-Oriented Development	While the term may have originated with the seminal book *The Next American Metropolis* (Calthorpe, 1993) as an outgrowth of earlier work illustrated in *The Pedestrian Pocket* (Kelbaugh, 1989) and followed up with *The New Transit Town* (Dittmar & Ohland, 2004) all of these owe a debt to Howard's Garden City (Howard, 1902) (and many other developers of rail-suburbs) in which the options for cities to leverage investments made in public transportation could be linked with increased residences and workplaces in walkable multi-use environments. Reconnecting America, based in Oakland, California, 'is a national not-for--profit that integrates transportation and community development' and defined TOD as: 'more compact development within easy walking distance of transit stations (typically a half mile) *(800 meters)* that contains a mix of uses such as housing, jobs, shops, restaurants and entertainment.' (Reconnecting America, 2014) *emphasis added*
Transit-Oriented Region	The Transit-Oriented Region is based on the enumerating of expected population increase and finding the space for residences, workplaces, retail shopping and recreation in dignified mixed-use and mixed-income walkable environments across an entire metropolitan region. This avoids the piecemeal approach of TOD, as practised, which relies on large amounts of political will, expensive planning approvals and extensive public discourse for one-off projects which ultimately may not be well coordinated, or sufficient, across the region. It is an extension of the TOD

	concept writ large to tackle greenfield growth and extensive automobile dependence.
Traffic Analysis Zone	Traffic Analysis Zones are the smallest unit of measure for most Traffic Impact Assessments. They feed the traffic generation numbers into Four Step Traffic Models. They are criticised for being arbitrary, too small or too large, discounting pedestrians and longer trips avoided due to local services.
Urban	Urban, as opposed to suburban, refers to those places which are at a density threshold which makes necessary, and supports through patronage, high-capacity public transport. Typically this is found between 35 and 75 persons per hectare (Newman & Kenworthy, 1999; Newman & Kenworthy, 2006; Chakrabarti, 2013) of night-time residents and/or day-time workers.
Urban Grain	The fine details of a city's character, such as street widths, door recesses, overhangs, setbacks, materials, roof pitches. It is the characteristics of a place which are often referred to, in some circles, as Façade and Interface, what can be seen standing on a street corner.
Urban Fabric	The middle scale details of how the streets are laid out, the depth and length of blocks, the distribution of amenities (parks, schools) and third-places (shops, cafes) and adjacent land-uses. What can be seen from a low-flying helicopter.
Urban Form	The scale at which the transport network's multiple effects may be viewed in their interaction with residential, retail, commercial, recreational and ecological land uses. This may comprise the entire urban region depending on the size of the conurbation and displays how the overall urban system operates. This is what is referred to in other places as 'Urban Structure', what can be seen from the window of an airplane.
Urban Design	For the purposes of this research, this is defined as the concern for the physical layout in the entire suite of urban conditions. This includes the daily interactions of humans with the built environment as well as the natural environment's bioclimatic facts of the location. This includes, therefore, the aesthetics but also the 'systems-thinking' involved in

	homes and jobs locations and the transport network between, the facades, local footpaths, regional parks and distribution of third places and much more.
Statutory Planning	Planning which is concerned with the laws and bylaws regarding building height and bulk, specific mix of use, traffic impact reports from transport engineers, parking ratios and location, public open space and landscape requirements, fire and building codes among others.
Strategic Planning	Planning which is concerned with longer, five to fifty years, targets and objectives, the locations and spacing of populations, housing and jobs, schools and service locations, overall densities of areas, transport provision to support the target densities, ecosystem protections and amelioration, among other tasks for small to large areas.
Amenities	In this thesis /dissertation Amenities will refer to typically privately owned, for profit, places or activities in the urban fabric. Examples such as restaurants, bars, cafes, gyms, shops, cinemas, grocery stores and so on.
Services	In this thesis /dissertation Services will imply those beneficial places or activities typically offered by the local or state government. Examples are schools, hospitals, universities, parks, sports fields, recreation centres, community halls and art centres.

ACKNOWLEDGEMENTS

1 - INTRODUCTION

There are several gaps in both academic literature and professional practice regarding urban futures. Though we are comparatively data rich and have new tools for examining the available data, there is still uncertainty about how best to provide future urban living conditions at a scale commensurate to the issues facing global cities. This is especially the case with reducing car dependence. There is a gap in reflecting what opportunities are revealed in the data in evaluating the impact of specialised transport-oriented precincts on the whole of the metropolitan region.

A second gap appears in recent literature that may be described as 'detail-free manifestos'. In these manifestos the rhetoric is sound, but there is little application to professional practice or governance structures because the relevance to daily work is not made clear. For example, how much walkable urban fabric is required to achieve region-wide goals for health or greenhouse gas abatement? What does walkability really mean in different cities and how would one achieve it, given the overwhelming automobile-oriented path-dependency of most conurbations?

Third, and most important for this research, there is a gap in both academic literature and professional practice between strategic and statutory planning. Long-range strategic planning is often moderated by statutory rules and transport engineering standards which override vision and leadership (Te Brömmelstroet & Bertolini, 2010). What can strategic plans take from statutory and transport planning 'standards' to reinforce the optimal vision of walkable, transit-oriented, mixed-use, creative, knowledge-based, urban transformations?

This research will attempt to fill in some of these gaps.

Meanwhile, the physical tasks facing all cities grow larger daily. Excess carbon leads to climate change which is altering the world's energy balance (Shrestha et al., 2014). World trade is globalising and the globe is urbanising (UN, 2011). Urbanism happens in regions. Regions comprise interlacing topography and ecosystems, rivers and lakes,

transport networks linked to homes and parks, jobs and shops, intersections and corridors, aspirations and opportunities. Global urban regions, from small to large, are expected to provide – in no particular order – jobs with high rates of productivity, well-located housing, right-sized transportation technologies to suit the task of connecting jobs with homes, and deal with a host of matters such as clean water, fresh air, safe public environments, restored ecosystems, food production, energy decentralisation and overall lowered carbon footprint (Grimm et al., 2008). Culturally, cities are no longer thought of as places to be escaped from as an act of resistance (Wright, 1935; Unger, 1979; Jacob, 2006); rather they bring us together to be more productive and innovative in the company of our peers (Glaeser, 2011). The pressing needs of daily life may suture these gaps, but the wounds keep growing.

A triage-like response is required to keep up with mounting concerns and also to keep up with the flow of data, studies, articles and manifestos.

The quest to build urban infrastructure to a suitable scale, right-sized to the task, over the next fifty years is an enormous challenge. The challenge will include asking OECD (Organisation for Economic Cooperation and Development) urban residents to live in higher density, to walk to high-capacity public transport and to find as much pleasure in public realm life as in the private realm. There is evidence that this transition is underway (Newman, 2011; Newman, Peter et al., 2013). For governments this requires shifting investment priorities to re-urbanising the urban footprint with upgraded infrastructure while incentivising the housing market to help both reduce – through costs avoided – and contribute, via taxes and rates, – to the expenses of providing public services. All of this is politically fractious. Meanwhile, in the non-OECD countries the urban project is ripe with opportunity to improve the lives of lower and middle income groups with better housing, schools, hospitals and transport options but with a lower carbon footprint, by implementing current and expected best practices (IPCC, 2014).

One widely proposed means to locating and providing these urban services is via Transit- Oriented Development (TOD) (Calthorpe, 1993; Bertolini & Spit, 1998; Cervero, 1998; Dittmar & Ohland, 2004; Newman & Kenworthy, 2006; Renne, 2009; Schiller et al., 2010). TOD is intended to link new urban developments for housing and jobs with public transport services in a complementary manner desirable to most people. It is sometimes

touted as a panacea to resolve many or most of the problems, as listed above, facing the global urban regions at a local level (Kelbaugh, 2002; Litman, 2012; EPA, 2014a; Litman, 2014). However, there are problems with the implementation and the potential outcomes. Provided even a modicum of TOD can be constructed within current planning constraints, while taking account of public and private financing mechanisms or public demonstrations against neighbourhood change, when is a certain amount of TOD adequate? How much TOD do we need to build to provide sufficient housing for a stated target of population growth? What mix of land uses is enough to provide the destination-rich walkable urbanism sought? Which transport technology enables TODs to happen best? How do we protect or rehabilitate ecosystems in this process? If we don't place disincentives on automobile use and limit the land supply, will TODs produce strategic long-range results?

The typical targets of TOD are, in no particular order: higher density to house a stated percentage of population growth, higher jobs/housing balance, lowered Vehicle Kilometres of Travel (VKT), lowered carbon dioxide (CO_2) emissions and improved liveability. How, though, do we know we are achieving sufficient results to overcome regional automobile-dependence (Newman & Kenworthy, 1999)? Though single TOD projects are an admirable start, a piecemeal approach may not be sufficient to achieve all the goals for urban regions around the world.

The research presented here will seek to answer these questions by pursuing a more complete regional approach to TODs. It will explore the third gap presented above, the one between the promise of TOD in the literature and TOD in implementation; in essence, this could be expressed as the gap between strategic planning and statutory planning. This research expands the scope of strategic planning from the limiting and hard to achieve Transit-Oriented Development to a broader and integrated Transit-Oriented Region. Concomitantly, this research opens for examination the physical dimension of spaces required to achieve the goals of a walkable, transit-oriented, liveable region for a growing population.

Below (Table 1) are the most obvious projected assumptions behind the work in this research. These are the most important principles that underlie the work done. If they were not in the end proven to be correct then many of the conclusions would be difficult to

make. They are typical of the current urban expectations presently widespread in the planning community (see Literature Review).

Table 1 Projected assumptions of this thesis

In the projected scenario elaborated in this thesis, the city changes for the better. The assumptions underpinning this betterment are that urban land gets redeveloped towards a higher use due to:

a) a metro-region wide effort (policy/zoning) to maximise returns on infrastructure (especially rail) investments through property; and

b) the amalgamation of lots into properly sized parcels a developer might be interested in as the market forces move towards multi-family real estate.

All of this will become necessary in the future owing to a combination of three causes:

a) the city grows in population;

b) highways are found to be an inefficient means of mass transportation compared to rail; and

c) people will increasingly prefer, evidenced through real-estate purchases, to walk to destinations in well-designed, amenity-filled, job-rich environments.

However:

a) many of these urban lands will have a very high premium on the rent gradient due *in part* to transit accessibility (being prime locations already) while;

b) other urban lands may become candidate sites for higher intensity infill *only* due to a massive increase in accessibility from rapid & frequent transit

1.1 SIGNIFICANCE

The aim of this project is to fill in a very large gap between high-level strategic planning and on-the-ground quantitative assessments of physical space and capital expenses needed for a liveable 'green' city. This is of significance, both academically and in professional practice, as it is based on existing literature, develops a novel approach, and provides a new method to develop an argument for compact cities.

The main significance of this work to demonstrates transforming broad policy on land-use and transport integration to specific land redevelopment opportunities with demonstrable outcomes. This work will enumerate the costs and benefits of achieving metropolitan-wide aspirational goals by detailed calculations of issues site by site across the region. The outcomes will be quantified following transparent assumptions based on citable literature. The outcomes will be meaningful - from a human-scaled perspective - for the residents, for the city as an entity, the broader surrounding rural region and even the nation as the pay-offs and trade-offs are made apparent. The outcomes will be presented as metres for housing, offices, retail, parks and parking; numbers of residences and work places; area of sprawl avoided; dollars which may accrue to government coffers from the real-estate yields; costs avoided; GHG and VKT reduced; and level of public service provision, including high-capacity public transport, which should follow from strategic encouragement for the private sector to build homes and workplaces for the future.

The research proposes three models at the global, regional and local scale which will provide transparent and flexible assumptions to objectively measure the extent of change possible even in an automobile-dependent city. The model will use Perth, Western Australia, as a case study for a hypothetical high-capacity public transport investment cycle to support reductions in VKT and CO_2 emissions, while also finding space to accommodate the increase in population, with local jobs available in walkable mixed-use re-urbanisation precincts, set in a regional context, over the next 50 years. This is significant as rarely are all these flow-on benefits accounted for in a transparent model.

The research provides a timely and novel approach to imagining the nexus of transport planning, regional land-use planning, financing and urban design professions to

create a transit-oriented metropolitan growth strategy. All of these aligned professions must overlap and rise to the challenge of shifting automobile-dependent urban fabrics, place-by-place, to create a region of increased walking, bicycle and public transport mode with numerous flow-on effects. The method is also intended to bridge the sciences of engineering and transport planning, as well as the arts of urban design and landscape urbanism.

Effectively, the three models together provide a two-way track bringing details up to the strategic regional scale to create a more 'realistic' portrait of what is possible, and scale strategic planning down into details for higher resolution and consistency. The modelling will reveal a formula in positivist scientific-notation to express the attainment of a 'Transit-Oriented Region' as a product of forces and levers being artfully applied.

However, despite the precision, the results of the formula/model may not be accurate. Rather, the outcome will be identifying the 'scale of the operation' and the 'volume of the opportunity' as calculated by the method in transforming, not just the case study city, but many global automobile-dependent cities.

The cities for which these models are most useful are those which are automobile-dependent, growing in population and economy, and expanding outwardly into greenfield areas, and those which have the capacity to build infill developments in beneficial, amenity-rich ways. For such cities the concept of TOD has long been seen as a major tool to help provide options and opportunities for those who may want to reduce their car dependence. However, what has not been done is the extension of the TOD concept into a regional system that, with synergy, is able to transform the options and opportunities available to the city as a whole. Urban systems have properties that are different in each precinct, TOD station area or corridor due to the networks and linkages that are involved. This approach shows how a whole urban system can overcome its car dependence.

The research provided in this PhD thesis will outline the potential progress in one of the world's most automobile-dependent and low-density cities to achieve a policy setting oriented to walkable, transit-oriented, activity-centred and compact-city aspirations. The implications are globally significant in demonstrating a method to understand the scale of the operation to change our automobile-dependent cities towards a 'self-actualised'

(Maslow, 1943), sustainable, compact urban fabric based on non-motorised modes and public transport.

1.2 THESIS QUESTIONS

Density creates amenities, but also amenities attract density. This is particularly obvious when the amenities are associated with a public transport node (Newman & Kenworthy, 2006).

Everything that was built in 179 years will need to be reproduced in the next forty (Weller, 2009).

This sub-chapter will set out the primary thesis question and set up other follow-on questions which have guided and structured the research.

A table revealing the following series of nested questions has been prepared to more clearly see the flow of investigation.

Table 2 Thesis question and sub-question

Question and sub-questions		
		Outcome and Chapter
Thesis Question	Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?	It is speculated that the urban form and fabric of an automobile-dependent city can be changed over the next 50 years to produce a green-economic urban fabric of polycentric, walkable, transit-served complete communities.
Sub Question 1	What in the literature is missing from the debate on urbanism?	Chapter 2 will provide a global overview on the dominant ideas and ideals which have shaped the way we think about cities, urban

		life, preferable aesthetics and transport-oriented agendas.
Sub Question 2	How might one devise an experiment, replicable for different cities, to render clearly the impacts of policy choices in planning for urban futures?	Revealing a methodology devised through this research will be the most important aspect of chapter 3.
Sub Question 3	What are the policy levers and how do we measure them in a meaningful way?	What preconceived outcome for our cities do we hold as ideal, acceptable and not acceptable? Fleshing this out into a series of charted numerical results will be the question for chapter 4.
Sub Question 4	How best may we analyse the outcomes of the methods and results within academic and professional practice in the expanding field of Urbanism?	Chapter 5 will analyse and discuss the underlying tension and discourse the research has uncovered.

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1.2.1   THESIS QUESTION

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QUESTION

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Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?

The problems with automobile dependence (Newman & Kenworthy, 1999) are numerous. They include automobile-based transport emissions' deleterious contributions to local air and global atmospheric quality (IPCC, 2014); damage to personal and governmental financial well-being as the expense of maintaining automobiles is eclipsed by the cost of building and maintaining automobile infrastructure including highways and parking (Shoup, 2011; Marohn, 2012); increased obesity, coronary problems and diabetes as automobiles engender a lifestyle which precludes walking or cycling for daily tasks (Frank & Pivo, 1994; Frank et al., 2004; Frank et al., 2011); and demand for architecture and urban planning which prioritises the automobile over pedestrians/public transport with ample parking and grade-separated limited-access freeways (Hanson & Giuliano, 2004; Roth, 2007), the antidote to which is often broadly referred to as 'Smart Growth' (Kelbaugh, 1989; Calthorpe, 1993; 1000 Friends, 1997; Ewing & Cervero, 2001; Grant, 2002; Bertolini & le Clerc, 2003; King, 2011; Litman, 2012; Smart Growth BC, 2012; Benfield, 2013a; Litman, 2014), occupying space while denying place (Tuan, 1977; Bachelard, 1994) and limiting the ability of citizens to develop a sense of belonging to the culture and institutions with *civitas* (Sennet, 1990). These issues regarding automobile dependence will be approached tangentially through the modelling, and not directly.

Likewise, as the discourse regarding aesthetics of cities, and the site-specific urban design qualities which make them operate to their highest, has been well covered elsewhere (Duany et al., 1991; Garreau, 1991; Kunstler, 1993; Duany et al., 2000; Fishman, 2000; Duany et al., 2003; Dittmar & Ohland, 2004; Roseland, 2005; Krier, 2009; Ewing & Clemente, 2013), this will not be a core focus of this research, though of recognised importance.

This research strives to avoid rehashing the problems and instead looks forward to solutions. It speculates that the urban form and fabric of an automobile-dependent city can be changed over the next 50 years to produce a green-economic urban fabric of polycentric, walkable, transit-served complete communities.

In 2006, Newman and Kenworthy wrote succinctly:

> An automobile-dependent city can be restructured around a series of transit cities of 20 to 30 kilometres in diameter, with a Town Centre as its focus and Local Centres linked along the transit services feeding the Town Centre. Although linked across the city for many functions, these transit cities with their centres can provide a

level of self-sufficiency that can form the basis for a far less car-oriented city (Newman & Kenworthy, 2006 p.48).

This statement has led to much speculation on how best to design and deliver on such a momentous task as rearranging the very form and fabric of a living, dynamic, barely contained thing as a regional metropolis. The speculation leads to an attempt in this research to quantitatively arrange a plan for a new urban fabric in the transport corridors and nodes of the existing urban fabric (Newman & Kenworthy, 2006). The results can be shown to not only contribute to the land use and urban planning professions but also to those seeking to find how cities can contribute to opportunity, sustainable development, green growth and the green economy (Brundtland, 1987; UNEP, 2011a, 2012c; Chakrabarti, 2013).

The research has created three models to demonstrate relationships at three different urban scales. These will be proposed as a transparent and flexible methodology for global cities to integrate land-use changes and transport investments from the regional to the local scale by creating a Transit Oriented Region, and discussed in chapter 4 Results.

The following sub-questions will form the basis for the chapters 2-5 with the principle question being dealt with directly in chapter 6.

1.2.2   LITERATURE QUESTION

The literature, from the ancient texts up to the present, has informed the global practice of urban design and planning; it has framed the problems but also set up a seemingly unattainable level of expectations. While fascinating as an intellectual discourse on the optimal means by which to improve levels of light, air, positive winds, social discourse, security, health, environment, open space, transport or other, there is still a wide gap between the rhetoric and practice of urban planning. Though optimistic, the literature on how to plan for less automobile dependency, better land-use and transport planning and overall city shaping does not keep pace with the residential and work-place growth on the urban edge where walking and transit services are, invariably, poor. Why, if we know so much, do we keep making poor decisions? **What in the literature is missing from the debate on urbanism?** Is it a matter of synthesis, analysis, inaction or that the literature is not applicable to the development market? Chapter 2 will provide a global overview on the

dominant ideas and ideals which have shaped the way we think about cities, urban life, preferable aesthetics and transport-oriented agendas.

1.2.3   RESEARCH DESIGN QUESTION

If we accept that the world is urbanising and that we can expect great volumes of existing land to be re-urbanised to a higher use especially near high-capacity transit stations, how best might we learn from what is experienced daily and projected forward in a model? What is it exactly about the high-capacity transit which makes higher order urbanism possible? **How might one devise an experiment, replicable for different cities, to render clearly the impacts of policy choices in planning for urban futures?**   The models will need to be not only replicable but also easily adjusted for local conditions; reliant on readily available planning documents, data and standards; and provide answers which use the grammar of the professions, but are presented in the language of the layman. Revealing a methodology devised through this research will be the most important aspect of chapter 3.

1.2.4   RESULTS QUESTION

At the intersection of regional planning, urban design and transport engineering there are several 'building blocks' of policy we can use to measure, model and manage the pay-offs and trade-offs of new urban fabrics in a transit-oriented region. **What are the policy levers and how do we measure them in a meaningful way?** What will the new transit-oriented region (TOR) urban fabric look like at the local level and how do we build to support local human opportunity while maintaining regional ecological function? What preconceived outcome for our cities do we hold as ideal, acceptable and not acceptable? Fleshing this out into a series of charted numerical results will be the question for chapter 4.

1.2.5   ANALYSIS QUESTION

Aside from numbers resultant from the methods and methodology presented here the overall research deserves a broader examination. The numbers are fluid and will change with the application of design professionals' standards, funding questions and political

pressures over the decades of these models' projected timeframe. **How best may we analyse the outcomes of the methods and results within academic and professional practice in the expanding field of Urbanism?** Chapter 5 will analyse and discuss the underlying tension and discourse the research has uncovered.

1.3 THESIS OUTLINE

Chapter 1 Introduction
• Thesis Questions
• Thesis Outline
• Scope, Goals, Aims
• Significance
• Context

Chapter 2 Literature Review
• Automobile Dependence
• Land Use And Transport Integration
• Perth Metro Region
• Global City Shaping

Chapter 3 Research Design
• Methodology
• Participants
• Instruments
• Procedures
• Ethics and Limitations

Chapter 4 Results
• The Global Scale, Model 1
• The Regional Scale, Model 2
• The Local Scale 1, Model 3.1
• The Local Scale 2, Model 3.2

Chapter 5 Analysis and Discussion
• From Regional to Global
• Polycentric Urbanism
• Country of Trees, Towers and Trains
• A Hierarchy of Urban Needs
• An Approach to Urban Renovation
• An Approach to Urban Science

Chapter 6 Conclusion
• The Transit-Oriented Region
• Evaluation
• Further Research

Bibliography

Appendices
• Developer /Amenity Curve
• Urban Design for Public Transport
• Urban Design for Active Transport
• Costs per Passenger KM /Year
• Others

Background

Core

Synthesis

Figure 1 Thesis Flow Diagram

SOURCE: AUTHOR, 2013 THE ABOVE CHART MAY SERVE AS A MAP TO ILLUSTRATE THE RELATIONSHIPS BETWEEN CHAPTERS.

1.4 THESIS SCOPE, AIM AND GOALS

Below is a chart of the Scope, Goals and Aims.

Table 3 Thesis Scope, Goals and Aims

	Scope	Goals	Aim
Data	Make use of existing base line data;	Analyse the capacity of land, in volume and persons, to accommodate higher activity densities with each change in public transport levels of service;	To develop a working model which is both flexible and transparent to illustrate the pay-offs and trade-offs of shifting automobile-dependent cities to higher and greener land use and transport integration (LUTI);
Calculations	Make use of population projections;	Calculate the public transport mode capacities, in persons per hour per lane, to serve compact polycentric region policies;	The input variables are clearly shown, making for *flexibility* for any local area or urban region;
Forecasts	Make use of housing demand forecasts;	Enumerate the direct and indirect economic costs and benefits of high-capacity public transport as a part of the growth of opportunity in the Green Economy;	Make reasonable human-scaled projections of the impacts, listing them as residents, jobs, metres, dollars and other;

Standards	Use published Traffic Generation numbers and Parking Ratios to highlight the severity of the problem of automobile-dependence;	Quantify the costs of construction, social benefits, economic productivity, traffic generation and parking requirements in a manner which is meaningful;	The assumptions used are *transparent* with citations to a source document in the model;
Physical Mapping	Use the existing survey and current planning documents as a base level of information; and	Map and visualise the changes as they may occur in one scenario, at various scales, in an urban region currently among the most low density urbanised areas on the planet: Perth, Australia; and	Detailed metropolitan plan accurate to the metre by scalable vector-based software;
Answers	Provide answers to some basic questions regarding how much development, where and how high for whom.	Create spreadsheet calculations to give key dimensions to low-carbon urbanism.	Illustrate with charts in dollars, kilometres, homes, metres of living space (for playing, shopping or working).

1.5 CONTEXT TO THE THESIS

> If we have learned one thing from the suburban experiment, it is that you can't grow a green economy on bitumen (Speck, 2012).

This section is not intended to take the place of the literature review, in chapter 2, but to place the project within two large camps. In the first camp is the 'urban debate' about cities and the appropriate design for human and ecological function, and in the second camp is the multi-decennial 'ecological discussion' on large-scale resource use, the biosphere and the quality of human life lived in a greener manner. These contexts then lead the research towards the thesis statement and the approach that promulgates the global, regional and local models for a Transit-Oriented Region.

1.5.1   DEBATES ON CITIES

The current debates regarding urban futures are wide ranging and, surprisingly, divisive (Corbusier, 1967; Dent, 1996; Cox & Utt, 2004; Troy, 2004; CNU, 2011). The debates often seek to find an objective truth about the way in which the individual lives in a community, along with strong opinions on how they travel to work and play. As such, the core of debate is about the permissive and restrictive policies which allow urban growth, and the structure of a person's lifestyle and livelihood, to occur in one manner or the other. The debates range from the rate and location of population growth, new innovative industries in the local economy, aesthetics of density, the suitable mix of land uses to bring jobs and homes closer together, the appropriate mode of transport to overcome automobile dependence, local air quality and global climate change, the role the landscape setting may have in shaping the urban form, and many more (Jacobs & Appleyard, 1987; Troy, 2004; Waldheim, 2006; Shoup, 2009; Speck, 2012; Duany & Talen, 2013). This research will not solve any one of these or examine them in detail. Rather, this research offers a macro-model using human-proportioned measurements to provide a reasonable 'scale of the operation' (the urban systems scale) to achieve the anticipated benefits from compact-city action (Smart Growth) and other land-use and transport integration (LUTI) strategies (such as TOD), in regional metropolitan planning. It will use a series of models to demonstrate options and opportunities for transit-oriented patterns of living latent in the remnant urban fabrics of the automobile-dependent OECD countries' cities.

Framing the discussion is a range of monographs, journal articles, blogs, presentations, websites, letters, tweets and conversations. Despite all these resources, there tends to be very little overlap between the disparate professions concerned with analysing, designing and building our cities. Due to division of professional services and academic leanings there is a mismatch of talents and objectives in regards to the complexity of urban potentials: the decision makers don't design or calculate; the designers don't calculate; and the calculators don't design. For example, at design schools no statistical formulas are prepared, in social sciences it is only statistical formulas with no design, and in engineering schools there are formulas to find rational value but not the value of urban vitality or biological life. In short, there is a series of gaps between progressive policy and on-the-ground action, between strategic planning and standards implementation, which this research will attempt to fill with a transparent and globally applicable methodology.

To compound the issue, with rare exceptions (Girling & Kellett, 2005; Roseland, 2005; Ewing & Clemente, 2013), most academic literature offers little clear physical design direction based in quantifiable measurements as a means of reducing car dependence. The lack of professional overlap and the want of academic specificity lead to misinterpreting the true complexity of the urban situation. Rarely in published literature are there examples of clear and transparent modelling to demonstrate, from the regional scale to the individual level, the capacity of land and transport optimisation to create economically beneficial, compact and polycentric, transit-oriented and walkable, mixed-use communities. While there are often plans which show the physical layout of places (Sitte, 1945; Lynch, 1981; Duany et al., 1991; Duany et al., 2000; Duany et al., 2003; Roseland, 2005; Newman & Kenworthy, 2006; Weller, 2009; Smart Growth BC, 2012; Weller & Bolleter, 2012), the long-term cost of over-engineering infrastructure (Martin, 2011; Marohn, 2012), calculation of carbon emissions (Kinesis, 2014), calculation of ecological footprints (Wackernagel & Rees, 2013), health in the obesogenic built environment (Frank & Pivo, 1994; Frank et al., 2011), analysis of transit station precincts (Cervero, 1988; Cervero & Kockelman, 1997; Cervero, 1998), equations to understand transport networks (Vuchic, 2007; Condon & Hein, 2011; Mees & Groenhart, 2012), reviews of walkable cities (Frank & Pivo, 1994; Gehl, 2001; Giles-Corti & Donovan, 2003; Frank et al., 2004; Falconer, 2008; Soderstrom, 2008; Speck, 2012) and promises of a Green Economy (UNEP, 2011a, 2012c), rarely have these been brought

together to form a complete projection of what may be achieved across a metropolitan region.

This research will prepare a methodology and series of methods, presented as models, to overcome these disconnects.

1.5.2   A NEW WAY TO LIVE IN A GREEN(ER) ECONOMY

This research may also be placed in a broader, multi-decade discussion of high-level strategies to reduce resource intensity while maintaining and augmenting the quality of all life (Leopold et al., 2001; Carson, 2002). While the issues of impacts on the environment have been spoken of for many decades, and perhaps best illustrated by the text and diagram in the book *Our Ecological Footprint: Reducing Human Impact on the Earth* (Wackernagel & Rees, 2013), the broader scale was clearly identified in the 1986 Bruntland Commission.

> Industrialized countries must recognize that their energy consumption is polluting the biosphere and eating into scarce fossil fuel supplies. Recent improvements in energy efficiency and a shift towards less energy-intensive sectors have helped limit consumption. But the process must be accelerated to reduce per capita consumption and encourage a shift to non-polluting sources and technologies. The simple duplication in the developing world of industrial countries' energy use patterns is neither feasible nor desirable. Changing these patterns for the better will call for new policies in urban development, industry location, housing design, transportation systems, and the choice of agricultural and industrial technologies (Brundtland, 1987 :62).

While this research does use such foundational sources as a basis, it moves beyond the generalities of 'changing … for the better' to relating the dimensioned and costed implications of altering 'urban development' and 'transport systems'. This research will provide a suite of options, detailed via modelling and three-dimensional simulations of the policy settings and physical massing of reduced resource-intensive lifestyles inside the existing urban footprints of global cities.

> Another important fuel-saving strategy especially in the growing cities of developing countries is the organizing of carefully planned public transport systems (Brundtland, 1987 :102).

However, it is no longer simply a question of reducing fuel use to clear local air and save dollars as per the Bruntland commission quote. Neither is it a question of an economy measured in kilowatts of 'green power', as this actually fits under a broader economy of increased consumption. Neither is it a matter of local food production which, while a net-positive effort, is not sufficient to alter high consumption lifestyles. Rather, it is a much deeper and broader question about how we may promote the opportunity to live a higher quality life with walking to local shops and patronising public transport over automobile dependence. This project is about resource-reduced efficient and maximised Urbanism, not utopic Landscape Urbanism or anachronistic New Urbanism.

The measurable greening of the economy has much more to do with density and location of residents, distance to jobs, transport options and adjacency of services (Benfield, 2013a; Chakrabarti, 2013) than with architectural style, local produce, or electric cars, for example. The aspect of the Green Economy important to this research is the portion devoted to the creation and retrofitting of urban environments to support walking and cycling through amenity-rich places in which the provision of cycleways, footpaths and public transport renders the private automobile the least needed or desirable means of transportation. The Green Economy supports the restriction of practices such as greenfield developments, which remove ecological services and functions in the farms and forests, by limiting the outward march of automobile-dependent lifestyles. In so doing we preserve the productive capacity of the land to provide natural habitat, food, fresh water and air to the urban dweller, while the urban dweller maximises their personal potential for creativity by collectively innovating new opportunities. Yet, the gap remains, to be hopefully closed somewhat by this research, for all of these co-benefits to be accounted for in a quantifiable measure of hectares, dollars, and persons. This gap is the one that lies between policy and practice, strategy and construction of the urban environment.

One of the best means to achieve these objectives is to plan for complete communities with high enough density to support local shops, jobs and public transport services commensurate to needs. From the inside these precincts will have walkability and public transport planning values, rather than automobiles, and be arranged so that the public transport service may link these nodes with an efficient accessibility provider taking people to services, amenities and jobs. All of this has largely been agreed upon by many of today's planners and designers for particular precincts and broad strategies; there is

nothing new in stating so, but there is novelty in showing how to do it and with what quantitative results.

What is missing most of all are the hard quantifiable numbers: dollar costs to construct public transport modes versus highways, numbers of persons who may find residences and jobs, hourly throughputs per lane or rail track, health and economic benefits of so living. These are rarely enumerated. Into this gap the research will present a method by which, not just the case study of Perth or Australian cities, but global cities of the OECD and non-OECD countries may come to better understand their capacity and potential to become Transit-Oriented Regions. Below is a review of the relevant literature on the topic.

2 - LITERATURE REVIEW

THESIS QUESTION: Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?

The Literature Review will focus on historic, contemporary, academic, governmental policy and non-governmental organisations' catalogue of persuasive urban solutions for transport and land-use integration. There will be an attempt to shed a new light on the current debates on global urban growth. This chapter will ask: **What in the literature is missing from the debate on urbanism?**

The first topic will be the current state of global automobile-dependence showing trends in driving patterns and Vehicle Kilometre Travel (VKT) changes in the world.

The second topic will discuss the modelling literature and its usefulness in eliciting opportunities to change urban centres towards a higher degree of quality Land Use and Transport Integration (LUTI). Included within this section will be a review of the opportunities for employing Transit-Oriented Development (TOD) strategies for agglomeration economics and value capture.

The third topic will be describing the Perth Metropolitan Region as an example of an extensively planned for but excessively automobile-dependent city and region.

The fourth topic will be the influence transport options have had on urban fabrics through history as a primary city shaping function. This will look backwards to both built and proposed environments as well as look forward to current thinking in this century.

These four topics will prepare the ground for the Research Design and Results chapters. There will be a summary at the end of the Literature Review to describe the findings and how they informed the Research Design.

To better frame the Literature review the following 'Periodic Table of Urban Elements' has been produced which will demonstrate the relationships in attempting to uncover the gaps. It is purposefully based on the Periodic Table of the Elements so as to arrange appropriately the most impactful authors by time, category and relationship to each other both horizontally and vertically.

The Periodic Table of Urban Elements

Cole Hendrigan 2014

Base metals to noble gasses
Mix the elements to compose new chemical chains

Ancients	19th C	early 20th C	early 20th C	mid 20th C	mid 20th C	late 20th C	Transport	Regions	Nature	Economists	Theorists
Aristotle — 1 Ar											Augustus — 2 Au
Plato — 3 Pt	Water — 4 W							P. Geddes — 5 Pg	W. Whitman — 6 Ww	J.M. Keynes — 7 Jk	R. Florida — 8 Rf
Hippodamus — 9 H	C. Sitte — 10 Cs							L. Mumford — 11 Lm	H.D. Thoreau — 12 Ht	M. Friedman — 13 Mf	W. Benjamin — 14 Wb
Vitruvius — 15 Vt	F.L. Olmstead — 16 FLo	E. Howard — 17 Eh	L. Sullivan — 18 Ls	L. Corbusier — 19 Cr	K. Lynch — 20 Kl	G. Cullen — 21 Gc	J. Zupan — 22 Jz	RPA — 23 Rp	A. Leopold — 24 Al	W. Alonso — 25 Wa	J. Brugmann — 26 Jb
China — 27 C	G.E. Haussmann — 28 Ha	Railways — 29 Rw	F.L. Wright — 30 FLw	M. van der Rohe — 31 Mr	D. Appleyard — 32 Da	D. Shoup — 33 Ds	V. Vuchic — 34 Vv	I. McHarg — 35 Im	E.O. Wilson — 36 Ew	J. Jacobs — 37 Jj	S. Sassen — 38 Ss
Islam — 39 I	Le Notre — 40 Ln	B. McKay — 41 Bm	B. Fuller — 42 Bf	R. Moses — 43 Rm	C. Alexander — 44 Ca	W. Rybczynski — 45 Wr	P. Newman — 46 Pn	LUTRAQ — 47 Lt	R. Carson — 48 R	J. Garreau — 49 Jg	L. Sandercock — 50 Ls
Donkey — 51 Do	Law of Indies — 52 Li	G. Pinchot — 53 Gp	W. Gropius — 54 Wg	SOM — 55 Som	J. Gehl — 56 Jg	A. Jacobs — 57 Cr	R. Cervero — 58 Rc	LRSP — 59 Lr	J. Lovelock — 60 Jl	E. Glazer — 61 Eg	B. Salt — 62 Bs

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Current non-American							
R. Koolhas — 63 Rk	A. Geuze — 65 Ag	B. Ingels — 67 Bi	J. Kenworthy — 69 Jk	R. Weller — 71 Rw	J. Corner — 73 Jc	P. Belanger — 75 Pb	L. Beasley — 77 Lb

Current American							
J. Speck — 64 Js	A. Duany — 66 Ad	T. Mayne — 68 Tm	R. Ewing — 70 Rw	J. Renne — 72 Jr	C. Reed — 74 Cr	M. Van Valkenberg — 76 MVV	J. Sadik-Khan — 78 JSK

Figure 2 The Periodic Table of Urban Elements

2.1 FROM AUTOMOBILE DEPENDENCE TO LIBERATION

Reducing global transport greenhouse gas (GHG) emissions will be challenging
since the continuing growth in passenger and freight activity could outweigh all mitigati
on measures unless transport emissions can be strongly decoupled from GDP growth
(IPCC, 2014 p.4).

The limits to car-based urbanity are increasingly apparent. Data now shows how automobile dependence increases: Vehicle Kilometres Travelled (Cervero, 2002; Cervero, 2003; BITRE, 2012a); the cost of parking vehicles (Shoup, 1999, 2011); and greenhouse gases emitted from car exhausts (IPCC, 2014) contribute to rising rates of obesity and diabetes in the obesogenic urban fabric (Frank & Pivo, 1994; Frank & Engelke, 2001; Rutten, 2001; Takano et al., 2002; Frank et al., 2004; Hoehner et al., 2005; Newman & Kenworthy, 2006; Kamphuis et al., 2007; Kerr et al., 2007; Maas et al., 2008; Montgomery & Roberts, 2008; Townshend & Lake, 2009; Frank et al., 2011; Kozawa et al., 2012). Added to this are the costs of building infrastructure including roads, sewers, emergency services, schools and parks ever further apart in the car-dependent urban fringes (Mumford, 1961; Reps, 1965; Garreau, 1991; Bertolini & le Clerc, 2003; Dodson & Sipe, 2008; Trubka et al., 2009; CIE, 2010; Ewing & Cervero, 2010; Newman, 2011; Marohn, 2012; OzInsure, 2012; Wackernagel & Rees, 2013).

Figure 3 Pennsylvania - Automobile Dependence

Figure 4 Los Angeles - Automobile Dominance

However, despite the bad news, there is a re-urbanisation trend which downplays the role of the automobile in determining urban space. This trend, especially noticeable in the industrialised world, shows a growing tendency to:

- live in smaller homes, town homes, apartments and other forms of multi-family higher density;
- live closer to well served public transport stations; and
- provide jobs and amenities in mixed-use walkable districts.

This trend has been noted, but collectively we are still uncertain about how to activate it into a fully formed new way of living across a whole urban region. The 'return to the city' that has been observed globally can only happen if there are more places provided there than on the urban fringe. Urbanism is easiest to rebuild in the areas where the urban fabric was originally built at a higher density in the first instance; however it is possible to rebuild any urban space into a new kind of dense, mixed-use urbanism. Not everyone can live or may want to live in the inner city, but there are typically many desirable places with qualities and natural amenities awaiting urban activation to higher use across a whole urban region. It is the intent of this research to demonstrate the appropriate locations, sufficient density, right-sized public transport mode, and increased accessibility and overall advantages of concentrating a higher proportion of metropolitan residential and jobs growth in existing and new transit-served districts. This research will include a search for candidate sites in the inner, middle and outer neighbourhoods, all within the existing urban footprint.

This re-urbanisation trend has been predicted by urban designers- and commenters on urban realms as a preferred lifestyle with numerous benefits for at least the last thirty years (Tuan, 1977; Condon, 1988; Duany et al., 1991; Calthorpe, 1993; Kunstler, 1993; Cooper Marcus & Francis, 1998; Duany et al., 2000; Gehl, 2001; Duany et al., 2003; Boddy, 2004; Dittmar & Ohland, 2004; Newman & Kenworthy, 2006; Waldheim, 2006; Newton, 2008; Turner, 2008; Waldheim & Berger, 2008; Condon et al., 2009; Weller, 2009; Condon, 2010; UBC Studio, 2010; Condon & Hein, 2011; Weller & Bolleter, 2012; Benfield, 2013b,

2013a). That we have patterns commensurate with the challenge is due in part to an even earlier generation of thinkers (Sitte, 1945; Geddes, 1949; Jacobs, 1958, 1961; Appleton, 1975; Bachelard, 1994) who laid the groundwork for thinking on urban futures.

> An automobile-dependent city can be restructured around a series of transit cities of 20 to 30 kilometers in diameter, with a Town Center as its focus and Local Centers linked along the transit services feeding the Town Center. Although linked across the city for many functions, these transit cities with their centers can provide a level of self-sufficiency that can form the basis for a far less car-oriented city (Newman & Kenworthy, 2006).

There remains much to be uncovered regarding automobile dependence, the benefits of re-urbanisation and the aesthetics of urban design. Yet, there needs to be a real examination of the thresholds, policies and levers which, while crossing several professional disciplines, will take us towards solutions for a whole urban region.
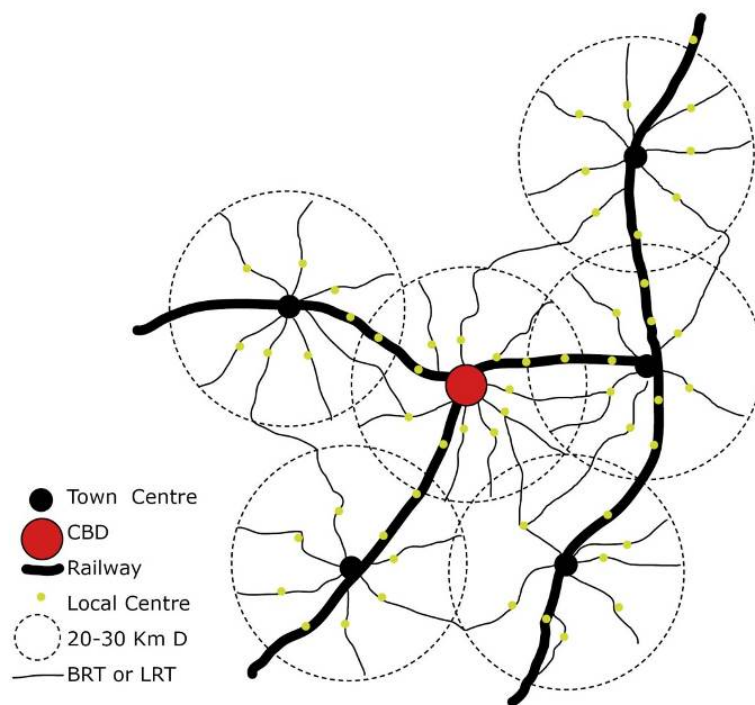
Figure 5 A potentially TOD rich city, after Kenworthy

Town Centre
CBD
Railway
Local Centre
20-30 Km D
BRT or LRT
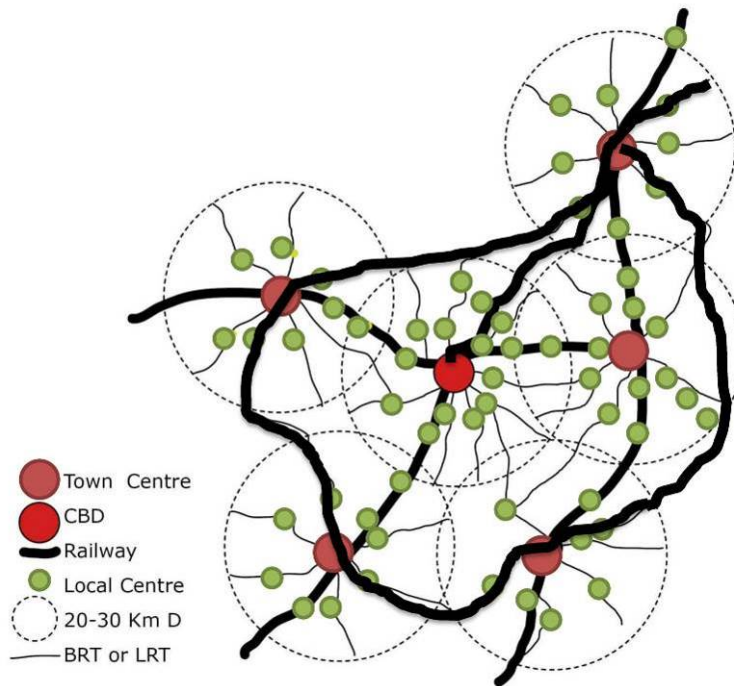
Figure 6 A Transit Oriented Region, author

2.1.1   GLOBAL CITIES TRANSPORT TRENDS

To better elucidate the problem, by comparing trends and measuring the effects of different policies and infrastructure investments globally, Dr Jeff Kenworthy has built the Global Cities Database (GCD). It regularly updates the metrics regarding cities, their urban area, population, density, transport services and a multitude of other sub-data. From these numbers we can gain insight into trends regarding density, transport use, mode splits, and relative automobile dependence. (Please see 'Urban Areas, Populations and Transport in 19 Cities' and 'Select cities from the Global Cities Database' in the Appendices). The main lesson from the GCD is certainly that the less dense a city, the more energy is used for transportation. While seemingly intuitive and noticed subjectively by many (that Parisians, say, drive less than those in Houston) this was the first large scale study to objectively place the cities in direct comparison. Along with a host of other partially explanatory factors such as kilometres of highway and transit, we could finally see through a miasma that if a reduction in automobile dependence was a goal then we must supply more transit kilometres and create overall denser cities.

> …the physical layout of a city does have a fundamental impact on movement patterns (Newman & Kenworthy, 2006 p.42).

Since this was first published it has been widely cited and foundational to the discussion about sustainable cities. However, despite this, not a great deal of physical action has been taken until recently where a shift has been noted. Current trends in driving and transport use have recently been compared which demonstrate:

> … new data on the plateau in the speed of urban car transportation that supports rail's increasing role compared to cars in cities everywhere, as well as other structural, economic and cultural changes that indicate a move away from car dependent urbanism (Newman, P et al., 2013).

This analysis has been illustrated by others such as the Department of Transportation's Federal Highway Commission data on the decline in driving. As we see in the following figure, since 2004 there has been a sustained decline but the trend was levelling off slightly earlier.
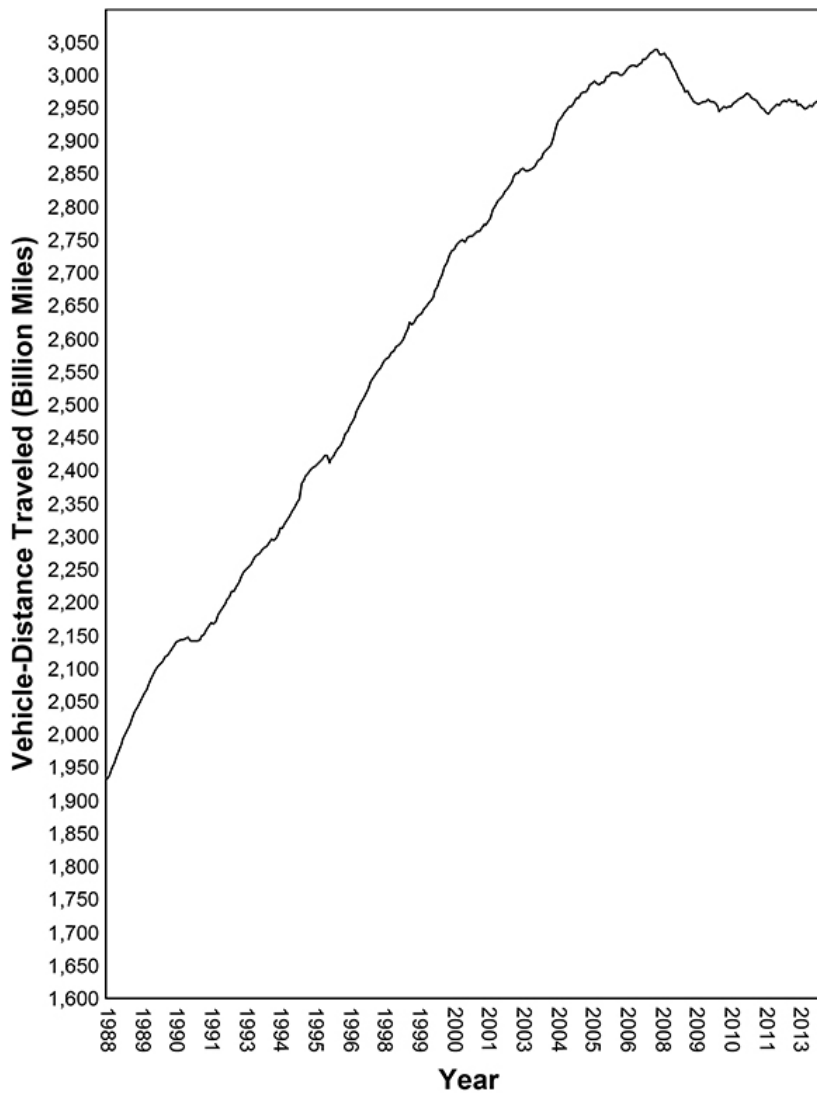
Figure 7 Vehicle Miles Travelled (billions)

Source: "Travel Monitoring and Traffic Volume" US DoT Federal Highway Administration, Office of Highway Policy Information

http://www.fhwa.dot.gov/policyinformation/travel_monitoring/13dectvt/figure1.cfm

Accessed January, 2014

These findings have been reinforced by Doug Short, a former professor and IBM Consultant who now specialises in charting financial data. He used the same Department of Transportation's Federal Highway Commission's data and crossed it with the growth in population to find even starker decline in per capita driving for all Americans over the age of 16 (Short, 2014).
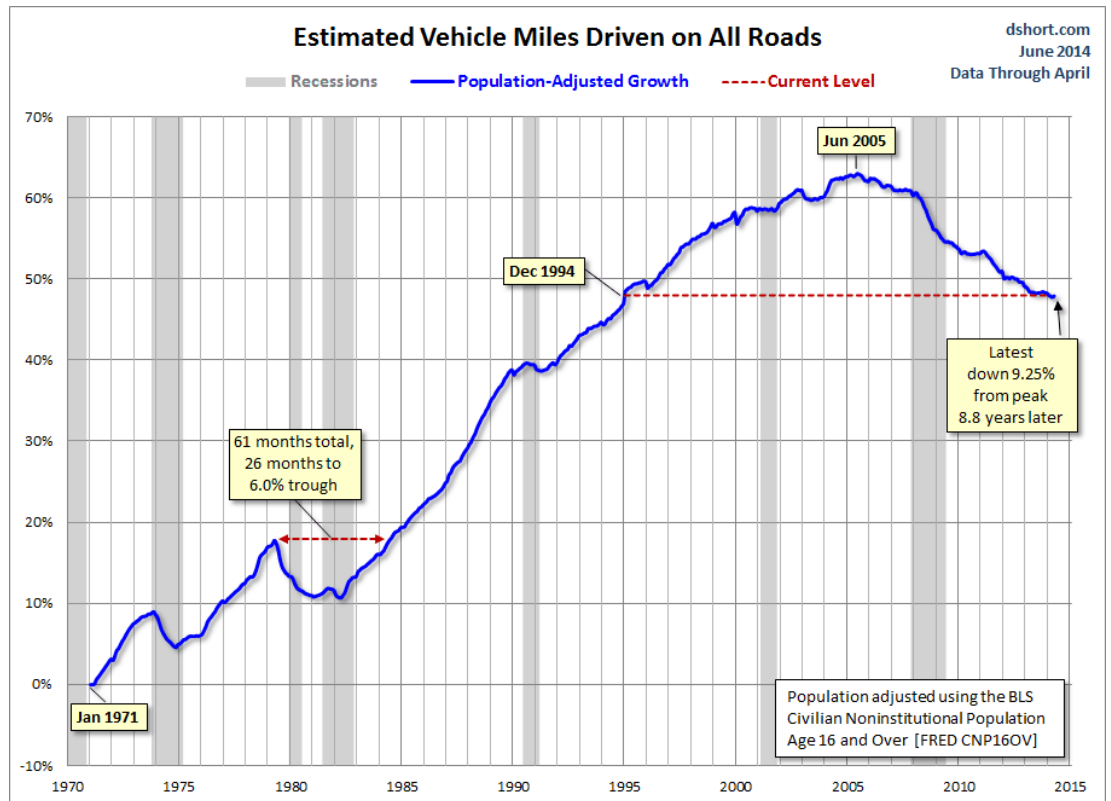
Figure 8 Estimated Vehicle Miles Driven on All Roads

SOURCE: ""VEHICLE MILES DRIVEN: ANOTHER POPULATION-ADJUSTED LOW"
HTTP://WWW.ADVISORPERSPECTIVES.COM/DSHORT/UPDATES/DOT-MILES-DRIVEN.PHP ACCESSED
JANUARY, 2014.

The results show a marked decline in driving beginning from 2005, well before the 2008 Global Financial Crisis. What, besides the price of gasoline (petrol), is behind this?

MILLENNIALS

One of the most recent surveys done on Millennials'[1] preferences, and especially their preferences for mobility, was recently published by the Rockefeller Foundation of

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[1] Millennials: Defined as those born from 1982 to 2004 and tending to use Wikipedia. "Millennials": http://en.wikipedia.org/wiki/Millennials. Accessed May 8, 2014

New York and complied by Global Strategy Group (Global Strategy Group, 2014; Rockefeller Foundation, 2014) and found that:

54% of Millennial respondents would consider moving if another city had more and better transit options;

and:

47% of Millennials would give up their cars if their city had robust public transportation.

It concluded that:

… cities that don't invest in effective transit solutions today stand to lose out in the long-run. Providing public transportation options has moved from a nicety to a necessity. As we move from a car-centric model of mobility, and become a nation that embraces more equitable and sustainable transportation options, Millennials are leading the way (Rockefeller Foundation, 2014).

According to the survey, Millenials drive less than their parents and, furthermore, *aspire* to drive less. They would rather spend money on electronic goods which bring them closer to other people via social media and on life-reaffirming experiences such as those experienced in the urban public realm. They prefer to live within neighbourhoods in cities with good public transport access to many places, shops, jobs and residential options. They do not wish to spend hours, days and weeks of their lives behind the steering wheel as their parents and grandparents may have.

MARCHETTI CONSTANT

… the basic instinct of a territorial animal is to expand its territory (Marchetti, 1994).

Despite the rising rate of public transit provision and preference (Rockefeller Foundation, 2014) there has, globally, been a steady increase and widening use of Single Occupant Vehicles (SOV) for many decades (Newman and Kenworthy, 1999). Historically, the need to travel to work and shopping has always occupied much time, though never so much *space* as currently required. There are limits to this willingness to travel from one place to another depending on the available modes of transport as after a certain distance and time people will begin to relocate or develop new resource centres. However, we are

now reaching a critical point in our relationship with SOV travel and its necessities of time and cost to both the personal pocketbook and the wide economy. Yet, this irrationality seems to have an instinctual basis.

Cesare Marchetti's work has revealed a constant which holds that people adjust their lives to suit preferred time expenditures, despite the cost, resulting in a classic mismatch between behaviour and economic rationality. He attributes this to an 'animal instinct' to have as many resources and opportunities as possible despite the expense and threats to safety.

> Personal travel appears to be much more under the control of basic instincts than of economic drives. This may be the reason for the systematic mismatch between the results of cost benefit analysis and the actual behaviour of travellers (Marchetti, 1994).

Marchetti gives an example from Berlin which has changed in response to new transport modes level-of-service delivery and how this shift of time expenditure results, ultimately, in other sites in the periphery gaining access to a new 'Functional Centre'. Marchetti describes the ultimate consequences of time management and accessibility as the proper progenitors of polycentric urban forms, with zoning facilitating rather than predicting the outcome.

> The Berlin of 1800 was very compact with a radius of 2.5 km, pointing to a speed of 5 km/hr, the speed of a man walking. With the introduction of faster and faster means of transportation the radius of the city grew in proportion to their speed, and is now about 20 km, pointing to a mean speed for cars of about 40 km/hr. The center of the city can be defined, then, as the point that the largest number of people can reach in less than 30 minutes. Reducing the access to the geometric center, for example, through zoning, can displace the functional center elsewhere, for example, outside the city. Shopping centers are a typical consequence of poor transportation toward the center of the city (Marchetti, 1994).

Marchetti's conclusion is that:

> Cars make all the difference. As they have a speed of 6 or 7 times greater than a pedestrian, they expand daily connected space 6 or 7 times in linear terms, or about 50 times in area (Marchetti, 1994).

from 1950 - Cars
from 1925 - Subways
from 1905 - Electric Trams
from 1860 - Horse Tramways and Buses
up to1850 - Pedestrians and Coaches
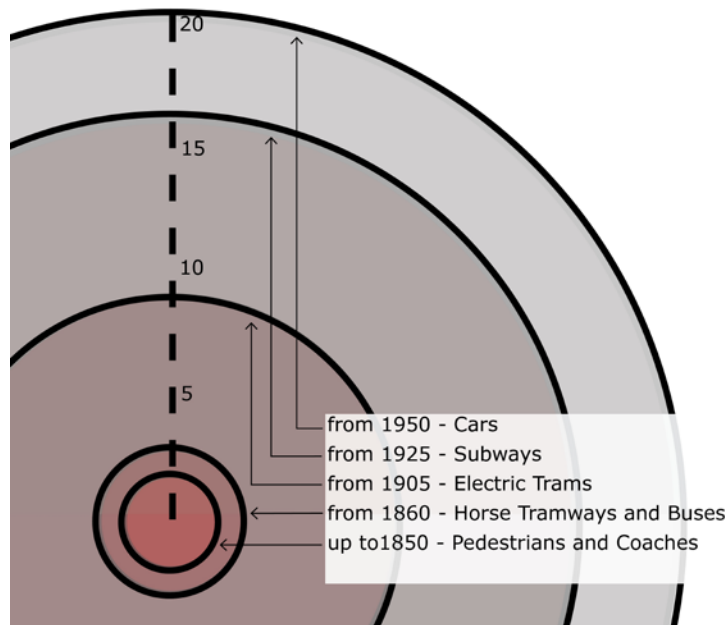
Figure 9 City Dimensions in Kilometres due to Dominant Transport Services

SOURCE: MARCHETTI (MARCHETTI, 1994), ADAPTED BY THE AUTHOR IN 2013.

The consequence of this expansion of the city by automobile access, according to the theory of Marchetti's Constant, is that most cities work until they reach an hour's trip time length after which the residents reconsider their mode choices, land-use options and manner of compacting or dispersing the populations and jobs.

> The Marchetti Constant explains how cities throughout history have functioned on the basis of an average one hour per day travel-time budget…. It can be used to explain why walking cities in history were just 5 to 8 kilometres in diameter, transit cities could spread to 20 to 30 kilometres, and automobile cities could spread to 50 to 60 kilometres. Due to the different speeds of walking, transit, and cars, these cities, regardless of physical size, were all "one hour wide" in diameter. Large urban areas today are combinations of these city types – with most journeys being within that "one hour-wide" locus (Newman & Kenworthy, 2006).

> Overcoming automobile dependence thus becomes a question of whether people can access the amenities of a city without a car. In particular for an urban center, it becomes whether the time available for car travel is less than the time it would take to access the urban center using a bike, walking, or riding public transit (Newman & Kenworthy, 2006).

SOV travel now often requires more than the one hour of travel in many cities and, when all trips taken in aggregate are considered, this becomes a very large drain on the

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productivity of the individual, household, city and nation. The hour, or even *hours*, of time spent daily in commuting replaces time better spent being productive. When added to the costs of owning, operating, storing and repairing the automobile one can figure a high dollar value which could go towards other capital costs in the household or nation. There is even evidence now that divorce rates can be linked to the extra time spent commuting (Committee for Perth, 2014).

A trend towards reduced driving has been measured in the some parts of the OECD and a historic pattern in preferred transport trip time uncovered by Marchetti. How are these relevant to transitioning a city or urban region towards being Transit Oriented?

2.1.2   TRANSITIONING THE AUTOMOBILE DEPENDENT CITY

> Transport figures prominently on green growth agendas … transport has major environmental impacts in terms of greenhouse gas emissions, local air emissions and noise. And managing congestion more effectively is part of the broader agenda for more sustainable development and better use of resources invested in infrastructure (Perkins, 2011).

In their 2008 *Vulnerability Assessment for Mortgage, Petrol and Inflation Risks and Expenditure*, or VAMPIRE index, Dodson and Sipe illustrate several key points regarding Australian cities' vulnerability. Regarding land-use and transport they begin by noting a need for high-quality public transport and 'less oil-dependent modes of travel'.

> Governments have a responsibility to redress spatial failures on features of the suburban landscape over which they exert the greatest control, such as the distribution of high quality public transport infrastructure and services (Dodson & Sipe, 2008).

> If Australian cities are to remain socio-economically resilient in the coming decades, our urban planning will need to give much greater emphasis to less oil dependent modes of travel, such as public transport, walking and cycling (Dodson & Sipe, 2008).

They suggest that rather than digging tunnels to replace existing at-grade public transport services in the Central Business Districts, it may be better to extend rail and bus services to the suburbs.

> An oil vulnerability perspective suggests that rather than using the $27.5 billion (for tunnels)in funds available for public transport improvements across these

three cities to replicate existing inner city infrastructure it ought to be directed to ameliorating the exposure of suburban households to higher transport costs. This could be done via new outer suburban rail extensions and through improvements to interconnecting local bus services (Dodson & Sipe, 2008).

Similar messages, somewhat appeasing apologists for sprawl by advocating taking transit to the suburbs rather than proactively planning to reinforce good land-use patterns, were echoed by Paul Mees in 2010. Mees called for governments to increase public transport services through the city to the outer suburbs to counter the growing influence of trip origins and destinations becoming further apart, and in so doing perpetuating automobile dependence:

> …public transport uses urban space and environmental resources more efficiently than the car if it can attract people with different trip origins and destinations to travel together. This task becomes more difficult as origins and destinations disperse, which is exactly what is happening almost everywhere in the world. Trip origins are spreading, as suburbanization lowers region-wide population densities; trip destinations are less concentrated, as the share of jobs and retailing in central business district (CBDs) falls; traditional peaks are spreading, as working and shopping hours are deregulated (Mees, 2010 p.148).

However, before we look at the relative merits of different transport modes, it important to note a few of the typical detractors' arguments. It is important because we need to understand the concerns the other parties have in regards to this question so that public transport and urbanism advocates might strengthen their arguments. Several examples, straining at extreme, include these selections:

> Forever seeking … levers for prying the world in directions they prefer, progressives say they embrace high-speed rail for many reasons—to improve the climate, increase competitiveness, enhance national security, reduce congestion, and rationalize land use. The length of the list of reasons, and the flimsiness of each, points to this conclusion: the real reason for progressives' passion for trains is their goal of diminishing Americans' individualism in order to make them more amenable to collectivism.[2]

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[2] Will, George. 2011 "Will: Why Liberals Love Trains" Newsweek http://www.newsweek.com/will-why-liberals-love-trains-68597 Accessed May 10, 2014

The costs of light rail, while large in aggregate, are often small when spread over the tax-paying population. (The cost of light rail in St. Louis totals about $6 per taxpayer annually). A large group of taxpayers facing relatively minimal costs can be persuaded to vote for light rail based on benefits shaped by the interested minority, such as helping the poor, reducing congestion and pollution, and fostering development. Even if these benefits are exaggerated and the taxpayer realizes the cost-ineffectiveness of light rail, it is probably not worth the $6 for that person to spend significant time lobbying against light rail (Castelazo & Garrett, 2004).

Another detractor, the well organised and self-promoting anti-public transport advocate Randy O'Toole, claims:

For many, rail transit's incredible expense is its main attraction. Auto-haters love rail transit because it consumes funds that could otherwise be spent reducing congestion. Politicians love rail transit because the companies that will profit from it are a source of campaign contributions. Transit agencies love rail transit because it boosts their budgets and national prestige. But the public should not be fooled: For everyone else, rail transit is a disaster (O'Toole, 2004).

O'Toole further illuminates us with his math:

Rail's high cost makes it ineffective at reducing congestion. On average, $13 spent on rail transit is less effective at reducing congestion than $1 spent on freeway improvements. Investments in rail transit are only about half as effective as investments in bus transit (O'Toole, 2004).

O'Toole regards public transport as a subsidy to the lazy, a disincentive to act on liberty and an overall drain on a productive individual's true ability to choose the life they should want to lead – buying new cars and eating at fast food establishments – in the automobile-dependent suburbs.

It is important to counter these arguments with capital and operational dollars related to mode capacity numbers as outlined in this thesis as well as the costs of urban development associated with such modes. Generally public transport will prove itself if the objective of a project is urban accessibility. (See 'Transit Capacities and Urban Form' for more information on the capacities of modes and 'U.S. Costs per yearly Passenger Kilometre Compared' in the appendices to see a breakdown of costs per passenger kilometre to construct public transport.)

The question remains, however: which transport mode and at what capacity is appropriate to undertake what tasks in city building? To respond to these questions there have been many possible answers.

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2.1.2.1 TRANSPORT PROVISION – ORIENTATION, NODE, MODE & CORRIDOR

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Over the last decade and a half there have been many calls for cities to devote an increasing proportion of their jobs and residential growth into areas zoned for intense activity around public transport nodes (Cervero, 1988; Calthorpe, 1993; Bertolini & Spit, 1998; Cervero, 1998; Newman & Kenworthy, 1999; Dittmar & Ohland, 2004; Newman & Kenworthy, 2006; Curtis, 2008; Curtis et al., 2009; Newman et al., 2009; Cervero & Sullivan, 2011; Litman, 2012; Newman, Peter et al., 2013). Together these fall under the specific rubric of Transit-Oriented Development, or TOD, which is often a strategy to orient new building mass towards an adjacent transport node, such as a rail station. Otherwise, more broadly, the term Land Use and Transport Integration (LUTI) refers to overall strategies to identify a spectrum of places and nodes (Bertolini & Dijst, 2003) which may be augmented through policy and design to support higher pedestrian activity and improved public transport. LUTI identifies locations which require special care to develop with higher residential density and improved private retail amenities and public services where the transport services are appropriate. While essentially looking towards the same future, TOD is a design strategy best looked at from a bird's-eye view while LUTI is a planning strategy best read in a document with measurements and targets.

Existing literature and conference papers devote volumes to opinion, modelling and evidence that show that co-located residential density and transit earns high benefits to the cities willing to create well-appointed networks of station precincts (Cervero, 1988; Messenger & Ewing, 1996; Ewing & Cervero, 2001; Porta & Renne, 2005; Renne, 2008; Waldheim & Berger, 2008; Zhao et al., 2009; Eidlin, 2010; King, 2011; Thompson & Brown, 2012; Topalovic et al., 2012). All these together formulate a rigorous body of work to explain the data behind the relative success or failure of transport policy.

Likewise, there is an avalanche of authors describing the benefits from living in cycle-enabled and walkable transit-served locations (Duany et al., 2000; Gehl, 2001; MTI, 2002; Duany et al., 2003; Roseland, 2005; Bruggman, 2009; Krier, 2009; Condon, 2010; Gehl,

2010; Smart Growth BC, 2012; Speck, 2012; Walker, 2014) who all point to the benefits of building and living in walkable locations.

However, aside from a few excellent examples, it is hard to see evidence that they are being heard. Politicians, and their accountants, do respond to traffic engineers' rationale for expanded roadways and parking provisions. The reasons they are heard is that the engineers have developed a quantified science of car-based transport. Against all the qualitative arguments for improved lives and beauty along tree- lined and safe walking routes to the ennobling civil-society crafting transport service are the hard quantitative numbers of the traffic engineer. The traffic engineer has been trained to move numbers of automobiles through corridors, gaining mobility not necessarily accessibility for people to and within places of residence or production. Accepting the traffic engineers' transport models as a totality of reality, rather than just a wedge of information to be used with discretion, has been misguided. Accepting the models at face value has led to ever-widening of roads, grade separation and widely dispersed land uses interrupted by surface parking area.

The question then becomes: what type of method might reveal an equally quantified and compelling argument to make transit-orientation happen? Though there is an evidence-based argument for compact, walkable, transit-served, mixed-use, low parking ratio cities, how can we apply all the information gathered to this point to make a compelling argument?

Preceding the matter of transport orientation for new developments is a burning question: which transport modes are the best suited to transitioning an automobile-dependent city into a Transit-Oriented Region? What other factors might we consider as foundational to a liveable urban region?

BUS, BRT, LRT, METRO: LEVEL OF SERVICE

A well-planned and convenient transit system has the ability to attract new ridership through improved accessibility. This expanded source of income can help fund the day-to-day operation of the system and sustain future upgrades and maintenance (Topalovic et al., 2012).

The mode of transport chosen must operate at a frequency commensurate with the current and anticipated load levels along the line as well as be an armature for a host of other trips and activities which it may support over time (Cervero, 1988, 1998; Vuchic, 2005, 2007; Cervero & Day, 2008; Renne, 2009; Mees, 2010; UBC Studio, 2010; Scheurer, 2012). Calculating the correct Level of Service, therefore, depends firstly on what type of city or region the urban area wishes to become (see Model 1), what the capacity of the land to support more urban development is across the transport network (see Model 2) and what other constraints and opportunities lie within policy settings for urban redevelopment yields (Model 3.2).

Though possible to build and operate a network without up-zoning land use and improving the public realm (as have cities such as Calgary, Edmonton, Perth, that the author is familiar with) it is sub-optimal. Yet, the results can still be very positive:

> Perth has set a strong precedent in Australia by going for a fixed rail service fed by buses with precise interchange times (the continental European solution). Across Australia the decision was met with scepticism by transport professionals but has slowly seeped into political processes (Newman, 2012).

One can only imagine how much more powerful such a network could be with land uses changing to respond to the accessibility offered by the transport mode; indeed market forces are such that density is increasing around these rail lines (McIntosh et al, 2014).

The characteristics of the different modes and their land-use associations, are described below.

1. BUS

Buses do, and will continue to, provide enormous passenger capacity on many networks around the world. In many developing world cities they are the only real transport mode, complemented by para-transit and plentiful walking. They offer flexibility in scheduling, headways and route while also being less expensive than the rail options (Cervero, 1998; Cervero & Golub, 2007).

Yet, it is important to note that:

> …flexibility is not always a desirable feature of transit systems; permanence, predictability and reliability of service are major positive characteristics of transit systems (Newman, 2012).

When coupled with scant evidence that they may not induce many people out of private transport, especially 'choice' riders, nor instigate redevelopment nodes around their networks – as they more often respond to new development nodes – it is difficult to imagine buses being other than a necessary but only complementary feeder service to higher capacity lines such as BRT, LRT and metro-type services in building the scale of urbanity required to overcome automobile dependence.

2. BUS RAPID TRANSIT

EMBARQ, a non-governmental organisation based in Washington D.C. and a part of the World Resources Institute, has taken the lead in promoting Bus Rapid Transit (BRT) as the optimal means of securing a carbon-reduced, equitable and vastly less expensive means of transportation. BRT may be defined as: bus technology; rolling stock with internal configurations favouring high standing capacity, over seated; with bi or tri articulation; on rubber wheels, with diesel, gas or electric propulsion; on short headways; with few stops as a more 'express service'; with a dedicated Right of Way as a lane in the road to avoid being wedged in automobile congestion.

It is likely that BRTs can be less expensive to install often requiring new kerbs (curbs), bus stops with better signage, painted lanes, and less expensive rolling-stock per unit. Furthermore it is likely that there will not need to be as much surface level disruption during construction or as much realigning of underground water, power, sewer and other utilities, saving on the infrastructure costs over rail. However, the true cost of operating a BRT system is revealed by digging a little deeper to include the ongoing labour costs, the replacement timeframe of the rolling-stock, the capacity per hour – what level of service is being provided to how many people – and the length of headways to avoid 'bus bunching'. (See 'U.S. Costs per yearly Passenger Kilometre Compared', Page 455),

Once a BRT is successful and many people are riding it at or beyond capacity, cities find it difficult to remove the service and upgrade to a rail-based higher capacity mode along the same route. Lastly, due to 'tire squeal', turning radius, acceleration and braking noise along with a perceived 'second-rate' service due to internal configuration and

swaying, Bus Rapid Transit may not attract 'choice passengers'[3] or attract urban redevelopment dollars. [4]

While indisputably a better alternative than private automobiles, there are several negatives which are often overlooked. (Please see 'Transit Capacities and Urban Form in the appendices for more information on comparing the modes.) Tod Litman surmises:

> Although bus transit is excellent for serving dispersed destinations, on major urban corridors rail tends to be more effective at attracting riders and more cost effective overall, since trains tend to offer a more comfortable ride, are generally propelled by electric motors rather than internal combustion engines (so train stations tend to be more pleasant than large bus stations), and can carry more passengers per unit. Light rail service has lower operating costs compared to buses with as few as 1200 peak-period passengers on a corridor, and is particularly appropriate for destinations with more than about 2000 peak period passenger arrivals to avoid the unpleasant impacts from large congregations of buses at a station (Litman, 2007).

3. LIGHT RAIL TRANSIT

Light Rail Transit has been promoted over the last 40 years at least, since the first conference on the topic held in 1975 by the Transport Research Board where it was claimed:

> Foundations of light rail lie in the streetcar mode, but progress from that technology has been so pervasive that a totally new dimension in public transport has been achieved (Taylor, 1975).

Since this time there have been great advances in the technology and its application. It can be defined as an urban rail technology which is faster than streetcars on longer sections, but can go as slow as streetcars in a shared ROW urban setting which is a desirable characteristic for downtowns or other activity centres. It has a short braking distance due to its lighter weight and can also quickly regain speed after stopping, so that

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[3] Those who have a choice between private automobile or taxi. Those who are not 'captive' with no options but to use the public transport system.
[4] See, for example "The Silly Argument Over BRT and Rail" from *The Transport Politic* of May 25th, 2011 http://www.thetransportpolitic.com/2011/05/25/the-silly-argument-over-brt-and-rail/. Accessed July 2014

its numerous stations are not as much a hindrance as heavy commuter or metro rail. Its carriages can be configured to be slightly wider and longer, with multiple consists, meaning much higher capacity per hour than streetcars or BRT, but less than most metros.

To show the benefits, in addition to carrying people efficiently to and from destinations, Todd Litman, of the Victoria Transport Policy Institute (VTPI), a consultancy in Victoria Canada, prepared this table:

Research Concerns related to Rail transit benefits (Litman, 2007)		
Research Concern	Benefits	Description
VKT	Congestion reduction	Reduced traffic congestion
VKT	Facility cost savings	Reduced road and parking facility costs
VKT	Consumer savings	Reduced consumer transportation costs
VKT	Transport diversity	Improved transportation options, particularly for non-drivers
VKT	Road safety	Reduced per capita traffic crash rates
POS	Environmental quality	Reduced pollution emissions and habitat degradation
GHG	Efficient land use	More compact development, reduced sprawl
N/A	Economic development	Efficiencies of agglomeration, increases productivity and wealth

N/A	Community cohesion	Positive interactions among people in a community
POS	Public health	More physical activity (particularly walking) increases fitness and health

Table 4 Research Concerns related to Rail Transit Benefits

Source: Litman, 2007

Rail public transport, of which LRT forms a part of the mode, features improved performance and comfort through grade separation, larger seats, better stations as well as lower operating costs. Rail further promotes strategically important infill development and is useful as a tool for planning objectives (Litman, 2007).

Light Rail Transit reduces air pollution from transport sources, carries more people than buses, reduces congestion, increases accessibility, makes land more valuable (SGS Planning and Economics, 2013) and contributes to walkable cities programs while also being a 'good return on investment' (Topalovic et al., 2012).

Put more blandly but precisely by a consulting firm's report on the matter:

> When comparing LRT to BRT, it can be expected that LRT will carry higher capital costs, and given the expected ridership levels, slightly higher operating costs. However, LRT provides greater long term capacity and is felt by some to provide a greater incentive for redevelopment (IBI Group, 2009).

Please see 'U.S. Costs per yearly Passenger Kilometre Compared' and 'Transit Capacities and Urban Form' in the appendices for a further breakdown on capacities, speed and cost of LRT.

4. METRO RAIL

Metro rail, also known as tubes, subways or other terms, comes in a variety of configurations: from rail on steel to rubber tyred, elevated to underground, with exclusive Right of Way, to a mix of some shared with some level crossings. What it really represents is a massive change in potential to move people per hour in a network of lines to multiple

destinations far quicker than any other manner including the automobile. Most large cities have them because metros need a large city to pay for them and, conversely, most large cities only operate as a large city *because* of the metro.

Newman, Kenworthy and Glazebrook (Newman, P et al., 2013) summarised the advantages of urban rail including:

- Lower per capita traffic congestion costs.
- Lower per capita private passenger transportation energy use.
- Lower per capita emissions from the transportation sector.
- Lower per capita traffic fatalities.
- Lower per capita consumer transportation expenditures.
- Higher per capita transit service provision.
- Higher per capita transit ridership.
- Higher transit commute mode split.
- Lower transit operating costs per passenger mile.
- Higher transit service operating cost recovery.
- Lower CBD parking per 1000 jobs.
- Better overall urban design in the city (Newman, P et al., 2013).

On the costs per passenger mile (or kilometre) please refer to, in the appendices, 'U.S. Costs per yearly Passenger Kilometre Compared', and for a chart depicting the influences of each mode on the urban fabric see 'Transit Capacities and Urban Form .

5. COMMUTER RAIL

For most practical purposes, the commuter rail uses similar technology to the metro system, however commuter rail travels with fewer stops, travelling faster to fewer and further destinations in the suburban and peri-urban parts of the metropolitan region. Metro is designed for dense urban areas with short stops. Commuter rail benefits include a displacement of needs for highway lanes, reduced central city parking, reinforcing the small town character on the peri-urban fringe among others.

1. PARKING

Parking is very determinative of the ultimate urban form in all redevelopment projects. Allowing unfettered access to cars brings people conveniently to shop, to businesses to work and to homes if the car is their main and only means of transport. It certainly has been a successful model if measured by only one indicator – mobility. If this is how a city or neighbourhood has been structured, it may be difficult to undo the physical infrastructure but many times more challenging to rework the social expectations of this unfettered mobility. In New York, for example:

> The new zoning code limited potential densities through height, bulk and use restrictions and introduced parking requirements throughout the outer boroughs and northern Manhattan in order to better serve automobile- oriented development. Parking requirements often reduce the buildable size of lots to levels below what is allowed, and reduce the likelihood of achieving densities that support transit (King, 2011 p.26).

Or, to paraphrase Donald Shoup, the value of all lands under asphalt and devoted to parking is likely far more than all the cars sitting on the asphalt.

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

Not only does automobile parking cover valuable land, it also:

- reduces profitability for developers in the short term as they need to provide minimum requirements for parking,

- reduces rates to governments in the medium term as fewer rate payers live and shop per service level, and

- further erodes long-term finances of governments as the roads and parking will all need to be maintained on 20 and 40 year cycles.

Furthermore, parking has the perverse ability to remove any sense of main street or traditional neighbourhood urbanity as it creates large areas hostile to human-based activity and interaction. Lastly, large areas of parking contribute to heat island effect, cover

ecosystems and shed stormwater, along with any pollutants and litter, into waterways (negating attempts for Water Sensitive Urban Designs), causing further ecological damage.

Buehler writes about the reasons some places in Europe are more successful as urban precincts:

> Not only is the supply of roads per capita much less in German cities than in American cities, but motorways are also mostly restricted to the outskirts of German cities and rarely penetrate city centres. By comparison, most American cities and suburbs are criss-crossed with extensive networks of high-speed motorways and wide arterials. Most German cities have reduced car parking supply and increased its cost, whereas most American cities continue to focus their redevelopment plans on increased provision of low-cost or free parking for cars (Buehler & Pucher, 2012).

Or, as Jacobs and Appleyard wrote in 1987, density must rise and parking ratios fall if there is to be urban life:

> Density of people alone will account for the presence or absence of certain uses and services we find important to urban life. …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 & Appleyard, 1987).

Donald Shoup continues in this vein:

> 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).

And Manville agrees:

> 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 & Shoup, 2005).

In summary, excessive parking leads to a diminution of civic sensibilities and even a destruction of both urban and ecological life.

2. PRODUCTIVITY

Agglomeration benefits and transformational effects are often thought to be critical …for large urban rail projects, like Crossrail in London, which are much more relevant to development of the labour market (Perkins, 2011).

Agglomeration economies are the measured increase in new jobs that occurs due to the synergies created from density and scale (Graham, 2007; Glaeser, 2011; Trubka, 2011). Cities which pursue an integrated transport and land-use planning strategy have the opportunities of agglomeration benefits – greater opportunities for new jobs, better work/jobs balance in neighbourhoods, shorter commute times, shorter business to business contacts and increased activity leading to higher revenue streams from rates and an effective increase in labour pool. All of these benefits, and more, make the city more desirable in the global setting for investment and talent.

However, on the flip side, for those cities that wilfully pursue automobile dependence, as do most Australian cities, Jago Dodson warns:

...households in inner suburban locations typically experience the advantages, from an oil vulnerability perspective, of higher incomes and lower reliance on automobiles for transport than those in outer suburban zones. These patterns are not transitory but a durable structural feature of the Australian metropolis. Urban structure and the local conditions of resilience and adaptability that urban structure engenders will be a critical factor that shapes household socio-economic circumstances under conditions of higher petroleum prices or mortgage interest rates (Dodson & Sipe, 2008).

The implication of Dodson's warning is that mortgages may continue to rise, as may petroleum prices, impacting on lower income earners the hardest. This may be overcome on a personal level so long as there are other options, which there aren't as this is a 'structural feature' requiring massive investments in urban rail and increased permissive densities in the form of well-designed multi-family units (apartments).

These pressures sit beside the pressing changes to the atmosphere which may have profound impacts on the social and economic life of cities if they are not dealt with accurately and responsibly: extreme weather events, change in duration of weather events, rising sea levels and increasing water tables, some plant life being unable to cope while others take over the niches and flourish (IPCC, 2013).

3. CLIMATE CHANGE

That patterns of global weather are changing cannot be doubted. That climates have always changed is true, but rarely ever as fast as now. Winter and summer seasons in the north and south are becoming colder or warmer, respectively, while weather in the more temperate regions has become more violent in its effects (IPCC, 2013).

How much of this is due to humans and the burning of fossil fuels is debated, but one must still ask 'Where else is the problem coming from?' Oil and coal deposits represent thousands of years of photosynthesis and the stored energy is released in matters of minutes, compounded by hours, days and years, and we have a really great issue of excess carbon in the atmosphere.

If we could reduce the resource-intensive lifestyle of the OECD and provide a better, wealth-creating, low-carbon economy we will begin to combat the prevalence of carbon in the atmosphere. Designing our cities to match the crisis is a long project, but a worthy one (Roseland, 2005; Kenworthy, 2006; Turner, 2008; Condon et al., 2009; Perkins, 2011; Salat et al., 2011; Kelly et al., 2012).

4. AIR QUALITY

Likewise, the quest to have clean local air is of great importance.

> The data indicates that particulate matter and other toxins are in their highest concentrations along roadways and intersections than anywhere else in a typical city. This indicates that transportation traffic in the city contributes as much or more significantly to air pollution than surrounding industry does; and these emissions are directly related to acute and chronic heart disease (Topalovic et al., 2012).

To arrest the growth of private automobile emissions we will have to offer other means of travel on equally excellent multi-destination transport networks. Linking walkable

mixed-use environments is a significant strategy and fundamental to a Transit-Oriented Region.

5. HEALTH

Over the past two decades, there has been a growing recognition that our contemporary urban environments adversely affect our health in new and apparently more intractable ways than in the past (Townshend & Lake, 2009).

Diabetes, obesity, cardio-vascular disease, air particulates causing respiratory problems, stress are all being linked to living an automobile-dependent lifestyle. Those living in automobile-dependent cities don't walk as much as they ought to; they tend to eat more processed foods (high in fat, salt and sugar) as their time-budgets don't allow the flexibility of growing food and preparing proper meals; they tend to experience undue stress sitting in traffic congestion after a long day in the office, also sitting down and being stressed with timelines; and likewise, the act of commuting by automobile places them directly in the particulate- and gas-rich exhaust of many thousands of vehicles.

The link between obesity and car dependence is that if the whole travel time budget is taken up by driving, little time for walking will be found. Building cities where walking is part of the travel-time budget is a major reason for creating less car-dependent cities (Newman & Kenworthy, 2006).

There are many academics working in this area of linking health outcomes to lifestyle with most finding that automobile-dependent lifestyles are not adding to our quality of life. The list of citations here could be very long; relevant findings include these from Frank, Townshend, Edwards and Stokes.

From Frank:

Each additional hour spent in a car per day was associated with a 6% increase in the likelihood of obesity. Conversely, each additional kilometer walked per day was associated with a 4.8% reduction in the likelihood of obesity (Frank et al., 2004).

Increasing walking to about 2 kilometers per day is roughly equivalent to the public health goal of at least 30 minutes of moderate activity. This goal may be achieved through a variety of policy options that include shorter-term incentives for walking for both utilitarian and recreational purposes, and longer-term changes in the

built environment, such as increased mixed use, density, and street connectivity that make walking an attractive and viable option (Frank et al., 2004).

And to get there, Frank recommends:

> 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 & Engelke, 2001 p.215).

Townshend finds an interesting relationship:

> An interesting relationship that seems evident from these studies relates to people who live in traditional mixed-use neighbourhoods. These are those neighbourhoods where local shops and services, school and employment opportunities are easily accessible within walking distance of people's home of a type prevalent in the UK up to the 1960s. Here, people tend to over-estimate the number of opportunities they have at their disposal for activity, contrastingly those in more recently developed neighbourhoods, designed around car use under-estimate opportunities. If use levels are linked to perception, as much as actual availability, then it appears that traditional mixed-use areas are doubly advantaged (Townshend & Lake, 2009).

> Individuals living in neighbourhoods with higher population density, greater access to public transport and a greater mix of land uses had significantly lower BMIs compared to groups living in neighbourhoods that did not display these characteristics; though the study found no correlation to measurements of connectivity (Townshend & Lake, 2009).

Edwards finds that transit access promotes walking to the extent that it may reduce the chances of obesity:

> While no silver bullet, walking associated with public transit can have a substantial impact on obesity, costs, and well-being (Edwards, 2008).

Use of public transit is associated with more walking, by about 8.3 extra minutes per day. This is not enough walking to halt the spread of obesity, but it could substantially reduce it (Edwards, 2008).

And Stokes reminds us that the layout of the streets, in grid or modified grids, rewards the walker with closer destinations and safer routes:

Mixed-use development also provides more local commercial options that do not require automobile trips. Grid street patterns lessen pedestrian distances and provide a safer walking environment (Stokes et al., 2008).

6. OIL AND ENERGY

As a powerful, transportable, refinable energy source nothing is superior to oil. Oil's energy density is fantastic; it can harvest food and move products across oceans in ways which, if left to manual operations, would take years off lives better spent undertaking more productive tasks. That oil is so precious means we ought to be preserving it for things we cannot do by other means. This need not conjure a command economy approach to the resource: were policies and funding readily available for other transport modes, much discretionary travel would switch to public transit, commuting would be merely understood to be something done on foot, bike or public transit and highway freight may switch back to rail. As such, a policy approach to better urbanism and regional development may be much more effective than trying to restrict oil and the companies which control oil. If governments were to set new societal objectives as policy, match it with funding, and apply funds only to projects which are impossible to achieve otherwise (Search and Rescue Helicopters, for example). Regarding manufacturing and energy use, Richard Florida states:

One of the most surprising concerns manufacturing. Intuitively, you'd think that carbon emissions must be a function of the intensity of industrial manufacturing activity. When the subject is pollution, smoke belching factories are among the very first things that come to mind. But surprisingly, when we looked at the correlations between the metro share of manufacturing industry and all three measures of carbon emissions, we found no statistical relationship. Manufacturing plants have been under competitive pressure to eliminate waste and become more efficient for decades. ....transition of manufacturing from old-line to leaner, more agile production models that reduces or eliminate defects, inventory, and waste. Industry has become cleaner (Florida, 2012b).

Despite the recent fracking technological breakthroughs, oil is getting dearer and harder to extract. Even if this were not so, the expected expense of owning and operating a private motor vehicle has become daunting for many, and for everyone, no matter what they might be able to afford, a very bad investment. Cars depreciate every day, they never gain value and petrol is an input that knows no end and does not improve the product other than for the short-term gain of being able to reliably arrive at a destination. Again, Florida writes:

> Cars are huge emitters of carbon dioxide, so it stands to reason that car-dependent metros would emit more. Car commuting is significant culprit in emissions across metros. The share of people who drive to work is positively correlated to all three measures of emissions, while the share of people who commute on transit and by bike are both negatively associated with all three emission metrics (Florida, 2012b).

2.1.3   SUMMARY: AUTOMOBILE DEPENDENCE

Automobile dependence is both real and destructive, but potentially waning in the OECD countries as transit investments are matched with denser urban living patterns. The real challenge, however, will be in creating an aspiration for ameliorated urban living based on public transport *accessibility* to services and jobs, rather than congested *mobility* with automobile travel to ever further distant jobs, in both OECD and non-OECD nations' cities. In this will be the liberation from automobiles, taking them from the forefront to the background of urban and transport planning. What is missing from the literature, largely, are the details on how to tackle the issues at a regional and national level through a consistently applied urban design and urban prioritisation policy.

How land-use planning, and its subset of transport planning, may be useful in accomplishing this end will be explored in the following sub-chapter of this Literature Review.

2.2 REGIONAL LAND USE AND TRANSPORT INTEGRATION

> "..investments… should be enabled via policies, including land use planning to promote compact or mass-transit corridor-based cities…" (UNEP, 2011b).

This section will discuss the current status of modelling broadly, then more specifically about land use and transport modelling separately, with a section devoted to the combined efforts of land use and transport integration (LUTI) modelling.

It is entirely agreeable that we should have investments and land uses that promote mass transit but the questions remain: where and how? Despite the sometimes dismal on-the-ground evidence there are many professionals working on this question in most OECD cities. Every year some of the best meet to discuss the issues pertinent to city and regional transport matters at the Transport Research Board in Washington D.C. There are dissenters though:

> The problem with the TRB (Transport Research Board) Annual (Conference) is it is full of people with a math solution looking for problems… rather than design geometry or land use (Per Comms. Anonymous consultant delegate from Baltimore at a TRB conference on Light Rail, 2012).

There is no lack of modelling regarding urban futures. There are many consultancies, research units, academics, governments and non-government organisations using available data to project robust forecasts of how urban growth and transport provisions will be expressed. While there are many such models[5], the scope of this project is to fill in a very large gap between strategic planning and the implementation of housing, jobs and modes of transport needed in a liveable 'green' city. There remains a large disconnect between professions and the politicians and citizens in regards to the process of developing an urban region or local area. Models need to be easier to implement and prepare, less exacting in all the data required, malleable as a tool to test scenarios (rather than as a generator of

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[5] A list of various models may be seen at "Transportation Forecasting". Wikipedia. http://en.wikipedia.org/wiki/Transportation_forecasting Accessed May 12, 2014

'the right answer'), easy to understand and change assumptions where the implications of the scenarios for citizens and politicians can be communicated. In short, the models need to become less 'black box' and oracle-like.

The models developed to test the hypothesis for this thesis will, hopefully, achieve this flexibility and transparency.

To affect the 'scale of the operation' in changing our urban form and fabrics one needs to work within the system, speaking a language understood by the decision makers and engineers. These are the politicians who agree to raise taxes or levy fees on citizens to pay for infrastructure changes and the engineers who will design and construct the physical changes to the urban fabric. To make these changes to this operation, one needs to know how it works. Therefore, this research project asks how, within the policy settings and the urban footprints inherited, we may begin to create a new type of urban form and fabric. Yet, the gap remains between modelling and practical considerations of outcomes, policy and practice, strategy and implementation. To close, or bridge, this gap will require knowledge of how each side regards the issue. This research project will demonstrate one such method.

To review the current status of land use and transport modelling will require breaking down the discussion into four distinct areas: Density; Transport; Land Use; and Integrated Transport and Land Use.

2.2.1   DENSITY

Urban design, reflected chiefly in population and job densities, emerged as the most significant determinant of the travel patterns in cities around the world (Newman & Kenworthy, 2006).

Cities struggle to deliver transport services and accommodate population growth. This was the likely situation in the first cities in Mesopotamia and into the Roman, European, colonial and in other times of rapid population expansion. Unfortunately, today many cities are trying to balance the growth in exclusively automobile-based urban fabrics. The rising wealth in global urban settings has contributed to higher demand for consumer goods, including the private automobile. Furthermore, the rising population growth in almost all cities, with a few exceptions in the wealthy industrial countries, has led to a high

degree of urban growth being directed towards areas with few urban amenities and especially a lack of high-capacity public transport.   This two-pronged fork, of rising wealth and broadening city footprints forged in automobile dependence, has been the case in OECD countries over the last century and dramatically in non-OECD countries' cities more recently.

There are certain cities which have automobile-dependent urban fabrics designed to accommodate the private automobile to the exclusion not only of the pedestrian and cyclist but also, purposefully or not, to limit the capacity of public transport to support efficient land use.   There are also a great number of cities, such as Buenos Aires and most Asian cities, which have a larger proportion of walkable and transit-ready urban fabrics, but which suffer from an onslaught of automobiles crowding the street, sidewalks and intersections in congestion. Many civil servants, academics and concerned citizens are already very aware of the limitations of automobile dependence and have formulated cogent arguments against automobile use-inducing highways, have catalogued the problems of low-density single-use sprawl, remarked on the noticeable lack of walkable third places and loss of community, calculated the cost of building and maintaining infrastructure, enumerated the habitat loss in greenfield development, written about their local and global air quality concerns, and expressed a number of other anxieties. Despite all the best written arguments against 'sprawl', it requires policies at the planning departments of cities and regions to activate the land use and transport changes which can turn cities towards walkable, transport-appropriate, mixed-use, urbane environments suitable for the best of human relationships (Newman & Kenworthy, 1999; Ewing & Cervero, 2001; Frank & Engelke, 2001; Turner, 2008; Cervero & Guerra, 2011; Speck, 2012).

Please see Appendix H, Appendix I, Appendix J and Appendix K starting on page 460 for a graphics on the topic of density.

Often the tangible ideals of 'comfort and liveability' are pursued in cities, inexactly and expediently, through zoning which limits height, bulk, residential and commercial densities. Properly expedited, zoning maintains an urban environment which does not negatively affect the surrounding land uses and yet permits certainty in investing in urban growth. Yet, zoning rarely achieves these stated aspirations. For example, in New York there is still a great deal of unrealised zoned mass:

The 1916 zoning code did regulate building height and bulk, but famously had (New York City) been built out to full extent allowed by the code, it would house over 55 million people today (King, 2011 p.24).

While a New York City built out to its maximum possible population seems unlikely and untenable it does reflect the factors, including parking (see BUS, BRT, LRT, Metro: Level Of Service p.63), that govern the difference between aspirational and possible yields in any one project (see Results: The Local Scale - Stirling City Centre **Model 3.2** p.332).

Richard Florida reiterates that denser cities have several benefits including innovation and lower energy:

Emissions are negatively correlated to both population size and density, according to our analysis. Bigger cities and denser, more compact living patterns offer a double benefit: They not only stimulate innovation and leverage productivity, but also use less energy and generate fewer emissions per person (Florida, 2012b).

Jeffery Zupan, a formidable and long-standing researcher on the topic of the land use and transport nexus, makes the very clear point about the need for density to support transit:

The basic point … is that you need density to support public transit. In all cities, not just in New York, once you get above a certain density two things happen. First, you get less travel by mechanical means, which is another way of saying you get more people walking or biking; and, second, you get a decrease in the trips by auto and an increase in the trips by transit. That threshold tends to be around seven dwellings per acre[6]. Once you cross that line, a bus company can put buses out there, because they know they're going to have enough passengers to support a reasonable frequency of service (Owen, 2004).

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6 7 dwellings per acre to convert to metric: (1 hectares= 2.47) 7 per acre equal 17 dwellings to the hectare. Multiplied to include residents of 2 per dwelling gives 35 residents per hectare and at 2.5 residents per dwelling approximately 43 residents per hectare. Jobs would be higher as, perforce, jobs require less space than living space.

Interestingly, seven (7) dwellings to the acre converts to approximately thirty-five (35) persons per hectare, the same as Newman and Kenworthy described in *Urban Design to Reduce Automobile Dependence* (Newman & Kenworthy, 2006).

Yet, due to automobile dependence the opposite has tended to happen. In the most extreme cases, there are once dense areas of the city which become abandoned as those who can afford automobiles move out to areas better spatially arranged for their automobiles. Unlimited mobility ought to bring us closer together to create a truly rich and diverse resilient city, yet automobiles do not deliver this goal very well:

> A Mobility strategy:…some people will commute by plane occasionally, some will drive, some will be using trains to commute, but the largest modal shift will be towards walking. We are going to have a lot more people who are going to live closer to where they work, or work in their own home, and the mobility will be a mix of those strategies (Florida, 2012a).

Recently, in Bristol in the United Kingdom, there was an attempt to establish a level ground of understanding regarding the 'smart growth', 'new urbanism', 'compact city' debate over urban intensification. After realising that a higher density of people living together filters the volume of 'trips' with fewer automobiles in favour of more walking and public transport, the authors report that:

> ...planning policies which increase population densities will, under 'normal circumstances' reduce overall vehicle use, but increase its concentration in the intensified areas, causing a range of local environmental and social problems, unless significant steps are taken to constrain the generation of additional traffic. It is important that this paradox of intensification is recognised, to avoid false expectations…(Melia et al., 2011).

And then slightly further that:

> At the level of the individual development higher densities will, under most circumstances, generate more traffic: positive measures to promote modal shift are unlikely to counteract this on their own.

Suggesting finally that:

> At this level policymakers face two choices: accept the local consequences as the price of wider progress, or take more radical measures to constrain traffic growth in intensified areas (Melia et al., 2011).

While at first a finding contrary to the aims of this research, this does actually support the main thesis questions: What is the appropriate level of transport services (mode, frequency, speed, capacity) which must accompany urban intensification? And in reverse: What level of urban intensification via land-use changes across the region (along with other physical planning policy) is required to make the economic arguments and mode-splits to support the introduction of costly high-capacity public transport?

Or, put another way: If we want a multi-modal urban environment, in which all modes are equally planned for, what density do we need locally and regionally to make best use of their introduction? Once we have the density, what is the best mode of transport to carry the appropriate daily throughput which makes the service useful and desirable across the region? An approach to resolving this question will come through the modelling for a Transit-Oriented Region.

> ...in order to realize significant net positive economic impacts compared to the base case, land uses within the corridor must be permitted to, and encouraged to, change and intensify significantly (IBI Group, 2009).

2.2.2   LAND USE MODELLING

It has been understood that there are a suite of influences in regards to urban land development processes (Suzuki et al., 2013).

Two features of the built environment are commonly thought to exert a significant influence on travel behaviour: densities and levels of land-use mixture (Cervero, 1996).

Land use, broadly, is characterised by differing rations of residential, commercial, retail, industrial, institutional and public open space (POS) uses. Each of these has various other shades of uses; under 'institutional' will fit schools, universities, hospitals, civic buildings and so on, while under 'POS' fall public utility lots for stormwater, ornamental parks, ecological reserves, sports grounds, playgrounds, beaches and such. How much of each use and how it is distributed for a variety of concerns including car parking, traffic movement, incompatible noise and air quality, historic character, watershed, views and so forth is typically a contentious issue. These concerns are the preview of planners, citizens and city hall in established areas, and typically landscape planning and engineers in new greenfield subdivisions. There can be considerable sophistication in the planning and design of places, however the distribution of these land uses is often premised on only one of these listed criteria. Unfortunately, for much of the 20th century that one criterion has been to facilitate automobile mobility.

By pure chance, certain characteristics of these older areas made renewal easier. The interweaving of residential buildings and commercial premises created mixed-use neighbourhoods that gave residents easy access to a range of shops and services. A diverse range of building types (including former factories and warehouses) enabled the conversion of existing structures to new uses. Rich public transport networks and proximity to jobs lifted land values and made redevelopment viable…..But the communities being established in greenfield areas lack these qualities. Instead of mixed use neighbourhoods, different activities are largely kept separate. Detached houses on similar lot sizes are the norm. Ownership is fragmented across large areas of land that are used for a single purpose. In the future this will make it hard to assemble larger parcels of land for redevelopment. Transport networks can be weak, jobs are often distant (Kelly et al., 2012).

2.2.2.1 LAND USE PLANNING - DYSTOPIAN OR UTOPIAN?

The value placed on private vehicle ownership will have far-reaching impact on functional and transport morphology (Dent, 1996 p.287).

One could say the current urban land development system does enact this exact macro-analysis (analyse, calculate and enumerate) responding to pressures from society: they are called the Market and Government Policy (Cox & Utt, 2004; O'Toole, 2004; Cox, 2014). These two factors are a powerful blender of demographics, engineering standards, developers and bankers, financial certainty, civil servants and their politicians all working in sequence. Though the current system produces aesthetically displeasing 'traffic sewer-oriented strip-mall' corridors with inefficient housing and jobs location mix, it does demonstrate what is achievable and tolerable. Furthermore, the argument goes that the market provides commodious housing and that the considerable drive for most new home-owners is a part of an overall healthy economic Gross Domestic Product.

Yet, to reach for the 21st century goals, for example of cleaner atmospheres, improved health or regional planning targets for compact population growth, the market needs to operate as an equally efficient developer of a *sufficient* residences and jobs mix at high-capacity public transport locations. The strengths of housing production within the current markets systems must be harnessed to create a broader typology of urban environments including more single family detached houses where appropriate, and split-level townhouses, stacked townhouses, apartments and condos at various heights. Likewise, the strengths of infrastructure production within the current market system may be shifted from an automobile orientation to provide on-site construction and off-site manufacturing jobs in provision of the rail and rolling-stock for a new priority of public transport priority. So long as the government policy supports the compact city and diversity of choice direction, rather than the opposite of highway expansion for low density suburbs, the market will produce an optimal density to support locally constructed public transport. Markets are framed by regulations.

The density and transport mix suggested in the research may lead to images of dystopian futures, or accusations of being not-mindful of the 'local context' of existing neighbourhoods, which is a fair position to take.

However, it has been taken as a position that the far more dystopian future and disregard for 'context' is the situation we are currently driving towards. The current

situation includes housing affordability being predicated on extensive highway construction to greenfield sites of flattened farm and forest. The unintended consequences are further increases of 'ecological footprint' as ecosystem services are replaced by carbon-emitting homes and automobiles; expenses to the personal and national economy over the middle to long term as the cost to operate a private automobile and maintain the network of the highway; the simple act of walking for daily services and amenities occurs at a density which is far too low to support local shops or a desirable public transport service.

In actively promoting a methodology supporting compact, walkable, transit-supportive urban redevelopment it is assumed there is a requirement for a concerted effort to create useful and enjoyable urban places 'between the buildings' (Jacobs, 1958; Lynch, 1960, 1981; Jacobs & Appleyard, 1987; Gehl, 2001; Jacobs et al., 2001) that are not deleterious to the human habitat. This type of housing/jobs mix adjacent to primary transport infrastructure has been present throughout the long history of city building and can be replicated in spirit if not in the flesh. As land use with transport integration has been normal throughout history, the results of this research should appear undramatic and far from utopian. Rather, the research will point towards change, but change towards a more vibrant and opportunity-rich urban environment which is entirely recognisable, just performing much better.

There have been many propositions preceding the current debate (Fishman, 1982); most try to dismantle the existing city or build a new utopia (Hall, 2002). There have also been several high-level research publications which deal with change in urban form and the to the human footprint such as Richard Weller's work on Australian cities (Weller, 2009; Weller & Bolleter, 2012) and Pierre Belanger's work on the Great Lakes Watershed as an urban and ecological network of overlapping resources and pressures (Belanger, 2013). While treading a fine line, the research in this thesis will try not to be utopic or detail free. Rather, the results presented here suggest that leveraging the latent capacity in our existing transport corridors will provide sufficient access to many under-performing urban sites for the next 50 years.

The research suggests that we need to use the proven public transport technologies to their best and highest use on land which has been up-zoned to its best and highest use,

without promoting fantastical utopian scenarios or submitting to the forces of automobile dependence.

Several cities have, in some ways, already prepared themselves for a new future; these will be discussed below.

This section will review the outcome of three different strategic regional plans: one from Portland, Oregon, was derived by a consortium of NGOs and consultants; Metro Vancouver's regional plan was the product of a regional planning body under the auspices of a provincial government; the third was produced directly by a state government while the fourth was the creation of a board established by state authority. What will be contrasted, but not compared, is their ability to achieve the goals set out in the documents. This brief overview will cross not just national boundaries of the automobile-dependent Anglosphere but also represent the different levels of engagement by concerned citizens. These are all cities facing enormous automobile dependence and trying to turn urban growth towards transit-oriented urban form and fabric.

L U T R A Q

Our Mission: Working with Oregonians to enhance our quality of life by building liveable urban and rural communities, protecting family farms and forests, and conserving natural areas.[7]

A century and a half plus after being settled via the Oregon Trail, a conveyance to populate the 'vacant and under-utilised' (by Europeans) fertile land, Oregon was once again at crossroads. It could see clearly the consequences of mismanaging the growth of the city by looking south towards Los Angeles and north to Seattle and it knew there had to be another way. To mark directions at this crossroad, 1000 Friends of Oregon, a non-government organisation in Portland, Oregon, underwent a rigorous process to delineate what the citizen of the Portland Metro region wanted from the future. The results were published in the multi-volume report *Land Use, Transportation, Air Quality* (LUTRAQ) between 1991 and 1997.

From Volume 7 of the LUTRAQ report:

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[7] "Our Focus". 1000 Friends of Oregon. http://www.friends.org/about/our-focus

From principle to practice: Incorporating transit-oriented development into an alternative for an environmental impact statement process required thorough analysis of demographic projections, vacant and underutilized lands, and market trends. The analysis revealed several factors favouring development of TODs:

- Increasing demand for multi-family housing

- Rapid growth in retail employment

- A good supply of land in proximity to existing or planned transit routes

More than 22,000 acres, approximately one-third of the land inside the urban growth boundary in Washington County, were identified as vacant or underutilized. From this supply, unbuildable lands (wetlands, steep slopes, and protected areas) were removed. Of the remainder, lands within one-half mile of the light-rail and express-bus system were considered eligible for Mixed-Use Centres and Urban TODs…(1000 Friends, 1997 p.10).

Compared to other scenarios the analysis produced these results:

	No Build	Highways Only	LUTRAQ	LUTRAQ TOD Areas Only
Work Trip Mode Choice:				
Walk/Bike	2.8%	2.5%	3.5%	5%
Transit	7.5%	8.8%	18.2%	28.2%
Carpool	14%	13.6%	20.1%	17.2%
Drive Alone	75.8%	75.1%	58.2%	49.6%
Vehicle Trips/Household	7.53	7.5	7.17	5.79
Vehicle Hours of Delay (compared to No Build)	–	-43%	-53.2%	
Vehicle Miles Traveled (compared to No Build)	–	1.6%	-6.4%	

Source: LUTRAQ Vol. 5: Analysis of Alternatives

Figure 10 LUTRAQ vs. Alternatives

SOURCE: LUTRAQ (1000 FRIENDS, 1997 P.15)

It was demonstrated that, by following a constrained land supply as per the Urban Growth Boundary; increasing permissible density near public transport services; increasing

public transport levels of service; and emphasising the pedestrian environment to be both safe and pleasant, projections showed 22.5 percent fewer work trips by automobile; 27 percent more trips made by transit, walking and biking; 21 percent greater access to jobs; 7.9 percent fewer GHG gases and 7.9 percent less energy consumed (1000 Friends, 1997).

Contemporaneously, to the north of the United States' border in Vancouver was another group, though this one was led by one level of government under the auspices of a higher level, targeting similar outcomes for a similar urban region.

LRSP

Metro Vancouver's Liveable Regions Strategic Plan (LRSP)(GVRD, 1996) marked a turning point in acceptance of the role regional planning could play in the Vancouver region. Prior to this time there had been other plans (Harcourt & Cameron, 2007) but during the duration of the LRSP politicians, media, designers, citizens all reported that LRSP was the blue-print document driving the priorities for every investment from transit to playgrounds.

With clear targets for density and mixed land uses in each sub-area of the region, it is relatively short at only 34 pages; it accomplished a great deal with few words. The fundamental strategies of the LRSP are to:

> Protect the Green Zone; Build Complete Communities; Achieve a Compact Metropolitan Region; Increase Transportation Choice (p.9)

Yet, it only sets targets, leaving the details to the local government.

> The Strategic Plan includes targets for population, housing and employment for the entire region and for the Growth Concentration Area. This helps to define the region's long-term development vision, and provide a framework for municipalities to manage growth at the local level (p. 12).

When it comes to complete communities the policy pursued by the GVRD board is to achieve:

> 8.1 a better balance in jobs and labour force location throughout the region;

> 8.2 a diversity of housing types, tenures and costs in each part of the region in balance with job distribution;

8.3 an equitable distribution of public social and cultural services and facilities;

8.4 development of a network of high-quality, mixed activity urban centres supported by an appropriate level of public transit and a range of community services and cultural facilities for residents and employees.

The final plan was deceptively intuitive; it seems simple, but to anyone familiar with the process and the region it all seemed very plausible.
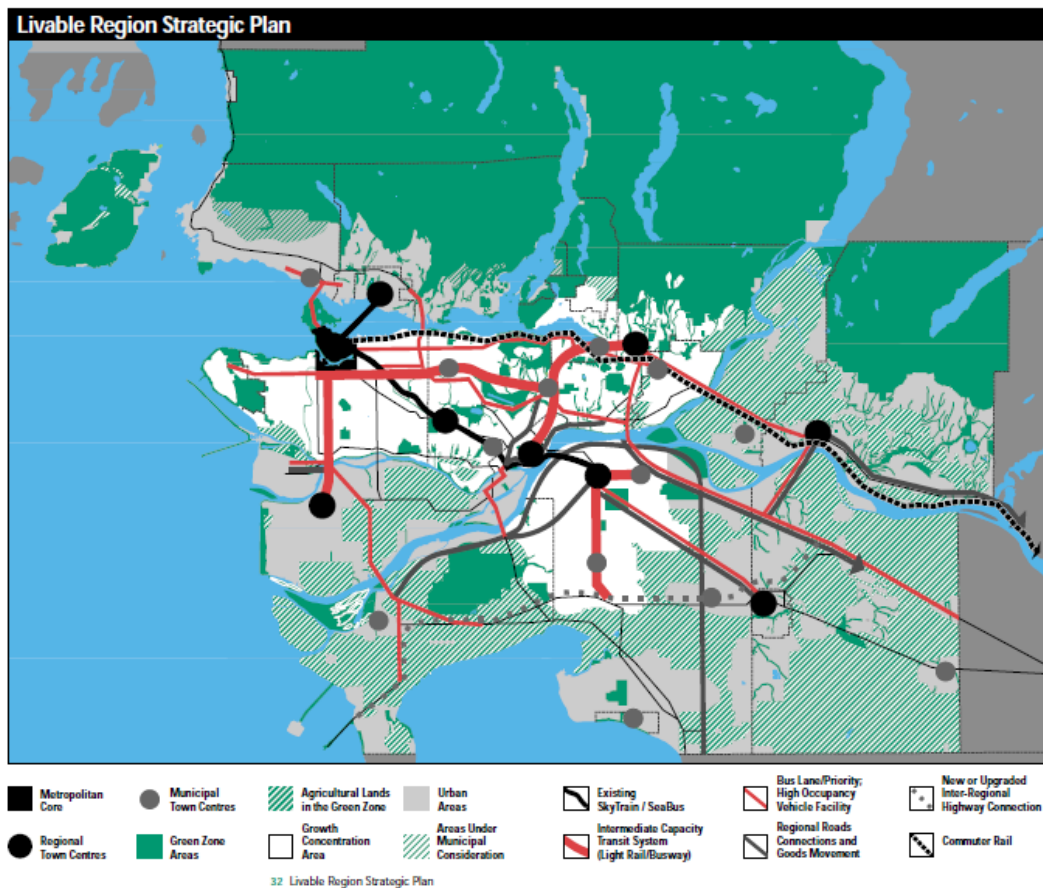
Figure 11 LRSP of Vancouver, 1995

SOURCE: GVRD (CURRENT METRO VANCOUVER)(GVRD, 1996)

This has now been converted into the most current regional plan iteration called Metro Vancouver 2040.

Metro Vancouver's population is currently 2.4 million, and we anticipate another 1 million people by 2041. As a result, we also anticipate an additional 500,000 jobs. Regional Planning develops and implements long-range land use and transportation policies that: direct this anticipated growth to Urban Centres and along

frequent transit corridors; establish and maintain a strong urban containment boundary; support a strong and diverse economy; and vibrant complete communities; and protect the region's vital industrial, agricultural and conservation lands.[8]

By many measures, Vancouver is succeeding in achieving the goals. The 2009 Sustainability Report, the latest report, shows that increasingly people live closer to work, find better ways of commuting and that the urban land area is not increasing.

Figure 12 Commute Distances - Metro Vancouver 2009 report

8 "Regional Planning" Metro
Vancouver: http://www.metrovancouver.org/PLANNING/DEVELOPMENT/Pages/default.aspx Accessed February, 2014

Commuters are beginning to choose alternatives to driving alone

	1996		2006
🚶	5.8%	⬆	6.3%
🚌	14.3%	⬆	16.5%
🚗	6.6%	⬆	7.1%
🚲	1.7%	➡	1.7%
🚗	70.6%	⬇	67.3%

JOURNEY TO WORK BY MODE SPLIT, METRO VANCOUVER, (1996 TO 2006)

Figure 13 Mode Share - Metro Vancouver 2009 report

The area of urbanized land is not changing

HECTARES	2001		2006
Rural Residential	4,844	⬇	4,408 hectares
Residential	30,243	⬆	31,383 hectares
Commercial	16,297	⬆	16,789 hectares
Other	15,357	⬇	14,161 hectares
TOTAL URBAN AREA	66,741	➡	66,741 hectares
Indian Reserves	1,471	➡	1,471 hectares
Total Non-Urban Area	195,301	➡	195,301 hectares
TOTAL METRO VANCOUVER	263,513	➡	263,513 hectares

Figure 14 Urban Land -Metro Vancouver 2009 report

SOURCE: "METRO VANCOUVER SUSTAINABILITY REPORT" (METRO VANCOUVER, 2009)

DIRECTIONS 2031

Perth has had a metropolitan-wide strategic plan since 1955 and the ability to deliver it through a statutory plan and a regional planning body with funds for infrastructure and land purchase (Hedgcock & Yiftachel, 1992). These mechanisms were all used to build a completely car-dependent city. When contrasted with the last two strategic plans in Perth for its ability to deliver, the present plan, Directions 2031, does not come out favourably, except in two ways.[9] Firstly, it is the first plan to begin to try and reduce automobile dependence but on this it is very cautious; by being more cautious and *not* overly prescriptive it does allow for more inertia. However it does also anticipate the provision of the knowledge needed to make a less car-dependent city with several scales and iterations of TODs as found in East Perth, Subiaco, Joondalup, Cockburn Central and Wellard. Though not strong, the plan does facilitate growth of sub-centres along public transport lines. Secondly, it moves the conversation towards the goals, building willingness and expectation among the developers and residents, acting as a 'capacity building' exercise. (For more on Directions 2031, please see The Perth Metropolitan Region: from Colony to Global City p. 115)

ENVISION UTAH

Envision Utah brought together all the stakeholders in the state to evolve a common set of principles to guide their urban and economic growth. Commonly heard aspirations from the residents, elected officials, developers, conservationists and others were: to be safe in close-knit communities with opportunities for children, with ample time and access to good jobs. To this end a comprehensive state-wide plan was developed to guide the following suite of concerns from the regional to the local scale. Priorities were set by a series of scenario plans in which concerned citizens were able to choose a level of tolerance

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9 'Direction's 2031' is discussed more fully in Section 2.3: The Perth Metropolitan Region: from Colony to Global City.

for traffic congestion, air quality and extent of development footprints on the rough, yet delicate, landscape of Utah. This then led to visioning different physical spatial futures for many large and small cities around Utah, and especially greater Salt Lake City, to uncover what the citizens desired 'in the midst of change, preserve what we love while improving our communities'.[10] To this end, a list of 'tools' was developed and used to spread a new gospel about the costs and benefits of choices, to build capacity and to have a more educated, and less misinformed, reaction to the process of urban growth.

The results of these interactions with community and stakeholders have underpinned decisions to invest in light rail and streetcars and to create more TOD, along with significant urban uplift and infill, in areas directly influenced by the proximity of the new high-capacity rail network. The success has been the accepted adoption of the TOD principles (Envision Utah, 2014) and participation across the state mostly known for its wilderness, powder skiing and canyons, and much less for Brigham Young's platting of broad streets and establishing of irrigation water resources.

SUMMARY

The most important difference between the four plans is that the first aimed to protect green space, and prepared population and jobs targets across the board along with air quality and transport figures; the second aimed at protecting green space also while adding exact numbers of population and jobs into named sub-areas and expecting good results from these efforts in regards to transit use; the third only nominates sub-areas and makes no motions towards numbers or targets other than that 47% of new growth should be as infill on already urbanised lands though follow-up targets have been produced for each local government area; and the fourth is primarily aimed at building a common dream in a state not previously known for its urbanism. The four are each ambitious in their own way within their political dynamics, but to different degrees and ultimately leading to different levels of success. Portland envisages itself a medium-sized city with small town

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[10] Envision Utah: Regional Visioning Guidebook. http://envisionutah.org/process/regional-visioning-guidebook Accessed September, 2014

pretensions; Vancouver sees itself as a global city with big city pretensions; Perth sees itself as a big country town with the pretension that all the problems facing it will simply, in an ad-hoc way, self-manage; while Salt Lake City sees itself as a city ripe for re-visioning. Each is succeeding according to plan. You get what you plan for.

2.2.3   TRANSPORT MODELLING

The emphasis (in the Black Book) on secondary sources, elasticities and mathematical equations produces a kind of fog that makes it hard to see the real world (Mees, 2010 p.166).

While counterintuitive, most of what is urban is not *urbane*. The vast majority of daily life in automobile-dependent cities is not the product of an Urban Designer's wishes. Rather, the vast majority is due to the transport modelling and the implementation of 'mathematical equations' by transport engineers.   Various iterations of the four-step model[11] have been designed – based around mono-centric urban environments – but they have not yet prepared a positive response to the automobile dependence in most Anglo-Saxon countries. It is beyond the scope here to discuss the positive and negative aspects of the modelling except that the models successfully 'predict and provide' automobile use which, in turn, has justified expenditure on urban highways and more parking.   Both highways and parking induce, rather than manage, increased automobile transport in a feedback loop.

For example, the United States' Department of Transportation has projections for Vehicle Miles Travelled (VMT) some 11% too high. As the SSTI, of the University of Wisconsin, states: 'This is troubling in a report that is widely regarded as a gauge of the "need for funding new highway capacity" ' (Sundquist, 2014). Expressed as a chart, this over-estimation appears like this:

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[11] The Four Step Model for Traffic Assignment uses standardised Traffic Generation, Distribution, Mode Choice and Route Assignment predictions based on observed traffic behaviour to provide for Levels of Service (LOS) including vehicle lane numbers, width and speed; turning bays and radii; lights and stops at access points; and parking. It is used to enable free-flowing vehicular traffic but not build vibrant, walkable, urban environments.
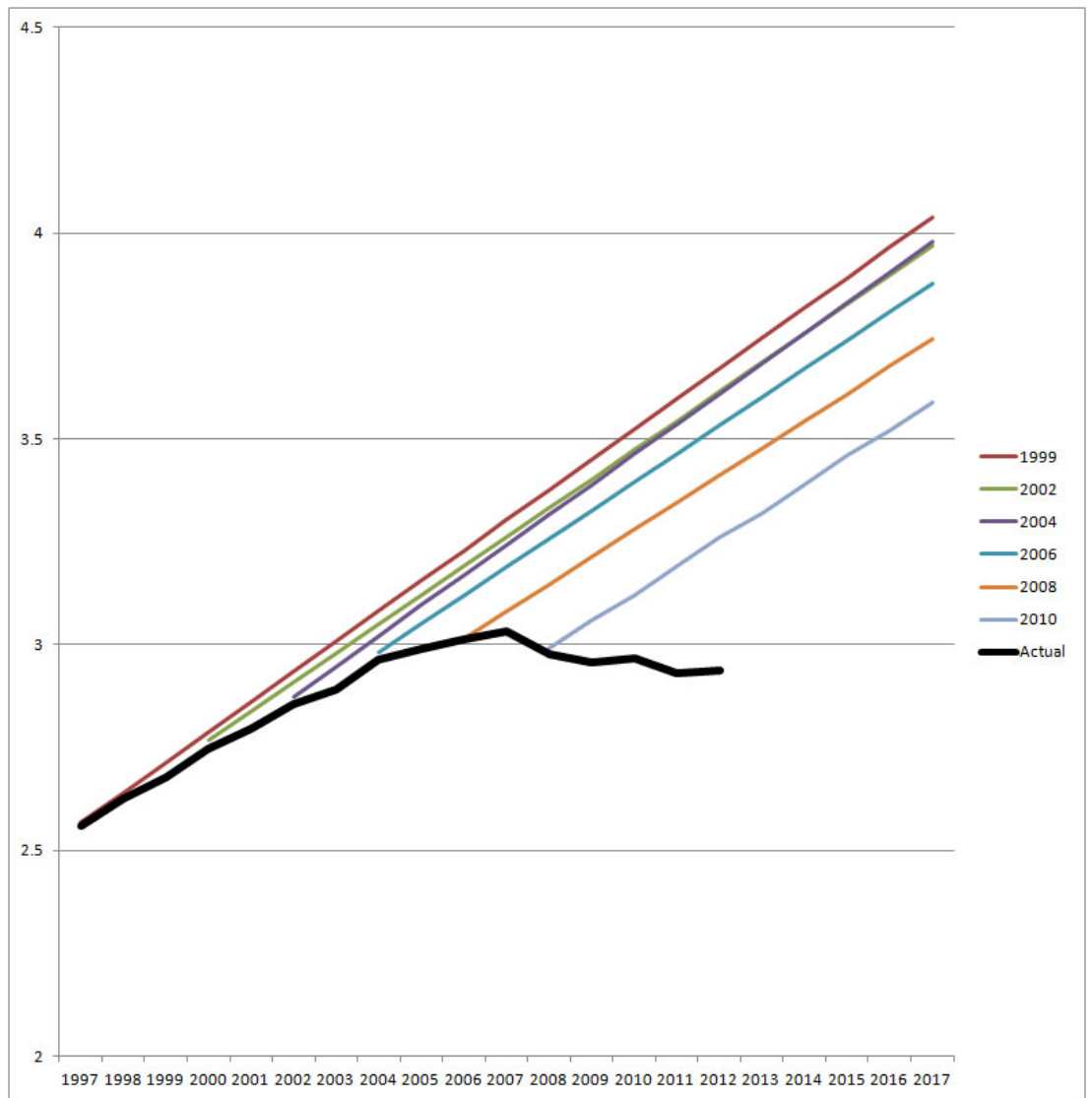
Figure 15 USA VMT as projected and reported

Source: (Sundquist, 2014)

The land use and transport nexus includes efforts to plan across the metropolitan region to achieve built form outcomes, to house the increasing population with the appropriate mix of uses to create walkable neighbourhoods and to have the right-sized transport mode suited to the task. Four-step transport modelling will be informative and useful in this process especially once parking ratios and trip generation numbers are recalibrated to include and promote walkable, transit-served, urban places.

Indeed, (Vuchic, 2005) identifies that transport and land use must be planned for together and for long-range goals across the metropolis:

> …since transportation planning strongly interacts with virtually all activities in urban areas (housing, industry, commerce, services, and others), transportation planning must be coordinated with land use plans, urban form, and the area's character and lifestyle. Therefore, all these aspects must be planned and designed through comprehensive, long-range planning procedures (p.470).

Transport modelling is useful as part of the process in planning for 'rational goals' and not, as it has been used, the end.

> ...quantitative models (such as four-step) can be used to evaluate plans, but for (transportation network) design, professional knowledge, experience, and judgement are indispensable. ...The models are behavioral, rather than normative, so that their use strengthened the procedures based on trend extrapolation, rather than on planning towards rational goals (p.476).

This is echoed by Mees who says that before considering the modelling or concerns for transport technology we first need to incentivise public transport. We must also identify the land uses to provide a complementary series of destinations along any such transport network.

> Effective public transport agencies are most likely to prosper when incentives for sustainable transport are complemented by disincentives for the automobile….It remains true that land-use planners can help or hinder public transport, particularly through their influence over the location and design of trip attractors such as employment, retailing and services (Mees, 2010 p. 161).

> Ideally, (network planning) would begin with a regional transport and land use plan that sets serious targets with appropriate institutions and resources. The public transport network is then planned to serve these goals, with decisions about fares and technology coming later in the process, not the beginning (Mees, 2010 p.166).

Clearly the method of four-step modelling is well and truly advanced. It has predicted and provided exactly what it sought to understand: the private automobile. To optimise the efforts of urban professionals to create a multi-modal, multi-destination, polycentric, Transit-Oriented Region we will need a new series of models to reinforce the 'knowledge, experience, and judgement' latent in the practices (UBC Studio, 2010; ACNU & Jones, 2012).

NOTE:

To comply with the ideal that the models will be both engineer and layman ready, the Road and Transport Authority of New South Wales' *Guide to Traffic Generating*

Developments (RTA, 2002) was used to determine trips and parking rates. It is similar to the AASHTO (American Association of State Highway and Transportation Officials) and other similar transport engineering guides in spirit if not in letter. These have been used, unaltered in their first use in the Regional Model, Model 2, and altered with each step-change in public transport capacity in the Local Model 3.2. The RTA's guide was used as it was deemed a 'standard' at one point by Main Roads of Western Australia and by local practitioners.

2.2.4   MODELLING A MULTI-MODAL TRANSIT CITY

For transit to succeed, transit managers must look beyond everyone's self-interested demands and find the patterns — like lattices of all-day high-frequency service — that make transit the most useful to the most people. In the end, the volume and diversity of all-day ridership show this to be the best way to forge permanently successful service, the kind of service you can build a city around (Walker, 2014).

Currently we are no longer able, as individuals, to resolve the issue of developing new 'resource centres', or towns. We do not have legal access to the land to build new homes on a frontier without significant government oversight. For better or worse, we are subject to the planning system. In much of the industrial OECD the only option which offers good schools and green space with affordable housing is location in the car-dependent urban fringe. This is not really a choice; there are often no viable options providing opportunities to live in amenity-rich locations served by public transport..

However, increasingly in academic literature, professional practice and current political discourse there is the idea of the Transit-Oriented Development. For the most part it is seen as an ideal for one or several nodes along a public transport line, typically along rail transport lines, though it has been proposed for bus-rapid transport lines and at ferry landings.

2.2.4.1 TOD AND URBAN FABRICS

The success of German public transport is due to a coordinated package of mutually supportive policies that include the following: (1)more and better service, (2) attractive fares and convenient ticketing, (3) full multimodal and regional integration, (4) high taxes and restrictions on car use, and (5) land-use policies that promote compact, mixed-use developments. It is the integrate package of complementary policies that explains why public transport in Germany can compete so well with the private car, even among affluent households (Buehler & Pucher, 2012).

Many cities are now trying, through active strategic planning and changing statutory planning, to develop options for their cities' growth. Frequently the discussion returns to consolidating population growth around public transport nodes. Often this is referred to as Transit-Oriented Development, as a means of master-planning a neighbourhood around public transport services. More broadly it is described as 'Land Use and Transport

Integration', or LUTI, which encourages the market to uptake the land-use permissions based on the capacity of a public transport service provision. Employing either concept will, ideally, create better walking cities as more amenities will be closer to homes; provide more economic opportunities through agglomeration benefits; and encourage co-ordination of strategic capital expenditure. Furthermore, this has the potential to help pay down the expenses of the infrastructure by broadening the tax base and applying Value Capture schemes including better structured developer contributions.

However, implementing TOD or LUTI strategies requires strong political will, first to commission planners to undertake the studies, and then pass new by-laws (ordinances) to enact the best of intentions. But it then requires strong backing from the courts and on-the-ground enforcement (i.e. strong negotiating teams) to convince developers to contribute (in-kind or monetarily) to offset the impacts on civic infrastructure from their projects, and to convince local residents that strategic change in their neighbourhoods can bring measurable benefits in levels-of-service (LOS), for schools, parks, public transport, libraries, health services and other.

Despite the last two decades of discussion, TODs provide a very small percentage of yearly economic growth and less still of overall population, residences or work places. Our best option then is to select homes and jobs in transport-served locations. This is called 'willingness-to-pay' and is studied via a hedonic model to uncover the price premium on residential and commercial properties close or adjacent to transit stations (McIntosh et al., 2014). However, it would be preferable for governments to recognise these trends and redirect planning efforts and state dollars to invest in such locations so that the potential of the land may be realised to its highest and best use.

> …implementing compact land development may be more efficient than supply-oriented transport programmes that focus merely on the provision of infrastructure (Zhao et al., 2009).

This is echoed by Robert Cervero, Newman and others who list as important mixed use as a driver toward more walking and more shared parking (Cervero, 1996), an ability to attain thresholds of between 10,000 to 100,000 residents and jobs density (Newman & Kenworthy, 2006), economic benefits stimulated by transit's presence (IBI Group, 2009),

providing a focus for community development and accessibility while generating higher land values for immediate and more distant locations (Fogarty et al., 2008).

In exploring the success of Portland, Oregon's transport and land use nexus, Fogarty found that, firstly in regards to land appreciation generally:

> In some cases the increase in value reflects an immediate benefit due to proximity to transit, such as when an office property can achieve higher rents due to its location near a new transit stip. In other cases the value reflects the expectation of future value (Fogarty et al., 2008).

> …a host of factors beyond simple proximity to transit, such as the potential for increased density, supportive zoning, neighborhood amenities and infrastructure, influence the potential amount of value created (Fogarty et al., 2008).

In Portland specifically this translated into successful re-urbanisation of the Pearl District:

> ...private development in Portland's Pearl District was facilitated by opening a large area for development that previously had no access (Fogarty et al., 2008).

In his very open examination of Beijing, Pengjun Zhao describes the TOD-type developments in China as aimed at improving quality of life, reducing travel times and being an efficient demand-side part of the transport equation 'to reduce mobility by implementing…jobs-housing balance'.

> …improving job proximity by providing affordable housing close to employment concentrations or creating job opportunities near residential areas helps to meet the spatial policy goals of shortening commuting time and enhancing the quality of life. Second, local compact development management has at least some potential to reduce commuting time, thereby reducing energy consumption and emissions. Finally, if the urban policy goal is to shorten commuting time in the long run, improving job proximity by implementing compact land development may be more efficient than supply-oriented transport programmes that focus merely on the provision of infrastructure (Zhao et al., 2009).

It appears evident that the notion of mixed-use lands will need to be examined to further understand the promise and limitations of this critical aspect of a regional approach to TOD.

However, there are limits to this model of mixing land use and transit. As Cervero cautions, mixed-use precincts *beyond* several city blocks apart from residential areas may induce automobile trips.

> If retail shops are within 300 feet, or several city blocks, from a dwelling unit, workers are more likely to commute by transit, foot or bicycle. Beyond this distance, however, mixed use activities appear to induce auto-commuting (Cervero, 1996).

This suggests a policy outcome that takes advantage of both old and new urban fabrics for planning objectives:

> … encourage denser, mixed-use development, at least in those areas that are well-served by public transit, where there are reasonable options for walking and bicycling to work, and where non-auto commuting is an explicit policy objective. Infill development and reurbanization of traditional centers represent one approach to creating viable mixed-use centers. Encouraging new mixed-use suburban enclaves and edge cities, interlinked by efficient mass transit services, might be another (Cervero, 1996).

Ralph Buehler and John Pucher write about the continental European experience planning for mixed-use, high-density transit-served precincts finding that, in comparison to the United States where land use plans discourage mixed use, Germany has:

> Higher population density and mixed land uses … facilitate short trip distances between public transport stops and trip origins and destinations. Many German cities specifically plan neighbourhood town centres that enable easy walking and cycling access to shopping and other daily needs (Buehler & Pucher, 2012).

This is not by accident, or due just to remnants of medieval, inherently walkable, pre-automobile fabric, but is due rather to current laws:

> German federal law mandates coordination of land-use planning among municipalities, regions, and states as well as among jurisdictions at the same level of government. German planning law also requires the integration of land-use plans with transport, water, energy, and environmental plans (Buehler & Pucher, 2012).

However, the authors find that the foremost difference between the two countries is that in the United States no level of government has put restrictions on provisions for profligate car use. In the US, these factors are insurmountable: highway design geometry, lane numbers and lane widths; subsidised roadways; lower taxed petrol; incentives and demands for parking ratios; free or tax-deductible parking, all encouraging automobile use. In short, no matter how mixed the land use may be, an automobile-oriented urban fabric hostile to pedestrians will invariably produce low public transport mode splits (Buehler & Pucher, 2012).

WENDELL COX'S DISDAIN FOR URBAN LIMITS

However, not everyone is convinced that trying to link public transport service with up-zoning and mixed land uses is worth the effort. Wendell Cox, a detractor of land use planning and public transport, writes in a diatribe like manner:

> The rationales offered for limiting suburban housing choices are many, various, and of questionable validity. At one point or another over the past half-decade, critics of suburban development have cited its adverse impact on "food security," wildlife, and air and water quality. Critics of suburban expansion even contend that suburbs contribute to serial killings, teenage angst, social alienation, low wages, obesity, asthma, and higher taxes. This last item, the belief that lower-density, "more sprawling" development fuels higher government expenditures, is the most common reason elected officials in many municipalities adopt measures to limit housing growth in their communities (Cox & Utt, 2004).

Wendell Cox concludes the section by stating that it is the high wages earned by municipal staff which is the root cause of the high government expenditures related to servicing the municipalities he measured. He claims the true cost to the economy is a lack of land release – sprawl – giving rise to scarcity of housing leading to unaffordable housing, all due to a cabal of unions and 'interests':

> Stronger bureaucracies, more powerful employee organizations, strong local business interests, political interests, and more rigid operating procedures …force costs in older municipalities to be higher than they would be in newer municipalities (Cox & Utt, 2004).

Yet, there are those who have devoted themselves to understanding the interaction from physical outcomes, not from ideology or trip generation formulae. Two of these will

be described forthwith along with their models to understand the urban world around them.

LUCA BERTOLINI'S PLACE NODE

Luca Bertolini, of the University of Amsterdam, has written extensively on the interplay between transport, of all modes and all tasks, and the urban development programme. He has examined the outcomes of the urban programme at the local and regional scale, and commented on the global positioning of the region in the broader context of flows of commerce, ideas, culture. He has elaborated a fascinating matrix along which any transportation node, public to logistic, may be placed according to its degree of activities formed around purely transportation to purely social 'activity'. It is called the Place-Node Model. 'Accessibility' is not just defined as transportation frequency, capacity and potential destinations reached *from* but also the number of activities available *within* the node. Buried within the model is an appeal to finding the right balance in mixing land uses so that each node may have a diversity of sub-destinations — such as retail, commercial, parks – at each transport node and that sub-destinations have quality transportation options to support their existence. Any transport node/social place too far on one side of the model is 'unsustained'.

> …where many, different people can come, but also one where many, different people can do many different things: it is an accessible node, but also an accessible place (Bertolini, 1999 p.201).

In describing his model, Bertolini writes:

> Along the middle diagonal line are areas where the node and the place are equally strong. At the top of the line are areas `under stress'. Here the intensity and diversity of transportation flows and urban activities is maximal. This indicates that the potential for physical human interaction is highest (strong node) and that it has been realised (strong place). However, these are also locations where the great concentrations of flows and activities mean that there is an equally great chance of conflicts between multiple, extensive claims on a limited space (Bertolini, 1999 p.201).
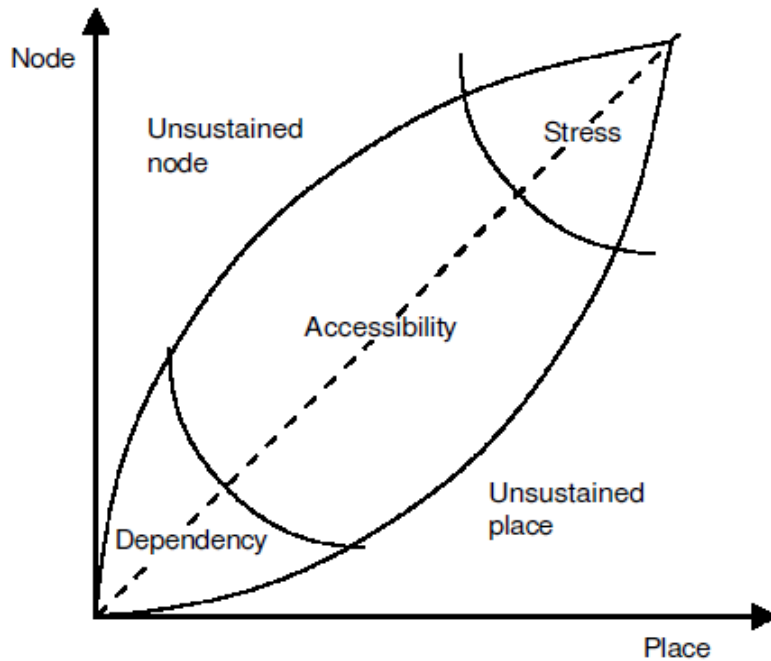
Figure 16 The Place Node Model – Bertolini

Awareness of these multi-centred dynamics is still limited, and so is the elaboration of its implications, for the economy, the environment, and the general quality of life of an urban region. In order to provide a firmer foundation to railway station area redevelopment programmes, more fundamental research needed on the potential roles of railway station locations in the emerging multi-centred urban regions… Station areas could be seen as potential 'centre of centres' with the region and the (inter)national space: that is, between the local and the global. The focus should be on relationships of competition and complementarity between locations in the context of evolving transport and land-use patterns (Bertolini, 1999 p.201).

JAN SCHEURER'S SNAMUTS

Dr Jan Scheurer has prepared an effective model to describe an urban region's accessibility. His model is not so concerned with 'place' but more with the network supporting the places. The Spatial Network Analysis for Multi-Modal Urban Transport Systems for twenty-one global cities analyses public transports' length of routes, headways (frequency) along routes, vehicle capacity and distribution of jobs and residences to give a fuller picture of global best practice.

The Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) system is an interactive decision tool designed to assist in examining

the performance of a city region's current public transport network framed around the accessibility of the transport network and accessibility of place (Scheurer, 2012).

The message to be drawn from SNAMUTS is that transport investments' strategic link with the people, jobs and places they wish to travel to in their urban lands may be compared, objectively, across continents and between cities. It reveals that some cities, such as Portland Oregon's renowned efforts at policy and technology, are *not* providing a public transport service commensurate to needs, yet.
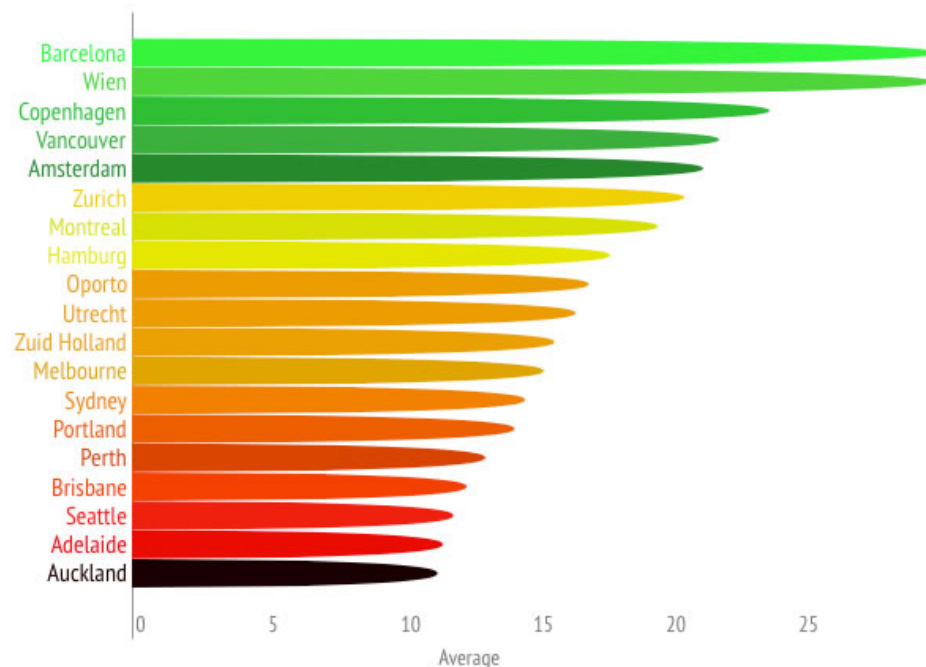
Figure 17- SNAMUTS Composite Index

Vancouver, the lone new world city in the top five will be discussed as a Transit-Oriented Region (TOR) due to a confluence of historical pushes and deliberate planning pulls in both the sections "2.2.2.2 : Strategic Plans".

The results of a SNAMUTS analysis are illustrated, as in this example of Vancouver, with glowing colours to vividly reflect the accessibility of public transportation in a metropolitan region.
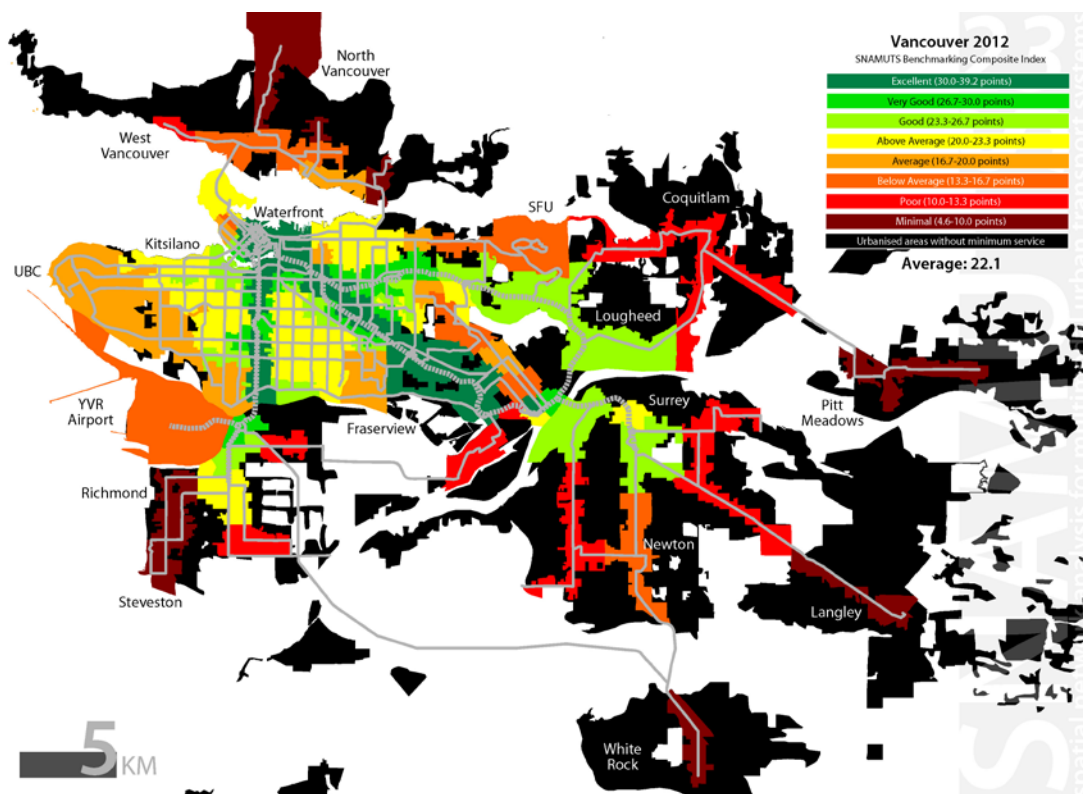
Figure 18 SNAMUTS Composite Index for Vancouver

SOURCE: (SCHEURER, 2012) "THE BENCHMARK COMPOSITE IS A COMBINATION OF EACH INDICATOR THAT EFFECTIVELY CREATES AN OVERALL ACCESSIBILITY OF THE CITY"

KNIGHT & TRYGG

In closing this section on regional-scaled LUTI, it is painful to be reminded that as early as 1977, almost 40 years ago, Knight and Trygg (Knight & Trygg, 1977) proposed the opportunities and limits of the integration of these two dominant factors in city-building. What is old is new again? The following diagram is an adaption, with additions by the author, of the factors influencing the ability of a developer to act on government policy and transportation capacities at an urbanisation site. The list of preconditions from Knight and Trygg in Figure 18 includes crime, blight, taxation and the national economy and others which fall outside of the scope of the project.

NOTE:

FOR THE PURPOSES OF THIS RESEARCH THE LIST PRESENTED ON THE FOLLOWING FIGURE HAS BEEN REDUCED TO FACTORS WHICH ARE TYPICALLY CONTROLLED BY URBAN PLANNING, HAVE PHYSICAL DIMENSIONS AND PHYSICAL OUTCOMES. THESE WILL BE FURTHER EXAMINED FOR THEIR INFLUENCE IN CONDITIONING A METROPOLITAN REGION FOR TOR IN RESULTS: THE GLOBAL SCALE **MODEL 1** SECTION BELOW.

PRECONDITIONS FOR
SUCCESSFUL LAND USE AND TRANSPORT INTEGRATION

Cole Hendrigan, 2014. Adapted from Knight and Trygg, 1977

PHYSICAL
Access, Blight, Compatible Land Uses

SOCIAL
Crime, demographics

ATTRACTIVENESS OF SITE FOR DEVELOPMENT

Infrastructure Capacity i.e. Highway and Sewer

Ease of Private Assembly / Land Amalgamation

Cost of Land and Site Preparation

AVAILABILITY OF DEVELOPABLE LAND

Urban Renewal

Transit Investment

LOCAL GOVERNMENT INCENTIVES

Urban Renewal

Private Development

Public Facilities

OTHER NEW NEARBY LAND INVESTMENTS

Commitment to specific Improvements

Implementation of Transit Improvement

Improvement in Accessibility

Parking ratios

TRANSPORTATION INFRASTRUCTURE

Neighbourhood Attitudes

Zoning and Development Incentives

Goals of Larger Community: Growth, Character, Plan and Dollar Priorities

LOCAL LAND USE POLICIES

Compliance With: Environmental Impact Review, Equal Opportunity, Affordable Housing

Infrastructure Provision

Taxation and Developer Contributions

OTHER GOVERNMENT POLICIES

National Economy

Regional Economy

REGION'S DEMAND FOR NEW DEVELOPMENT

INFLUENCE DECISION TO DEVELOP LAND

MEASURABLE IMPACT

Figure 19 Preconditions for Successful Land Use and Transport Integration

Source: Author, 2104. adapted from *Evidence of Land Use impacts of Rapid Transit Systems* (Knight & Trygg, 1977)

2.2.5 SUMMARY: REGIONAL LAND USE AND TRANSPORT INTEGRATION

The best transport plan is a good land-use plan (Toderian, 2012).

The literature describes many benefits of Land Use and Transport Integration, in particular the benefits of increased public transport access and more mixed-use communities: with an increase of people living clustered closer together there is more cooperation and innovation with flow on benefits for the economy; there is less destruction of farm and forest leaving land to provide food, leaving ecosystems intact to provide services such as cleaning air and filtering water for human benefits, and permitting the natural realm to exist in its own right; and there is an overall reduction of GHG as fewer resources are required through shared-wall insulation and more opportunities to scale-up alternative energy production such as co- and tri-generation.

When people may realistically rely on public transit to connect their residences and where jobs are available, it both increases the labour-shed of the region and shortens the travel time to work as transit, walking, cycling all conspire to avoid congestion. This of course, decreases overall transport costs to many works, leaving money in their pockets to be re-distributed within their community.

People living and working within eight hundred meters of transit drive less. This has the co-benefits of reducing local pollution and global CO_2; increasing active transportation within their neighbourhoods to the net benefit of their health; supporting local retail shops, grocery stores, restaurants and professional services.

A Transit-Oriented Region will need a suite of approaches to be successful. It will require: density to be properly planned for; land use modelling to predict a targeted distribution of jobs, residences, services and amenities; and traditional four-step modelling supplemented with other considerations, for example land uses supporting multiple destinations and even destinations so short – at walking distance – that they might not appear in a model. Furthermore, a multi-modal region of transit-rich centres will require a

balancing of automobile penetration and parking, the impacts mixed-use land assemblages have, the experiences of place and the effectiveness of a network planning, at a minimum.

We know this much; but why, then, despite all the best minds working on this issue, do we continue to build low-density, automobile-dependent, single-use development even in a city such as Perth, Australia, where decades of political effort have been put into the study of rail-based urbanism, place-making and liveability?

2.3 THE PERTH METROPOLITAN REGION: FROM COLONY TO GLOBAL CITY

The Metropolitan Region of Perth will constitute the study area for this thesis research. The question will be: where, how much and what mix of urban development is both possible and necessary for this urban region to become a Transit-Oriented Region.? Detailed modelling in the Results section will reveal the urban fabrics required to achieve a Transit-Oriented Region over the next 50 years.

2.3.1   LOCATION

Perth, Western Australia, is situated on the Swan Coastal Plain in the lower portion of the south west corner of Australia.
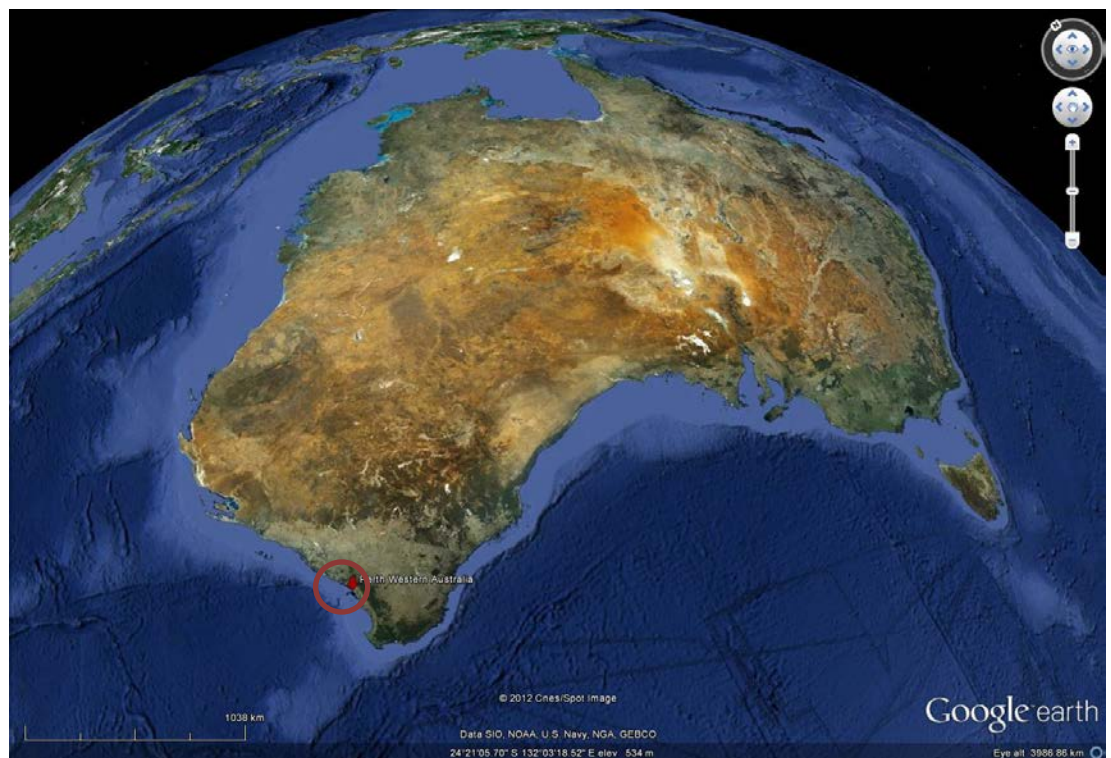
Figure 20 Perth's location in south west Australia

Figure 21 Perth, Australia – location

SOURCE: "TRAVELLING TO PERTH" HTTP://CAA2013.ORG/DRUPAL/TRAVEL ACCESSED MAY 2014

2.3.2   ABORIGINAL HISTORY

The Aboriginal history of Perth goes back many thousands of years, predating European's by 70,000 years (Rasmussen et al., 2011). The Aboriginal peoples were attracted by the varied terrain of coastal dunes, wetlands, freshwater river and eastern hills to live, with significant cultural meaning, in a recurring suite of places – seasonally and yearly – as have many hunter-gatherer groups (Levi-Strauss, 1992; Brody, 2002).

> Aboriginal people moved 'not in a landscape, but in a humanised realm saturated with significations' (Stanner, 1979).

When the first Europeans arrived, they saw a land of park-like savannah; a land they thought would provide hoofed animals good grazing and rejoice at the blade of a plough. Little did they know the land was actually cared for, in balance, to provide a society's needs (Gammage, 2012):

> All over Australia, when Aboriginal people speak English, they describe their burning practices as 'cleaning up the country'. There is a well-defined aesthetic country which has been burned is country which looks cared for and clean. It is good country because… you can see that people are taking care of it (Rose, 2009).

Unfortunately, the Aborigines, or Traditional Custodians, were largely displaced or jailed while the European settlers failed in their attempts to make the thin sandy soils produce a livelihood (Statham, 1981).

2.3.3   CLIMATE

Perth's climate is classified as Csa: humid subtropical (Mediterranean), as per the Koppen Classification, being 'warm with distinctly dry hot summers with strong continental influence, average winter temperature between +18 and -3 C, with summer average temperature over 22C'.[12]

Perth's climate is not a hindrance to positive human occupation. However, the sandy soils are nutrient poor and the threats of climate change which include possible droughts and sea-level rise (Steffen et al., 2009) are of longer ranged concern.

2.3.4   TOPOGRAPHY

The Perth Metropolitan Region has a varied topography. It is not perfectly flat, as on closer inspection there are ancient sand dunes and low-lying wetlands fringed by a modest escarpment known as the Darling Scarp. All comprised this area is known as the Swan Coastal Plain (Seddon, 2004). Along the Indian Ocean coast there are significant exposed limestone reefs guarding the shore from big swells and boats without excellent charts. It is an extremely easy place to model landforms into a desired (flat with a 2% slope) shape for infrastructure such as roads and sewerage; the land is immensely plastic and can be formed to will. The only limiting factor is the availability of fill material to create sufficient level and dry surfaces for the extensive greenfield developments planned for land-banked farms and forest.

2.3.5   AUTOMOBILE DEPENDENCE

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[12] Koppen Climate Classification Flow Chart:
http://www.utexas.edu/depts/grg/kimmel/GRG301K/grg301kkoppen.html Accessed July, 27, 2014

Perth is a highly automobile-dependent conurbation. It has grown mostly since the 1960s in the era of automobile-based planning. There are vast areas to the north, east and south of the central metropolitan area which have been developed on a standard suburban automobile-access plan. These areas have low residential density with a low rate of higher paid jobs in the locality. They also have single-use zoning pods separated by collector and arterial roads beyond walking distance to most daily activities. Perth is not unusual in this, as most of western North American cities have a similar pattern. However, one may view the majority of Perth as being under-serviced by highways, by lanes or speed, despite all these automobile-dependent single-use pods, which leads ultimately to peak-time congestion. This congestion has had, however, positive effects on public transport mode share as it encourages people to find 'alternative' means to travel.

Traffic congestion in Perth increased by an estimated 4% between 2011 and 2012, more than any other capital city (SOAC, 2013).

2.3.6   CURRENT PUBLIC TRANSPORT

Currently, Perth's use of public transport is rising despite increases in wealth which tend to raise VKT. Unlike major cities of North America it has, since the 1980s, been building up its train network so that it now has become a highly successful system in which the buses feed the train (more than 80% on the new Southern Rail line), and the train has high capacity and high speed to take people to the CBD or elsewhere. It is successful despite its urban fabric not fitting a standard definition for success. It is not 'standard' in that most of the Perth region has far too low a population density to by itself support high-capacity public transport. Yet, it does so by employing the buses to transfer people to train stations; by applying a high price on parking in the two (Perth and Fremantle) Central Business Districts; and by not (for a variety of political and economic reasons) building as extensive a highway system as many would expect for a similar size and age of city in North America.[13]

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[13] For example: Calgary, Canada with half (~ 1,000,000) the population of Perth having – effectively, though not perfectly – two rings of limited-access freeways compared to Perth's mere two intersecting freeways.

In 2011, a higher proportion of commuters drove to work in Perth (77.8%) than in Sydney (66.6%), Melbourne (74.1%) and Brisbane (74.5%). However, there was a decrease in the proportion of people travelling to work by car in Perth since 2001, particularly in the inner suburbs. This was accompanied by a rise in the proportion of people using mass transit, walking or bicycling for their journey to work (SOAC, 2013).

2.3.7   FORM

Perth Metropolitan Region's form is largely star shaped, with both railways and highways leading to its outline.

Originally settled by boat from the river, Perth worked in harmony with Fremantle, the port some 20 kilometres distant downriver, creating a di-pole urban form with walking city urban fabric.

In 1901, after 72 years of development (the Perth region) formed three clusters. Around Perth and Fremantle growth was restricted to human-powered transport. The major transport artery was still the river, with barges carrying goods and people between Fremantle and Guildford (further up the river). The Perth-Midland and Perth-Fremantle railway lines (opened 1881) were starting to influence development. Settlements…grew at regular intervals along the line (Dent, 1996 p.293).

There was little urban development aside from these two cities until the railways began to apply their capacity to settle people in denser nodes along its lines. Most notably population settlement occurred in places such as Midland and Armadale (as industrial/forestry/agricultural sites with residential) as well as Claremont and Cottesloe (as large-lot residential) over the years before World War Two. As with many western cities, the Perth region began experiencing enormous population growth in the 1950s which, along with the expansion of primary industries (mining, farming, forestry), saw the economy grow at very rapid rates.

Over the last 60 years, since the 1950s, there have been several influential people and plans which have had varying degrees of impact on Perth's urban form. Some of these people and plans have tried to tie together loose ends of the original survey by John Septimus Roe (below).
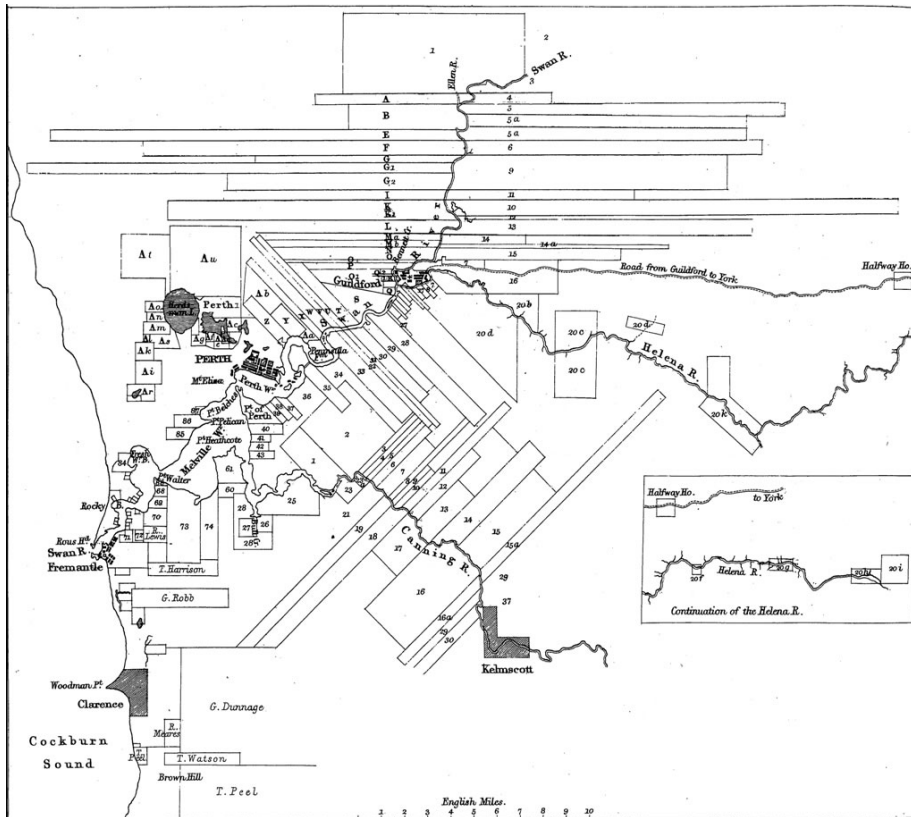
Figure 22 Roe's Swan River Colony Survey

SOURCE: "SWAN RIVER COLONY LAND GRANTS MAP". LICENSED UNDER PUBLIC DOMAIN VIA
WIKIMEDIA COMMONS -
HTTP://COMMONS.WIKIMEDIA.ORG/WIKI/FILE:SWAN_RIVER_COLONY_LAND_GRANTS_MAP.PNG#MEDI
AVIEWER/FILE:SWAN_RIVER_COLONY_LAND_GRANTS_MAP.PNG ACCESSED MAY 2014

Of particular note is the how this plan responds to the established land-ownership
patterns of the early colony. There was no attempt to impose a Baron Haussmann /
L'Enfant / City Beautiful type Beaux Arts axial plan or a Brigham Young type grid as Perth
was planned a few decades too early to be affected by these currents in civic planning.

STEPHENSON/HEPBURN

In the era of post-war growth the eminent town-planner and architect Gordon
Stephenson (Grose, 2007) drew the Plan for the Metropolitan Region, Perth and Fremantle,
Western Australia, 1955: a report prepared for the Government of Western Australia
(Stephenson & Hepburn, 1955) which outlined all the current and future 'optimal' land
uses. Significantly, Stephenson preferred a balanced transport solution, with all the modes

playing a role. While this plan for Perth was progressive in that it was a complete plan for a region, a rarity, it had unintended consequences. The separated land uses gave rise to highway connections linking the land uses and began a culture systemically devoted to providing speed and access to the automobile. It gave leverage to later planners, most of them besotted with the car, who preferred highways over rail public transport options.

Stephenson and Hepburn didn't intend the plan to be so unbalanced an approach to transport. Here they make an appeal for reasonable consideration of rail transport:

> 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 & Hepburn, 1955 p.130). Emphasis added.

> If this form of mass movement (automobile based) 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 & Hepburn, 1955 p.131). Emphasis added.
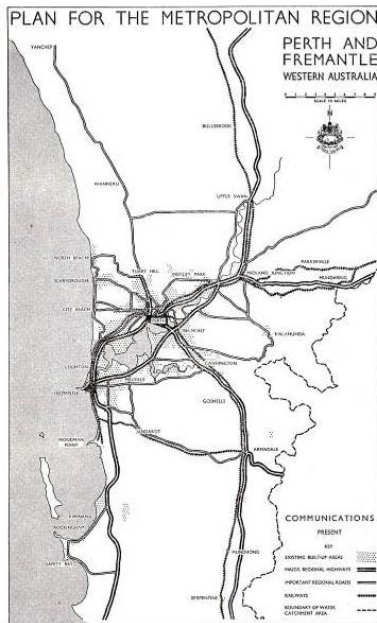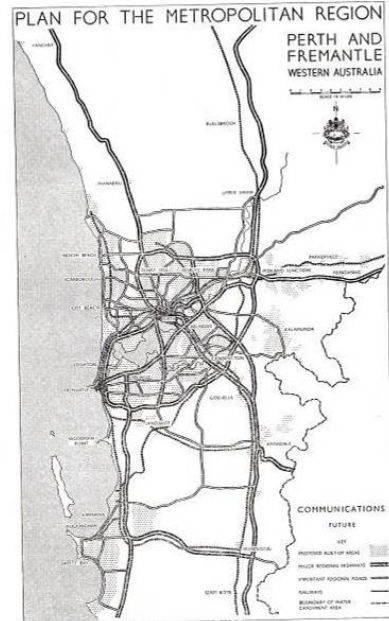
Figure 23 Stephenson's Plan - Communications Present and Future

Nonetheless, despite the appeals for reason in the matter of high-capacity public transport, the preference in the decades which followed was for private mobility. The Metropolitan Region Scheme facilitated mobility, highways and car parking; now Perth needs to redevelop from an automobile-dependent city into a Transit-Oriented Region, a task which will be very hard but which this research aims to give direction to.

M R S

Arising from the Stephenson-Hepburn plan was the first Metropolitan Region Scheme (MRS) of 1966 which further entrenched the separated land uses with linkages by private automobiles. As was common across many cities of the Western world, over the next decades railways were under-invested in while highways were built and plans for yet more highways were created. In this way Perth was seen as progressing and keeping up with the changes in the modern economy. Incrementally places began appearing away from the

train line running from Fremantle to Midland, in either the Perth Hills (Mundaring, Kalamunda) representing an early Tree Change[14] or along the coast to places such as Coogee, Floreat, City Beach and Scarborough representing the persistent trend of Sea Change (Salt, 2001; Gurran et al., 2005).

> By 1961 the first clusters of coastal and hillside suburbs had developed. Such satellite suburbs were made possible by the speed and flexibility of private motor transport. The movement away from the river and rail along the coast was clearly apparent by 1981 (Dent, 1996 p.295).

However, the government tried to convince the citizens that all railways needed to be removed for 'modernity' to take root in Perth. Modernity meant cars and maybe buses, but not the old tired diesel locomotives of the late 1970s (see below). Into this debate stepped two academics who rallied the cause for restoring rail transport and, ultimately, championing the expansion of the network to provide genuine alternative modes of transport. The debate was couched in terms of social justice, air quality, oil security, urban patterning, and reducing automobile dependence. While not an urban design question, it had the effect of changing the pattern of what is possible in this very automobile-dependent city form and fabric (see Definitions on page 17).

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[14] Sea Change and Tree Change are Australian colloquialisms describing the strong demographic shifts towards lifestyles outside of the busy and congested cities as proven by new housing tracts of ultra low-density hobby farms in the country (tree change) or the low density [often without backyards] sprawl in coastal areas (sea change).

Figure 24 Metropolitan Regional Scheme of Perth and Peel

Subsequent to the adoption of the MRS the governments of the day proceeded to purchase lands for highway expansion and interchanges, but not railway right-of-ways, as Perth launched into purposefully planned automobile dependence.

> …the Government's interpretation … was that the roads would be needed but the railways would not (Newman, 2012).

By September 1979, the government closed the diesel locomotive-operated Fremantle line and offered a bus in its place. This was not a propitious time to close the railway as the recent oil crisis had increased petrol prices and the force of persuasive analytical arguments by Peter Newman, Jeff Kenworthy and the Friends of the Railways. However, this was not an economic or transport related-decision by the government, being based partly on the global politics of the Cold War and the need to move war material around in case of Soviet aggression and also on the ideology of the local freeway lobby. After much civic action, strong public reaction and a general election based on transport, the line was restored and eventually electrified. It was a grass-roots political success led by an academic, Peter Newman:

> The system of democracy, the role of civil society (including academia) in setting vision, the commitment and energy of good public servants and the significance of good political leadership – they all became something to really believe in (Newman, 2012).

The opening of a further two rail lines to the north and south, development of several Transit-Oriented Development projects and a rise in patronage all owe a debt to Peter Newman and Jeff Kenworthy for their untiring work to save, electrify and expand the rail network so that the integration of the land use with a viable high-capacity public transport is at least an option.

> The first step is to envision a future that includes rail, rather than blithely taking the advice of so many in the transport business over the past few decades that new rail options are not a viable option for Australian cities. Once a vision is there, it is necessary to bring a parallel process of engaging the public and creating a suitable business case for the rail project (Newman, 2012).

The newly developed talent and enthusiasm for public transport as the correct armature for urban development provided an opening for the Network City plan.

NETWORK CITY

Network City was a much elaborated, community consultation-rich process to 'foster land use and transport integration to form a Network City'. Its stated aims were 'to unleash the creativity of the community and give new life to the concept of democracy, government by the people, by weaving citizens more deeply into decision-making' (WAPC, 2004a).

While an evocative written plan, it had some difficulties:

> Fundamentally, Network City is not a masterplan but a set of principles which… [although] recognised as a good set of principles, it has some problems. [For example, its] ...emphasis on polycentrism is problematic because many of the 120 nodes or 'activity centres' … are typically places within the existing suburban fabric of the city that have been built primarily as service nodes for cars, not people. Such activity centres, if they are to become epicentres of thriving and relatively dense residential development, will require substantial reconstruction to make them attractive civic spaces. Such reconstruction in turn drives up costs for infill development making it potentially unaffordable relative to greenfield suburban development with which it must directly compete (Weller, 2009 p.42).

Ultimately, its greatest problem was that it was never implemented. As an official plan it was never adopted by an incoming new government. Instead, the new government chose to undertake a less targeted and more gestural approach to planning for Perth's future, an approach which did not a) forearm local activists against urban density, nor b) send a strong anti-greenfield development message to the entrenched development community. This newest plan is called Directions 2031 and is still being paraded as the latest plan for the region.

DIRECTIONS 2031

Directions 2031 is the latest plan even though it is not formally accepted by the government after three years remaining in draft form. It has had very little noticeable impact, outside of several small nodes, and that was likely a political calculation to avoid local opposition to density or an overly negative signal to greenfield developers. It stands in place of the 'problematic' (Weller, 2009) Network City (WAPC, 2004a) and does not

advocate precise density increases, population and jobs targets, or say how the market was to respond to the plan. There were few limits placed on further greenfield developments except to target 47% of new development to be 'infill' (within the existing urban footprint). However, despite the target of 47% there was no direction as to how to distribute this to specific locations;, or in what densities, to what maximum heights, to what percentage growth in population, and in what housing types such as town-homes, apartments or other. Nor did it say which mode of transport could support the new density and avoid flagrant automobile trips, or how to measure and manage the outcomes.

As a first pass, the needs to create spaces for infill development to accommodate 47% (Western Australia Department of Planning, 2011) of the 1.8 million persons projected by the ABS (ABS, 2011a) to arrive in Perth by 2050, or 846,000 people, will pose a serious set of challenges. The challenges include underground service delivery, strains on the power system, strains on waste disposal and increased transport trips. There is also the social and political strain of the perception by the current residents that they are being asked to support the visual intrusion of large buildings, tolerate increased traffic, lose what privacy remains in an urban area and lose what remains of the 'sense of place' which, in Western Australia, is comprises large trees, bird songs, unrestrained space to park vehicles and ample room to play sports.

Despite this, some will want to be located near sites where amenities can be delivered efficiently. This is not a mechanical view of city life, but rather a more socially responsive view which may add to much higher security, more transport and housing options for all income brackets, diverse neighbours, for-profit amenities such as coffee shops, and public amenities such as libraries and swimming pools. To achieve these urban service delivery goals the region will have to begin to offer these and other services where they are best suited (i.e. at new development sites) and when they are most suited (i.e. at redevelopment sites perhaps as a part of developer contributions).

The challenges posed in this paradoxical state planning document are the ones which the models, presented below, are born from.
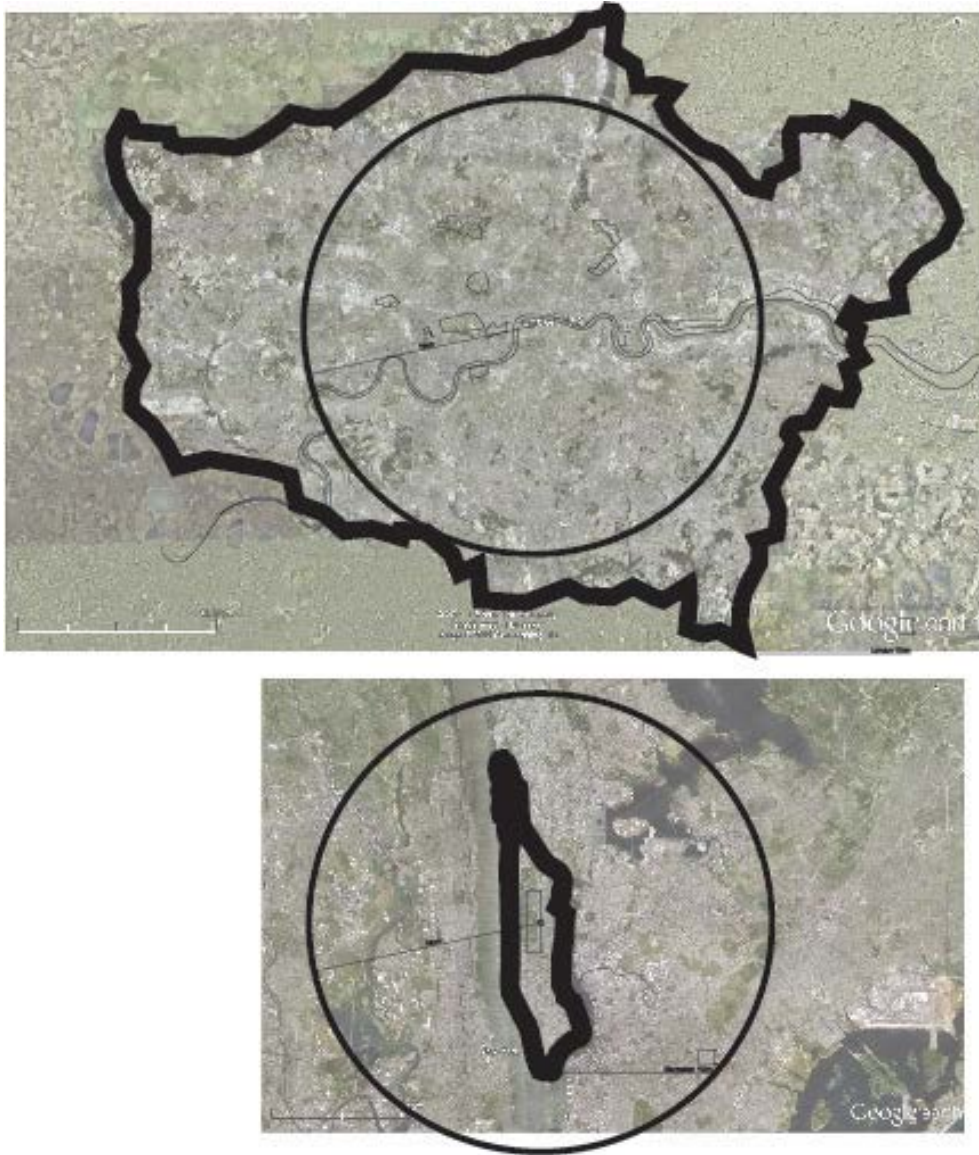
Figure 25 London, above, and Manhattan, below

SOURCE: AUTHOR, 2012. FOR PERTH TO PROVIDE HOUSING ALONE, NOT INCLUDING WORK SPACES, FOR THE NEW 'INFILL' RESIDENTS TO LIVE AT A PER PERSON BASIS OF 100 SQ.M. (REF ABS HOUSING SIZES) EACH EQUALS EIGHTY-FOUR MILLION, SIX HUNDRED THOUSAND (84,600,000) SQ.M OF SURFACE AREA. TO COMPARE, THIS IS GREATER THAN THE ENTIRE ISLAND OF MANHATTAN OF NEW YORK CITY AT APPROXIMATELY 50.5 MILLION SQUARE METRES BUT LESS THAN THE ENTIRE URBANISED AREA OF METROPOLITAN LONDON COMING IN AT APPROXIMATELY 138.3 MILLION SQUARE METRES.

Richard Weller, a professor of Landscape Architecture in Philadelphia, applied a high-level scale of thinking to the matter of Perth in his book *Boomtown 2050*. A few of his observations about Perth's planning stem from a rising need to accommodate the growth of the urban area, a task which, though technically possible, is being avoided by the politicians and their infrastructure priorities.

> To accommodate the projected 2050 (ABS of 1.5 Million additional residents by 2050) population increase, 651,078 new free standing homes (based on 2.3 people per dwelling) or 788,147, apartments,(based on 1.9 people per dwelling) will need to be built. Pending land availability, the housing industry in Perth says it can build 20,000 homes per annum so in sheer numbers it is do-able. But housing is one thing: the infrastructure needed to sustain such vast residential landscapes is quite another. It stands to reason that if the population of the city doubles then the entire infrastructure of the city will also have to double. Everything that was built in 179 years will need to be reproduced in the next 40 (Weller, 2009 p.35). [15]

> Adding more people to such areas also risks compounding the social problems generally associated with high-density residential areas in areas of relatively low natural and cultural amenity. (The)..need for more compelling forms of infill development if it is to become a genuine alternative to suburban sprawl (Weller, 2009 p.315).

> One such compelling idea ...is for Perth to build a new orbital rail loop around the city's inner core and maximise density and jobs along it. The loop would give rise to a string of development hubs and would connect two major universities, several TAFE colleges, various medical hospital facilities, the airport, the CBD and several under-developed suburban community centres. These development hubs are where there is the highest potential for growth in the knowledge economy. The loop would intersect Perth's radial lines providing accessibility to all Perth's major high density employment and activity centres. The string of development hubs along a new rail

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15 ABS predicts as of June 30, 2011 that 'In Series B (the moderate measure), Perth is projected to experience the highest percentage growth (116%) of Australia's capital cities, increasing from 1.6 million people at 30 June 2007 to 3.4 million in 2056', an increase of 1.8 million persons (ABS, 2011).

circuit would enshrine Network City ideas in one bold move and significantly boost the viability of Perth's overall public transport network. Many of the areas along this loop are, however, not exactly high in amenity but they could give rise to affordable higher density housing with excellent connectivity to jobs and the city centre (Weller, 2009 p. 315).

The proposition Weller poses is another challenge which the author has taken as a point of departure. How much of what Weller proposes is tenable, what are the transport tasks associated and what else is to be gained were it followed through on are all part of the models prepared below.

2.3.8   SUMMARY: PERTH'S METROPOLITAN REGION

In summary, it is not a lack of planning as in Houston, or uncoordinated planning as in Atlanta, or even excessive highway building as in Los Angeles, which has given Perth its particular flavour of automobile dependence. Perth could almost be blamed for being too well planned, too rigid in its expectations, holding too closely to an established pattern of suburban living without having to ask about the repercussions until the future, yesterday, arrived. [16]

It is anticipated that by 2021 the coastal arms will stretch up to 80 km. absorbing resort centres like Yanchep and Mandurah. …The projections are based on trends. Of course, trends may change (Dent, 1996 p.295).

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[16] Perth actually has very good metrics when compared to a select sample of other cities, in the appendices see: "Urban Areas, Populations and Transport in 19 Cities" for a broad comparison of urbanised areas and densities. However, for an even more revealing look at how Perth compares see, again in the appendices "Select cities from the Global Cities Database" which will show that Perth does have low density and high rate of roads per person (Figure 183 Urban Density, and Figure 184 Road meters per Person) while other charts (Figure 187 Density and Transit provision, and Figure 188 Transit Service Ratios) show that Perth does provide a fairly high ratio of Transit Service.

Yet, Perth is not alone in being concerned for its image, its feel, its sense of place. Many other places before it have also been concerned about how to live within its bounds, how best to express its character without limiting the future, and how to project itself as a desirable place to live and invest. The following sub-chapter will discuss what could be called, loosely, Urban Design and its precedents and promise.

2.4 GLOBAL CITY SHAPING

Through history there have been influential thinks asking hard questions about resource availability, human health and the optimal manner of living in harmony with others. This has been asked by many, too many to review properly here, but below is a quick review of primary literature.

2.4.1   URBAN PERCEPTIONS AND ENVIRONMENTAL PREFERENCES

To start, there has been an ever growing body of literature regarding perception of the environments we inhabit and how we appreciate, reuse, re-inhabit, occupy and make successful certain types of urban areas over others. An understanding of urban environments is imperative if we are to make transit oriented developments (TOD) or, as proposed later in this research, regions (TOR) proposals successful.

2.4.1.1 LOCAL ENVIRONMENTAL KNOWLEDGE

The Kaplans (Rachel and Steven) from the University of Michigan, have specialised in environmental psychology studying the relationship between willingness to walk – as a pedestrian in a forest or an urban setting – and a high degree of nature, fascination, visual extents, mystery and security (Kaplan & Kaplan, 1989). In many ways their findings reinforce the work of Jay Appleton's Prospect / Refuge theory which helped us to understand why and how we prefer to have a high combination of prospect, a place with a good view, and refuge, a secure place. An imbalanced human habitat may be too protected, refuged behind a high wall or beyond the furthest reach of an extensive highway in suburbia, with no prospects outwards to a view or to other social activities and opportunities. Conversely, an urban situation imbalanced towards prospect without the safety of a modicum of privacy becomes tiring, invasive and enervating:

> Where he has an unimpeded opportunity to see we can call *prospect*. Where he has an opportunity to hide, a *refuge*. And just as we can identify the desire to see without being seen as something conducive to, but more limited than, the desire to satisfy *all* our biological needs, so we can recognize its aesthetic basis as more limited than the aesthetic basis of that more comprehensive ulterior motive. To this

more limited aesthetic hypothesis we can apply the name *prospect-refuge theory* (Appleton, 1975 p.66).

Kevin Lynch of Massachusetts Institute of Technology, Boston, studied the interaction between the recollection of images and way-finding in determining what people liked about their city (Lynch, 1960). His conclusions drew us closer to an objective understanding of what makes for a desirable city and the types of city grain we ought to be striving for (Lynch, 1981). His findings flew in the face of the contemporaneous inner city Interstate highway building and 'slum clearances' of the epoch. Likewise, Jane Jacobs found that people matter more than do master-plans for highways. Jane Jacobs (Jacobs, 1958, 1961) described how the city, erstwhile a 'slum' needing clearing, functioned as a nested series of human actors working, living, sleeping and ultimately caring for their neighbourhood and others in it, even if with only passive 'eyes-on-the-street':

> The task is to promote the city life of city people, housed, let us hope, in concentrations both dense enough ad diverse enough to offer them a decent chance at developing city life (Jacobs, 1961 p. 289).

Allan B. Jacobs, of Berkeley, California, took the physical dimensions and properties of many of the best streets with multi-layered human activity on them and drew them to scale for comparison. He found that, among other things: safety; multiple openings in facades; short blocks; fine-grained building lots; building to lot lines; shimmering trees, bollards and other street furniture; high degrees of access; and other people, attract us to be there, contributing to the success of an urban area (Jacobs, 1995; Jacobs et al., 2001).

> People understand and respond to comfort. They seek out sunny or shady places, depending on the climate. The best street designers have understood that(Jacobs, 1995 p.275).

Jan Gehl has also worked extensively on providing comfort, quality and way-finding in many of the world cities he has consulted in. His seminal work described how we need to plan for people, not automobiles, to enliven and make liveable our urban cores and periphery (Gehl, 2012). Furthermore, by planning to design excellent spaces between buildings and not the buildings themselves, we gain street life which has value in strengthening the desirability of the precincts (Gehl, 2001).

This tangle of aesthetic and practical needs at the small scale in the urban fabric is seen by several observers as, if not fundamental, certainly contributory to the promotion of transport-activated land redevelopment. Foremost among the many commentators has been Vukan Vuchic of the University of Pennsylvania who writes that though network planning, mode capacity and frequency matter, primarily transport influences life the form of cities:

> The roles that transit and other modes play in a city are closely related not only in its physical form, but to the type and character of urban activities and living. Conceptually, the sequence of planning a transportation system for a city and its region should logically start by defining the type of city/region. This vision should be translated into the goals for the transportation system, especially the intermodal composition, because the roles of different modes have a major impact on the city's physical characteristics, activities and environment (Vuchic, 2005 p.480).

Robert Cervero, has spent his career studying the land-use and transport connection. In one seminal paper he and Kockleman examined in closer detail the effects of urban design, density and diversity in de-inducing vehicle travel to the benefit of transit use and walking. Their results showed that density and diversity in close proximity to transit hubs mattered more than the street furniture, pavers, trees, human-scaled lights or other such considerations of the 'design' component (Cervero & Kockelman, 1997). However, from 1997 to the current date he has come around to the idea that street character, safety, intersection density and grid can contribute to the increased likelihood of a successful TOD precinct (Cervero & Day, 2008; Ewing & Cervero, 2010; Cervero & Guerra, 2011; Cervero & Sullivan, 2011; Cervero, 2007).

Peter Newman's and Jeff Kenworthy's papers and monographs (Newman & Kenworthy, 1999; Newman & Kenworthy, 2006) on the required density (thirty-five residents or jobs to the hectare) and arrangement of transit nodes within the large urban area,(polycentric) to overcome automobile dependence have spurred and inspired much debate. The debaters included the late Paul Mees who argued that urban density doesn't matter as much as public transport frequency in driving urban lifestyle changes away from automobile dependence. Furthermore, Mees argues, public transport policy is easier to change than urban density when trying to 'save the planet':

> The good news is we don't need impossible increases in density to provide viable alternatives to the car. The relative attractiveness of competing urban transport

modes seems to influence mode choice much more than differences in density. …Transport policy can be changes more quickly and cheaply, and with less disruption, than city density, so it might even be possible to make the necessary changes in time to save the planet (Mees, 2010 p.66).

Since the 1990s there has been increased concern that even ecologically responsibly designs such as Woodlands (designed by McHarg, discussed from page 145 onward) outside of Houston, Texas, or Village Homes in Davis, California, were not sufficient in scale or in outcome to genuinely alter the high VKT and high GHG lifestyles. These prototypes, never widely taken up by developers, may have managed surface stormwater to re-establish ecological networks and provided trails for recreation, but there was still no mixed use to provide local destinations or density to support quality public transport services. At the local and personal level they succeed, but even at the middle or regional scale they were just as 'bad' at lowering VKT and GHG as any other sort of sprawl.[17] (Please see 'Ecological Services' p. 450 and 'Checklist for Landscape Architects' p. 452 in the Appendices for a description of the concerns used in many Landscape Architecture projects including Woodlands and Village Homes.)

From this realisation evolved diverse groups, mostly speaking the same language and offering profound – but implementable – solutions to automobile dependence. The Smart Growth group, Urban Land Institute (Urban Land Institute, 1998) Natural Resources Defence Council, Centre for Transit Oriented Development (CTOD), Reconnecting America, LEED - ND and the Congress for New Urbanism (CNU) all propose variations of the Compact City and Sense of Place concepts.

The basic tenets uniting these groups, some favouring transit over aesthetics, aesthetics over density, or any other opposite combination, include:

- Mix land uses

- Take advantage of compact building design

- Create a range of housing opportunities and choices

- Create walkable neighbourhoods

- Foster distinctive, attractive communities with a strong sense of place

- Preserve open space, farmland, natural beauty, and critical environmental areas

- Strengthen and direct development towards existing communities

- Provide a variety of transportation choices

- Make development decisions predictable, fair and cost effective

- Encourage community and stakeholder collaboration in development decisions (EPA, 2014a)

Again, as with Woodlands or Village Homes, the problem with Smart Growth is one of scale in the face of the challenges ahead of us. Similar results were found assessing the results of eleven New Urbanist developments in Perth (Falconer, 2008; Falconer et al., 2010). While commendable and likely restrained by statutory planning practice, Transit-Oriented Development and Smart Growth-like projects are not adequate. Alone or in combination they will do no more than provide a fraction of the overall growth in population nor contribute much to the reduction in VKT and GHG required. They are not adequate because they assume that the one project will somehow spur behaviour change or provide a new template for improving the urban condition.
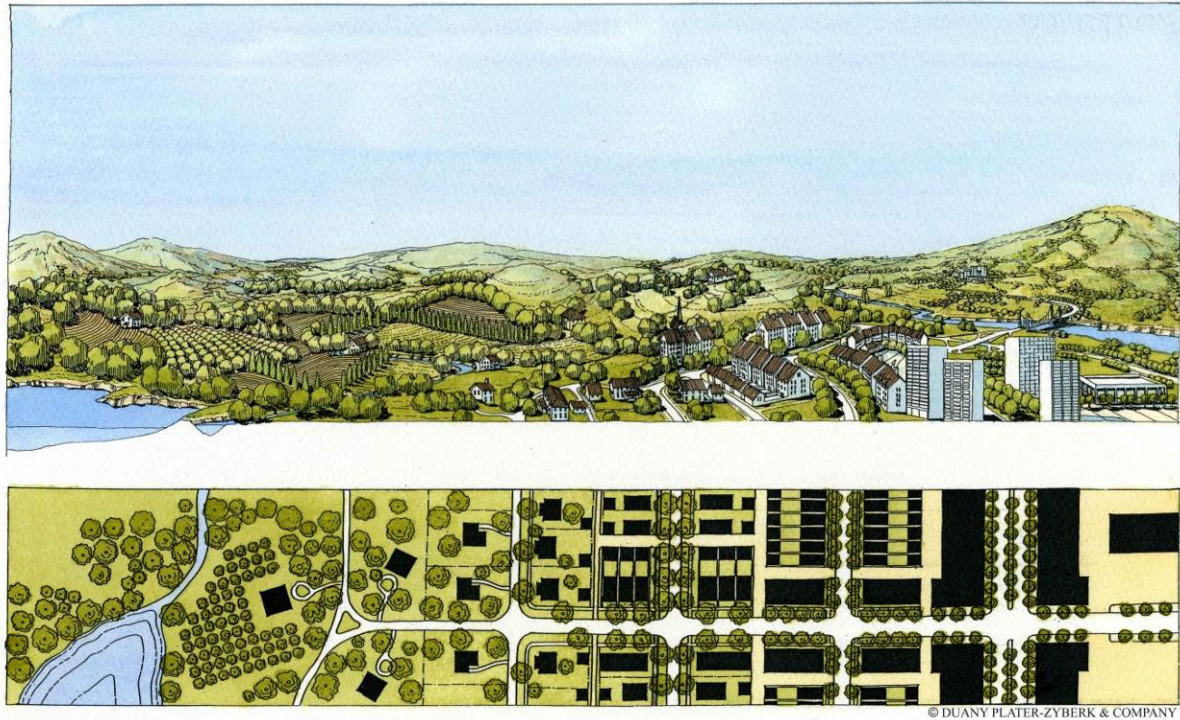
Figure 26 New Urbanist Transect

Rather, the operation to shift from an automobile-dependent region to a Transit-Oriented Region cannot rely on one or two projects with mildly ameliorated ecology or improved active-transport connectivity. Rather, there needs to be a concerted effort across the region to build new rail lines, optimise the current high-capacity public transport corridors, up-zone and re-zone to mixed use, reduce parking ratios, plan for pedestrians at every intersection and reduce expenditures on highways. We cannot, on one hand, expect limiting land supply (such as Portland's Urban Growth Boundary) to have effect without reducing parking and increasing the public transport network and frequency *across the metropolitan region*. Likewise, we cannot expect increasing capital-intensive public transport capacity (like Edmonton, Canada's LRT) to have an effect on VKT or walkability unless we limit the land supply and rezone significant areas of land adjacent to rail stations *across the metropolitan region*. If we don't approach it at this scale, there will be enormous

expenditure of capital and labour for not much result. (See 'Urban Design for Public Transport', 'Urban Design for Active Transportation' as well as 'Transit Capacities and Urban Form' in the appendices starting on page 447.)

> Many New Urbanist developments are emphasizing legibility and permeability of street networks, not density of activity. Hence we should not be surprised when the centers they design are not able to attract viable commercial arrangements and have weak public transport. However, centers can be built in stages with much lower numbers to begin with as long as the goal is seen to be to reach these kind of densities ultimately through infill at higher intensities (Newman & Kenworthy, 2006).

The purpose of this research is to understand the scale of the challenge before our cities and to propose a set of methods to explore the region at three different scales. The speculation is that the urban form and fabric can be shifted over the next 50 years to produce a green-economic polycentric network of walkable, transit-served, complete communities. The method then quantifies a plan for a new urban fabric, based in the corridors and nodes of the existing urban fabric, to permit personal opportunity within the broadened 'Common Future' (Brundtland, 1987) concepts of a Green Economy (UNEP, 2011a, 2012c). As a result, some of the basic 'building blocks' of policy we can measure, model and manage are more clearly understood, including the pay-offs and trade-offs of a new urban fabric.

To this end there have been many calls to strongly realign the economies of the world, starting from the local and streamlining national priorities through active investment in those technologies and processes which reduce harm and improve equality between genders and classes. Technologies such as electric trains through to water-sensitive urban design to keep waterways clear of eutrophic nutrient run-off, and processes such as free education and health care for all are but two easily defined and achieved goals.

2.4.1.2 LOCAL GREEN ECONOMY: A LOW CO2, HIGH GDP ECONOMY

> We need to "…envision a new and better way to organise the economic activity of our society. If we can envision it, we can make it happen (Etham, 2010).

> …an investment in the rail system is an investment in the real economy (Tierney, 2012).

The United Nations, based in New York, has been working in this field on at least these two, hopefully overlapping, fronts from the Environment Programme (UNEP) and the Department of Economic and Social Affairs (DESA). First from the UNEP we read that the Green Economy will be one in which economic growth will be more equitably shared within a low carbon paradigm.

For the purposes of the Green Economy Initiative, UNEP has developed a working definition of a green economy as one that results in **improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities**. In its simplest expression, a green economy can be thought of as one which is **low carbon**, **resource efficient** and **socially inclusive**. *(emphasis included)*

A green economy is first and foremost about transforming the way economies grow. Currently, growth is typically generated from investments in high emission, heavily polluting, waste generating, resource intensive, and ecosystem damaging activities. A green economy requires investments to shift towards low carbon, clean, waste minimizing, resource efficient, and ecosystem enhancing activities. The key indicators of economic transformation, therefore, include the shift in investments … and, over time, the consequent growth of environmentally friendly or environmentally enhancing goods and services and related jobs (UNEP, 2012b).

While acknowledging that growth forecasts for transformation are more likely than not to be incorrect, that it is still important to aim for reduced impacts and to account directly for those unpriced 'externalities', such as clean air and water as ecosystem services, which have a value especially once in scarce amounts.

"…forecasting future resource scarcities is an exercise in speculation, always uncertain and never without risk. Nevertheless, the point of investing in a green economy is to recognize those resource scarcities that are clear, unavoidable and (currently) un-priced, and to be one of the first to build these unavoidable scarcities into the economy (UNEP, 2012a).

The United Nation's Department of Economic and Social Affairs, Division of Sustainable Development, has prepared the Sustainable Development Goals (SDG) with sixteen Focus Areas (DESA, 2014). Focus area 10 is devoted to cities with specific, programmable goals:

Focus area 10. Sustainable cities and human settlements

Build inclusive, safe and sustainable cities and human settlements

a) By 2030, ensure universal access to adequate and affordable housing and basic services for all, and eliminate slum-like conditions everywhere

b) By 2030, provide access to safe, affordable, accessible and sustainable transport for all, improve road safety and urban air quality

c) enhance capacities for integrated urban planning and management

d) by 2030, reduce the ecological footprints of cities by x%

e) by 2020, increase by x% the number of cities adopting and implementing policies and plans towards resilience and adaptation to climate change and natural disasters

f) by 2030 enhance social cohesion and personal security, and ensure universal access to inclusive and safe public spaces

g) by 2030 ensure that all cities are accessible and offer opportunities to persons with disabilities

h) protect and safeguard the world's cultural and natural heritage (DESA, 2014)

Richard Florida, notably at the Martin Prosperity Institute at the University of Toronto, has also been concerned with cities. After attending the World Urban Forum in 2014 he prepared a list of eleven reasons why the UN should make cities the focus of its Sustainable Development Goals (SDG); regarding number eight he writes:

> **…cities play *the* central role in reducing climate change and improving the environment.** Cities are ground zero in the fight against climate change. Built right, they have lower carbon footprints per capita and can better withstand the rising sea levels and intense storms that the changing climate has already unleashed. Built wrong, they can lead to more auto-dependency. These aims cannot be met only by setting space-blind emissions targets. They require smart planning and design in advance of growth (Florida, 2014). *Emphasis included*

In regards to cities and the global effort to arrange our cities to provide more sustainable prosperity with reduced automobile dependence, he has written:

> Our built environment and development patterns are just beginning to catch up. A growing number of cities and metros, especially those with more knowledge-based and talent-driven economies, place a premium on being clean and green as

key elements of their quality of life and ability to attract talent. Bigger, denser metros which are less car-dependent generate greater energy efficiency and lower levels of pollution as well as higher levels of productivity and innovation (Florida, 2012b).

And in respects to the scale of the operation in building the physical quantity of services and amenities:

> We will be investing trillions of dollars on infrastructure over the coming decades to build railways, roads, buildings, parks. We need a way to imagine a way to develop infrastructure to build and manage more productive cleaner and more sustainable age of prosperity (Florida, 2012a).

Jeff Kenworthy has been working on this very topic for several decades, and it is important to re-read his contribution. Well in advance of Richard Florida's latest comments Kenworthy wrote:

> Economic growth needs to emphasize creativity and innovation and to strengthen the environmental, social and cultural amenities of the city (Kenworthy, 2006).

Though calling this an 'eco-city' and not a 'green economy', the ideals overlap with the critical dimensions listed as follows:

1. The city has a compact, mixed-use urban form that uses land efficiently and protects the natural environment, biodiversity and food-producing areas.

2. The natural environment permeates the city's spaces and embraces the city, while the city and its hinterland provide a major proportion of its food needs.

3. Freeway and road infrastructure are de-emphasized in favour of transit, walking and cycling infrastructure, with a special emphasis on rail. Car and motorcycle use are minimized.

4. There is extensive use of environmental technologies for water, energy and waste management – the city's life support systems become closed loop systems.

5. The central city and sub-centres within the city are human centres that emphasize access and circulation by modes of transport other than the automobile, and absorb a high proportion of employment and residential growth.

6. The city has a high-quality public realm throughout that expresses a public culture, community, and equity and good governance. The public realm includes the entire transit system and all the environments associated with it.

7. The physical structure and urban design of the city, especially its public environments, are highly legible, permeable, robust, varied, rich, visually appropriate and personalized for human needs.

8. The economic performance of the city and employment creation are maximized through innovation, creativity and the uniqueness of the local environment, culture and history, as well as the high environmental and social quality of the city's public environments.

9. Planning for the future of the city is a visionary "debate and decide" process, not a "predict and provide", computer-driven process.

10. All decision-making is sustainability-based, integrating social, economic, environmental and cultural considerations as well as compact, transit-oriented urban form principles. Such decision making processes are democratic, inclusive, empowering and engendering of hope. (Kenworthy, 2006)

Concern for the Urban Commons, Kenworthy predicted, will become the armature for a slow and gradual shift towards a less impactful urban lifestyle, being an approach promoting:

> … a city that is "greener" in its overall functioning through more use of green transport modes, traffic calming to promote greener, safer streets, less energy use and less environmental impact (Kenworthy, 2006).

Other authors have correctly noted that breakthroughs in 'greening of the economy' in innovation and financing will be achieved at the city region level. Matthews writing in The Conversation:

> …it is really at the level of cities that progress is likely to be achieved. Increasingly, the focus of efforts to green the current fossil-fuelled industrial system, as it spreads relentlessly worldwide, will have to focus at the city level for real solutions, both of technology and of finance – because it is at the level of cities that the most acute problems arise (Mathews, 2012).

There are many calls for a Green Economy, but rarely are these displayed as spatially coordinated. And likewise, among many designs are genuine small-scale moves which are

green, but they are rarely able to be scaled up to precinct or district level designs or are not actually genuinely 'green' in any other way than by name.

The Green Economy, if properly costed may well be referred to in the future as merely the 'economy' (Etham, 2010). It will be one having a lower use of non-renewable resources and providing inter-generational benefits. This may include being leaders and researchers in a directory of Green Technologies like solar, wind, wave energy, light rail transit (LRT) and personal rapid transit (PRT), large format composters for organic rubbish and recycling of most other wastes as well as co- and tri-generation plants for energy production. However, a genuinely Green Economy will also be one in which people walk a great deal more, drive automobiles a great deal less, use less resources, grow more food, exercise more, stay healthy, shop locally, grow locally, and are responsive to the needs of children and the elderly in all things including urban design. Green Economy has to be about another way of living which is just as fulfilling, amenity rich, choice enhanced and desirable as the current Carbon Economy. It won't be a distant and unrecognisable imaginary place; it will be all around us within the urban footprints we have already made.

However, despite the certainty that our generation is the first to broach the topic, it is judicious to remind ourselves of what others have already written on it. Since at least the classical era, authors have been concerned for the human in their environment and how best to artfully arrange the urban landscape for the best outcomes.

2.4.1.3 CLASSICAL

In the classical era of the West, several scholars approached the issue of regional planning, but only barely. Aristotle felt that public life was far more virtuous than private life and that cities existed for living well and nobly. One of the most important aspects of urban planning was, literally, its aspect in facing towards the healthy winds of east, as best, or south as a second best. He even described the preferred physical layout:

> ...the city should be open to the land and to the sea, and to the whole country as far as possible …The site of the city should … be convenient both for political administration and for war. With a view to the latter it should afford easy egress to the citizens, and at the same time be inaccessible and difficult of capture to enemies.

> The whole town should not be laid out in straight lines, but only certain quarters and regions; thus security and beauty will be combined. [18]

Hippodamus of Miletus, referred to as the father of urban planning, is remembered for laying out a rigorous grid-plan for cities and dividing the urban areas into sacred, public and private realms, including specifying that the *agora*, the public square, should be the centre of physical and social life.[19]

There was then an interlude of theory versus practice, in which the Romans constructed urban fabrics we can view as remains, such as Timgad, Algeria, or as living cities such as Paris, London and Florence. The Romans built military camps for defence which then grew to encompass much larger areas, for trade through ports such as Ostia and Caesarea and to reinforce the concept of *Pax Romana,* which included sanitation with aqueducts, baths and latrines as well as a law court *basilica* and arts *amphitheatre* (Kostof, 1992).

Vitruvius was one of few authors of the Roman period who left a testament to what we might now call urban design or planning. Though primarily concerned with individual buildings, he recommended that a city be arranged to take advantage of winds by opening large thoroughfares towards the winds to flush the city while the smaller streets should be well protected from prevailing winds to limit their penetration into homes (Broadbent, 1990).

Leon Battista Alberti, Andrea Palladio, and Leonardo da Vinci were great architects and all owe a debt to Vitruvius, but still they left nothing on overall 'urban design' beyond the scale of the building or an attempt to rationalise the flow of traffic. Only the Romans, in practice not text, accomplished city building on a large scale and across wide swaths of land. They did so for reasons of regional and international peace, but even more so as a testament to their values, sanitation along with bread and circus to appease the masses, in making the 'foreign' a part of their domain.

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[18] "Politics, By Aristotle" http://classics.mit.edu/Aristotle/politics.7.seven.html Accessed May 18,
[19] "Hippodamus of Miletus"
https://www.princeton.edu/~achaney/tmve/wiki100k/docs/Hippodamus_of_Miletus.html   Accessed May 21, 2014

When purposefully sanctioned and not an 'organic' outgrowth, city building through much of history has been primarily the province of engineers. It was concerned with defensive walls, bridges, draining storm water and sanitation. Then Camillo Sitte, an Austrian watching the city of Vienna grow up around him as the defensive walls were being lowered, commented on the benefits of taking concern for the urban environments being constructed.

> The large open areas in metropolises, especially when laid out as parks and perhaps supplied with expanses of water and with water works, form the air-pockets essential for breathing in the city. They have appropriately enough been called its lungs (Sitte, 1945 p. 169).

He called for the engineering of human habitat to be rendered an art:

> …city planning, properly understood, is no mere mechanical office task, but is actually an important and inspired work of art (Sitte, 1945 p.185).

Yet, after thousands of years of living in cities with hinterlands, there was scant literary understanding of the relationship between the home and the region, human tasks and the resources' provenance as a networked system. Indeed, the region, ecosystems, urbanism and the human element had to wait for Sir Patrick Geddes who described them in the mid-20th century. Though the exact meanings of his rambling findings are difficult to discern, his work is foundational. For example, he coined 'region' as a term to include all the activities within a bio-geographical watershed which support urban life, and 'conurbation' being the series of interrelated and dependent urban areas. Fortunately for us he left several illustrations to describe what he had found, such as the following figures.

MINER　WOODMAN　HUNTER　SHEPHERD　PEASANT　GARDENER　FISHER
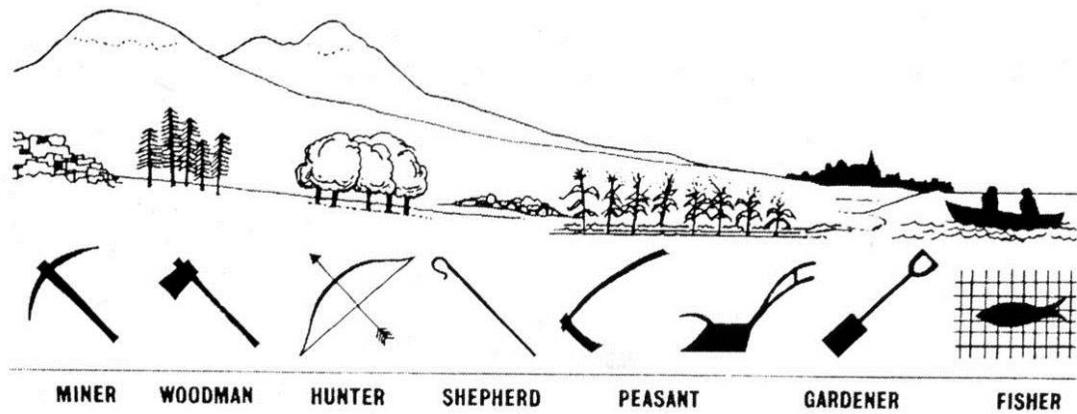
Figure 27 Patrick Geddes' transect

GEDDES DEMONSTRATES HOW THE LAND IS SHAPED BY HUMANS, BUT ALSO THE HUMANS SHAPED BY LAND (GEDDES, 1949)

While Geddes illustrations are precise, his text wanders. In describing the Valley Section:

> We visualise and depict our city from its smallest beginnings, in its immediate and wider setting, as of valley, river, and routes; we spread it upon its plain, tower it upon its hills, or throne it more spaciously by the sea. Our synoptic vision of the city, for each and all of its growth-phases, thus ranges through region to homes, and back again, and with pictured completeness as well as plans : first a rough jewel on the breast of Nature, then the wrought clasp upon her rich-embroidered garments of forest, vineyard, or orchard, of green pastures or golden fields (Geddes, 1949 p. 361).

After millennia urban persons now had the language to describe a few of the relationships between tasks and resources in their region. Geddes asks us to understand them to 'make something a little better of our paleotechnic disorder' (p. 398) to 'express, as did the builders of old, the spirit of our cities' (p.365).

The Valley Section and its social types: in their native habitat and in their parallel urban manifestations.
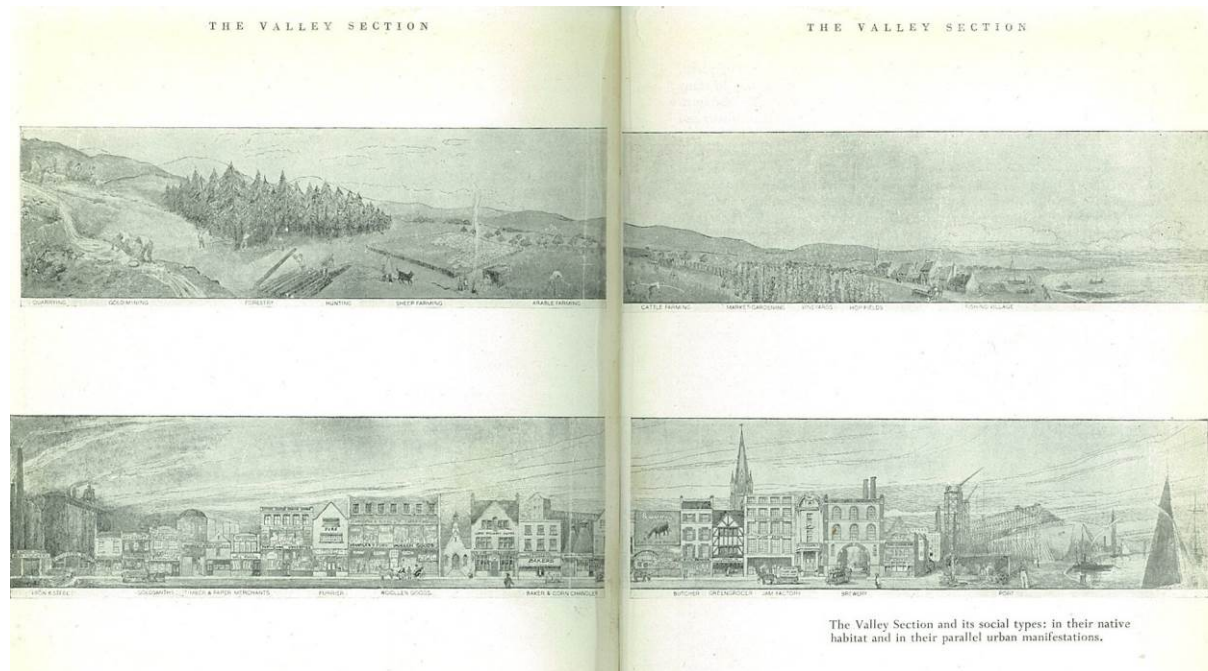
Figure 28 Patrick Geddes – The Valley Section.

The Valley Section and its social types: in their native habitat and in their particular urban manifestations (Geddes, 1949).

In every city there is much of beauty and more of possibility; and thus for the town planner as artist, the very worst of cities may be the best (Geddes, 1949 p. 364).

Lewis Mumford, author of 'The City in History' (Mumford, 1961), was immensely influenced by Geddes' thoughts, expanding through his work the notion that a city and its condition is the product of regional forces far beyond the immediately observable on a street corner. He, along with others, founded the Regional Planning Association promoting the well-arranged growth of conurbations and broader regions (Parsons, 1994) to the benefit of human enterprise and the environment. Looking back now this appears to be stating the obvious but at the time it was entirely novel; even today it is rarely accomplished. Along with Mumford was Benton MacKaye, the founder and author of much practised regional planning in the United States and across the Anglosphere, especially in regards to ecosystem and human-use management (MacKaye, 1968, 1990). Together they built on Gifford Pinchot's work in the first 'scientific management' of the nation's (United States) resources (Place, 1957) which suggested ameliorations in planning for the broad scale region.

Meanwhile Sir Ebenezer Howard's Garden City movement was flourishing under his writing and activism (Howard, 1902) and the capacity of Raymond Unwin. The garden cities were intended to be a new pattern of living, based on a shared and cooperative vision of industry, work, recreation and culture. The workers would live in simple but well-built homes and work at a local factory in between harvesting the bounty from the fields and plots surrounding the village. This utopic proposal was a response to crowded tenements with a lack of opportunity to rise fiscally or spiritually in the dirty cities of the Industrial Revolution. Ultimately the cost of purchasing land and building the cottages rendered the whole enterprise only suitable for middle class bohemian and fastidious gardeners of roses, not workers (Fishman, 1982). There is a lesson in the Garden Cities movement in that the scale was wrong: the scale was entirely sub-urban and only suitable to a class of people with the means and wish to purchase leafy green white-picket fence idealisations of 'nature'. There is the same outcome when we try to cluster density, slightly but not enough, in TOD precincts alone and without region-wide goals. Simply, they did not cross an urban (or urbane) threshold to be desired by enough people, affordable to all people or dense and mixed-use enough to become significant in lowering VKT or GHG.
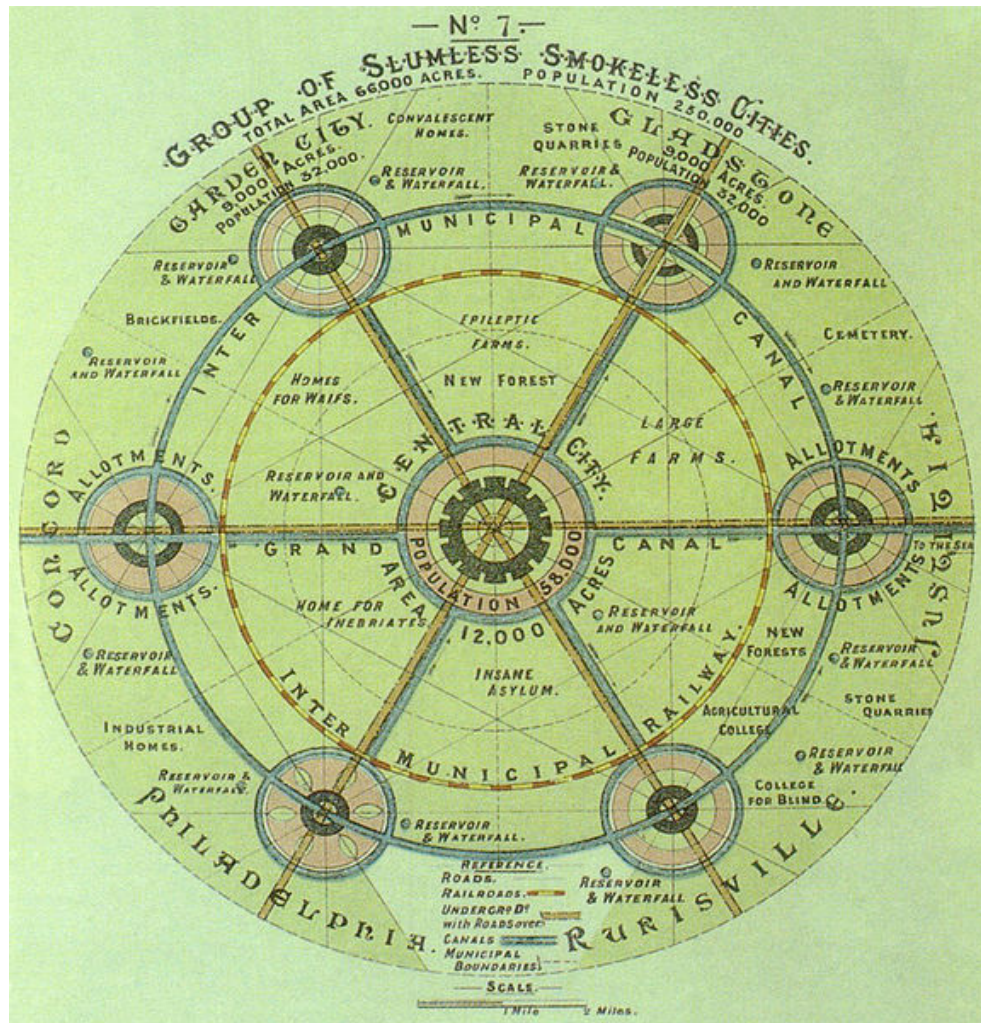
Figure 29 Howard's Garden City as a 'Group of Slumless, Smokeless Cities'

SOURCE: AUTHOR'S COLLECTION

At the other end of the physical and intellectual scale, The Radiant City (1924) of Le Corbusier (born Charles-Édouard Jeanneret-Gris to Swiss watchmakers in very idyllic La Chaux-de-Fonds) endeavoured to create the city in a new manner more befitting the common person. It included an open disdain for the streets of the late horse-drawn (faeces-slipping) and early automobile (pedestrian-killing) city of the 1910s and 20s. It turned away from the overcrowded noisome courtyard housing in which the workers of Paris and Berlin lived in lightless and airless rooms without running water. His building programme espoused light and air to permeate the homes of the inhabitants above all else, permitting their healthy qualities to improve the life of the European masses(Hall, 2002). In his Radiant City there was a clear distinction between living, working, shopping and

transportation modes and large swaths of ecological open space, sports fields, sunbathing zones and allotment gardens. The pattern attempts to combat the malaise of the era at a large scale. Corbusier planned for installation of precincts of highly mono-functional tall towers across the metropolitan region, but with overall moderate density due to the surrounding open space plan (Corbusier, 1967). That his ideas have been criticised so vigorously by many in the neo-traditional urban design field reflects a collective forgetting of what life was like in the – now romanticised – noisy, polluted, cobbled streets of *pre* social-democratic Europe.
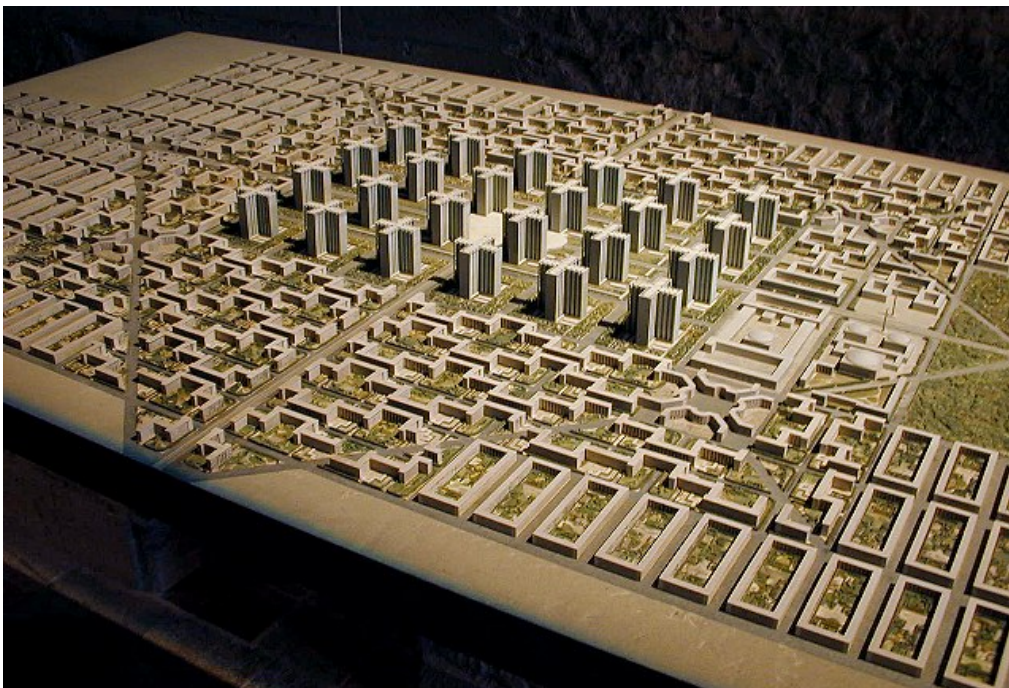
Figure 30 Corbusier's Radiant City

SOURCE: CORBUSIER, FROM AUTHOR'S COLLECTION . NOTICE THE LARGE AREAS OF GREEN SPACE BETWEEN, AROUND AND THROUGH THE URBAN FABRIC.

Complementing the Radiant City in spirit, but taking a more decentralised view than even the Garden City, was the Broadacre City of 1935 by Frank Lloyd Wright. He described the necessary decanting of the enslaving, congested city towards the long-standing American ideals of Manifest Destiny: personal liberty and space. In this he was echoing John Locke and Thomas Jefferson's ideal for the self-determined agrarian man, free to market his wares and travel as he likes (Marx, 1967; Hall, 2002). In regard to travel and trade

Wright pre-emptively suggests, by several decades, the Interstate Highway system of post-world war two.

> The traffic problem has been given special attention…Every Broadacre citizen has his or her own car. Multiple-lane highways make ravel safe and enjoyable. There are no grade crossings nor left turns on grade. The road system and construction is such that no signal nor any lamp-posts need be seen. No ditches are alongside the roads. No curbs either. An inlaid purling *(small bollard?)* over which the car cannot come without damage to itself takes the place to protect the pedestrian (Wright, 1935 p. 349). *Italics added*

Ultimately, the wide-scale decentralisation of the city into the rural regions will eventuate in a 'natural' life.

> Unwholesome life would get no encouragement and the ghastly heritage left by overcrowding in overdone ultra-capitalistic centres would be likely to disappear in three or four generations. The old success ideals having no chance at all, new ones more natural to the best in man would be given a fresh opportunity to develop naturally (Wright, 1935 p. 349).
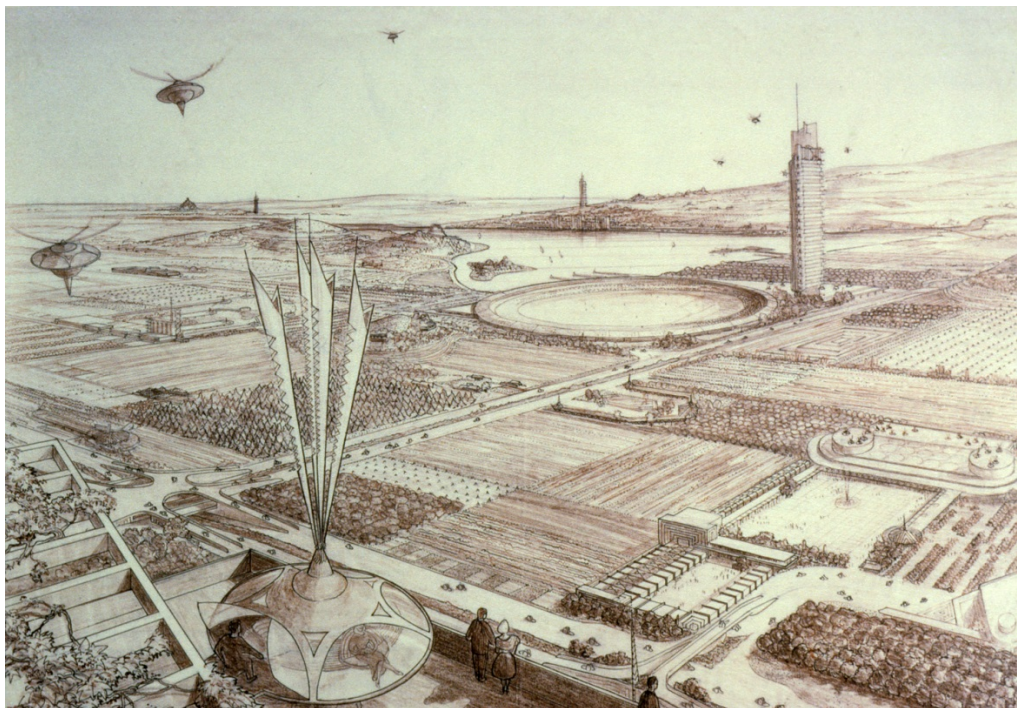
Figure 31 Wright's Broadacre City

SOURCE: F.L.WRIGHT, FROM AUTHOR'S COLLECTION. WIDE, OPEN, UNDIFFERENTIATED, PRIVATE SPACE CONNECTED BY AUTOMOBILES.

Wright, Corbusier and Howard had the courage to make proposals using what they knew and observed. They interrogated the class system and the economic powers that perpetuated a beaten-down underclass. These three believed that the agency of technology, knowledge and care would help build the cities, urban areas, regions appropriate to unleash the talents of individuals and the best that the land and culture might produce (Fishman, 1982 p. xii):

> Their plans, when compared, disagree profoundly…They offer us not a single blueprint for the future, but three sets of choices – the great metropolis, moderate decentralisation or extreme decentralisation – each with its corresponding political and social implications (Fishman, 1982 p.7).

Gordon Cullen, in apparent horror of everything listed above from Geddes to Wright, undertook a nostalgic review of the best of aesthetic urban design strategies. His travels took him sketching across Europe and even New Delhi, where Lutyens – the colonial architect – had perfected the vista-enhancing 'serial vision', to refine city building into replicable principles useful during the rebuilding of England post-Blitz. Such pattern making, and communication by pattern, have influenced Christopher Alexander's extensive Pattern Language (Alexander et al., 1977), Andres Duany's Traditional Town Transects (Duany et al., 1991; Duany et al., 2003) and a host of others such as Peter Calthorpe's Transit-Oriented Development pattern (Calthorpe, 1993), Doug Kelbaugh's Pedestrian Pockets (Kelbaugh, 1989, 2002), to Cynthia Girling and Ron Kellet's Skinny Streets (Girling & Kellett, 2005). Though Alexander's technique is beguiling, the outcome is a repudiation of contemporary design in favour of nostalgic corbels and spires, and a downscaling of urban centres toward a village picturesque which may never accommodate the jobs-housing balance required except for a wealthy few.

Ian McHarg, on the other hand, only thought big. After many long walks on heath between dales (McHarg, 1996 p.16), McHarg prepared the world for a radical rethink on planning. Following on from Geddes, a fellow Scot, he was concerned with applying knowledge and data about the natural world to find the best suit for human tasks. His use of physical transparent map overlays of geology, aquifer, slope, habitat vegetation, hydrology has evolved into the very commonly used Global Information Systems (GIS)

technology and the then radical Environmental Impact Assessment now used regularly to avoid or mitigate risks and costs to the natural world (Steiner, 2004).

His methodology, now known as the 'McHargian' approach, scientifically broke down the region into suitable uses for human agency and measures to avoid and mitigate damage to the ecosystem process in the pursuit. Although McHarg was able to tell us best how and where not to build, he gave no indication of how to build, what scale to build, to achieve environmental goals. The best use of his technique is to overlay information to find opportunities, but even this is mechanical when understanding of the human and ecological environment coupled with an intuition based in experience suffices.

With careful consideration of where our cities and towns grow, we can continue to preserve our recreational areas and agricultural land (McHarg, 1995).

Figure 32 The McHargian Region

SOURCE: (MCHARG, 1995) AS WE CAN READ IN THE QUOTE ABOVE AND BY THE EMPHASIS IN THIS DRAWING, MCHARG GIVES FEW INDICATIONS OF WHAT TO DO WITH CITIES.

The common link with all these authors listed above, from Aristotle to McHarg, is that they found their contemporaneous city lacking vision and confidence, that there were waste and lost opportunities. We needed to become better as a culture in balance with its natural limits; that large-scale problems loomed if large-scale action was not taken to right

the direction. Yet, despite all the plans, then as now, the best we can hope for are 'small scale renovation projects which might keep pace with the decay' (Fishman, 1982 p.xi).

> …regionalists saw a radical shift in metropolitan structure, away from a monocentric metropolis and toward a more dispersed network of cities and villages arrayed across a vast — although integrated — space they called the "urban region." After the mid-20th century, most new urban growth occurred outside the regional core, which fuelled the development of sprawling and often connected metropolitan areas (Fishman, 2000).

The review above does not attempt to be a complete listing of all the forces salient in the discussions on urban futures from the small to large scale, however it does show the trends of ever-deepening dialectic of bio-physical systems and the human-use patterns by which we move, distribute ourselves and our goods while displacing the environment.

2.4.1.5 RENAISSANCE IN URBAN DESIGN

After a period of stagnation, there has been a renaissance in urban design over the last 30 years. After reviewing the arguments for and against urban design as a strategy to encourage urbane living, including freedom from automobile dependence, this sub-section will look over a suite of large-scale urban redevelopments to instruct us on how to build precincts which matter and are desirable places within the thickened urban fabric of a Transit-Oriented Region.

There have been many attempts to understand the connections between urban design and the way people move through a space and the success of a place. Is a good space merely one which is wide enough, or one with benches and shade trees? Do pavers and rubbish bins matter? Lighting? Security?

Cervero and Kockleman's seminal work on the 3Ds (Density, Diversity and Design) of Transit-Oriented Development (Cervero & Kockelman, 1997) concluded that urban design had the least impact on choice mode decisions. This was not a good start in reviewing the positive effects of urban design in preparing transit-rich, high-density living.

Continuing on in this vein, more recently Cervero stated:

> It is unlikely that "livability enhancements"‖ like streetscape improvements and greening of transit corridors will be sufficient to offset the opposition to higher densities in traditionally more auto-oriented settings of the U.S. More than likely, external factors like higher motoring and parking costs will be more effective than well-intended urban design strategies at creating the kinds of urban densities needed for cost-effective transit services in the U.S.[20] (Cervero & Guerra, 2011 p.15).

Cervero is also known for the phrase 'mass transport needs mass', implying there must be activity density to support the economics of mass transport. Though mass public transport may need a mass of jobs and residential density, without an aesthetic appeal and functional pedestrian orientation to the densest redevelopment projects the real estate

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[20] The only comment being that these 'auto-oriented settings' may not have a choice going forward as land prices alone will dictate change. More amenity-rich urban environments, as a compensation for the change perhaps, will go hand in hand with the change.

may not sell, a new lifestyle may not take hold and the transit could not be supported. The 'well-intentioned urban design strategies' will play a key role in activating the public spaces which will make public life and transit use more likely, especially where the hard to convince public may not immediately see why they would live 'densely'. Such benefits of design will help as long as the basic structure of density and diversity is there to enable the fundamentals of time saving, according to Marchetti's time budget, to be applied. Design matters, but without the other Ds it is not going to succeed. Yet, Cervero does acknowledge in monographs the need for design:

> The desirability of the station area can be enhanced all the more through urban design – by providing internal bike paths, opening up civic gathering areas, an abundant landscaping the neighbourhood with trees, shrubbery and playgrounds. And, of course, where residents locate, so will convenience shops, grocery stores, movie theatres, and other activities that cater to them. Eventually, then, a compact, mixed use community will emerge…Transit is the magnet, the glue, that attracts this efficient cluster of diverse urban activities to a well-defined and internally walkable district…. Of course, this is all theory…Transit can be a powerful shaper of cities and regions, though rarely on its own (Cervero, 1998 p.82).

It goes beyond mere aesthetic 'design' to another level beyond decoration, and understanding that the best of cities have a wide variety of street widths and block lengths and desirable places to walk towards via various routing. This makes for personalisation, interest, delight and opportunity for formal and informal meeting, adding rich public life and privacy to what one may choose. To understand the complexity of design choices in the layout of streets and blocks Jean Hillier developed Space Syntax to illustrate the differences in connective urban fabrics. In a review of the work of Hillier and Space Syntax, the journalist at Wired had these sage words to say:

> They reasoned that a city's success depended largely on how easy it was for people to move about on foot.… What set Hillier and Hanson's ideas apart was the notion that a city's geometry did more for movement than any other design factor. They argued that every other cog in a city's engineering depends on the walkable grid. Cars, buses, trains, and bikes play a role, too, but only as much as they transport people to places where they then proceed to walk around (Stockton, 2014).

The be fair, the California-based Cervero is likely commenting on the design of the painfully slow retrofits of 'decorated' train station precincts in the middle and outer suburbs of automobile-dependent cities such as San Francisco. From an opposite

environment of highly accessible London, Bill Hillier developed Space Syntax to demonstrate the positive effects of the designed structure, the armature, of street networks and block sizes into which other urban amenities (parks, rail, buses, schools and so on) are placed. Likewise the work of Allan Jacobs, also of Berkeley, has shown how grids and small block sizes allow for a far greater degree of urban grain. In arguing his position, almost as though he and Robert Cervero had discussed this previously in the halls of their shared faculty, he had this to say:

> ...some will argue that the physical design of the street, or of almost anything in the urban environment, has little to do with its goodness, and that social and economic characteristics are the crucial variables. That may well be so, but it begs the question. Streets still have to be laid out and designed, and non-designers at least as much as designers are concerned with their physical as well as their socioeconomic development (Jacobs, 1995 p.6).

Even if there were an argument against trying one's best to create an attractive setting, preferring a merely technocratic functional one, there will still be an impulse to express 'values' to attract certain 'activities':

> Even assuming that the physical characteristics of the street are not an important criterion for deciding what makes one street better than another, one presumably wants to do ones' best to design and arrange the pieces in ways that will be better, that are more likely to please, uplift, attract, or achieve a desired set of values than some other arrangement. ...People frequent and enjoy some streets more than others, for physical reasons as well as for the activities or calm to be found there. We come back to the design of street (Jacobs, 1995 p.8).

The matter then becomes one of perspective: Is 'design' the chicken that makes the nest and lays the egg or, conversely, is 'design' the egg sitting inside an accidental nest with an unrealised potential?

2.4.1.6 SPATIAL AXIOM OF URBAN DESIGN

> If one can get the correct balance of prospect and refuge for each local condition at the correct time in the evolution of a city, one will have understood very well what it means to be an Urbanist. And this is critically important, for what works in Spain as a desirable urban outcome may very well not be the same as what one may find even in the Mediterranean , let alone in Western Australia a land mass of equal climatic range (Blumler, 2005).

There are several large, seemingly unrelated, concepts deeply ingrained in urban design. These divergent concepts will benefit from being unified, to find the preferred 'balance' of an 'urbanist' for the TOR strategy. Often the very basis for debate, controversy, approvals of a project, hinges on the relative 'openness' (prospect) or 'enclosed-ness' (refuge) of the design proposal (Appleton, 1975; Fishman, 2011). Generations of architects and planners have been and currently are being influenced by the preferences – expressed as a philosophy – of faculty members at different universities. They are talking about the same thing but speaking to different scales and outcomes. These designers will influence future attempts to build memorable and meaningful urban environments such as suggested in the TOR strategy.

The 'Open and Enclosed' (Fishman, 2011) is a paradigm within which much of current debate can be centred. The concept of preferred urbanity being either 'open' or 'enclosed' forms unusual allies and opponents. Essentially, there are the modernists who prefer 'open' urban plans with lots of light and air and punctuated with iconic building masses, and the neo-traditionalists who prefer streets with good enclosure and building masses subsumed into the urban fabric.

This was similarly elucidated by Patrick Condon in his 'Cubist Space, Volumetric Space' (Condon, 1988) article, decrying the modernist planners who placed buildings in undifferentiated space leaving large areas between with few remnants of a human scale or street wall along which a citizen may pleasantly wander 'window-shopping':

> "Cubist space, to simplify drastically, is made by placing solids in space; volumetric space is made by enclosing space with solids."

Condon goes on to give examples of Cubist spaces, such as many Modernist housing projects which deny association to the street and urban fabric in which they sit as buildings and landscapes filled with objects. He contrasts these, subjectively aesthetically, with places such as Piazza San Marco.

> Traditional urban space was explicitly bounded by buildings joined to form a continuous wall of facades at the street edge. In the Radiant City, shafts of structure would be placed as objects on the undifferentiated space of the city site. Thus the nineteenth century city of space becomes the twentieth century city of object buildings in space, obliterating the street as a figural spatial entity and consuming space without context….The city is no longer a series of interconnected voids but a

fantastic modern sculpture of immense yet perceptible extents, capable of being seen entirely at once. …In this way the transformation of experience over time and the interpretation of inner and outer space are expressed in urban form.

…the destruction of the existing city of corridor streets was also justified by the imperative to bring 'nature' into the city. Nature, with its warming sun and clean air, is the human need that validates Corbusier's entire urban design theory(Condon, 1988).

Yet, it is too easy to blame a style, materials, individual architects or even the programs which were at fault with any of these. Differently used, all these styles, materials and techniques can be used to arrange almost any sort of desired project. Corbusier wasn't to blame for the socially and physically stifling old European cities with no space; he merely proposed a solution.

The difference cannot be one of style, but rather in the mix of land uses, mix of building types, densities across the hectares, mix of activities within each building and the mix of mode share to be able to access each building. In these last items lies the germ of the real problem: mode capacity. If we don't plan for the appropriate mode to undertake the task planned for, then the best laid plans are for nought. Conversely, the appropriate mode is fundamentally a function of land use planning. Land Use planning is strengthened by a proper Site Planning exercise both at the level of the project and at how the project fits into the region. When all the pieces fit together a cohesive whole emerges, but when one piece doesn't fit the composition breaks down.

Fishman and Condon's theories are linked to one another. Each refer to the self-sorting people undertake based on primordial longings for pleasure and security. That people have preferences regarding a balance between 'prospect and refuge', view and security, was first proposed as an urban environmental determinant in 1975 by Jay Appleton. Prospect and refuge theory (Appleton, 1975) has to do with having both a prospect, an ability to look out for opportunity and danger, and a sense of security, refuge, in which nothing may attack from the rear. Such ideal locations command a real-estate premium and provide persons with a strong sense of 'place', identity, comfort and ability to craft a home. A prototypical place of this sort, wired into our prehistoric desires, would be a cave on a mountain overlooking savannah grasslands in which weather might be viewed,

fire can be avoided and enemies seen or food sought. It is a defensive place and an opportunity-presenting place. Today, without such fears people no longer need literal caves, yet those places with the best security and views do command a price premium around the world. This holds true be it from a house on a hill with limited access or a top floor of a secure condominium with a great view and great opportunities, to a house in a cul de sac.

Together these three authors, Fishman, Condon and Appleyard, can be called the Spatial Axiom of Urbanism. They combine the Open (Cubist/Prospect) and the Enclosed (Volumetric/Refuge) concepts into one whole.

Where along the Spatial Axiom (below) a project or a city design should fit, is fundamental to the current debate (CNU, 2011) – occupying plenty of academic airspace – between Landscape Urbanism (Waldheim, 2006; Waldheim & Berger, 2008) and the New Urbanism (Duany et al., 1991; Duany & Talen, 2013).

As we plan for the future we must imagine how strategic infill sites at public transport stations will operate. The changes to the urban fabric will be, in some instances, quite stark. Planning for each of them will occupy a great deal of time and money, as will their construction and delivery. Trying to get them all 'right', being 'correctly' dense and with 'appropriate' public realm, along the Spatial Axiom will be very difficult. Getting them right-sized to accommodate the regional goals of population and economic growth will be even more difficult.   It is time to call a truce in these debates and focus on what is really important now: Urbanism and not Nostalgia, the future and not the past.
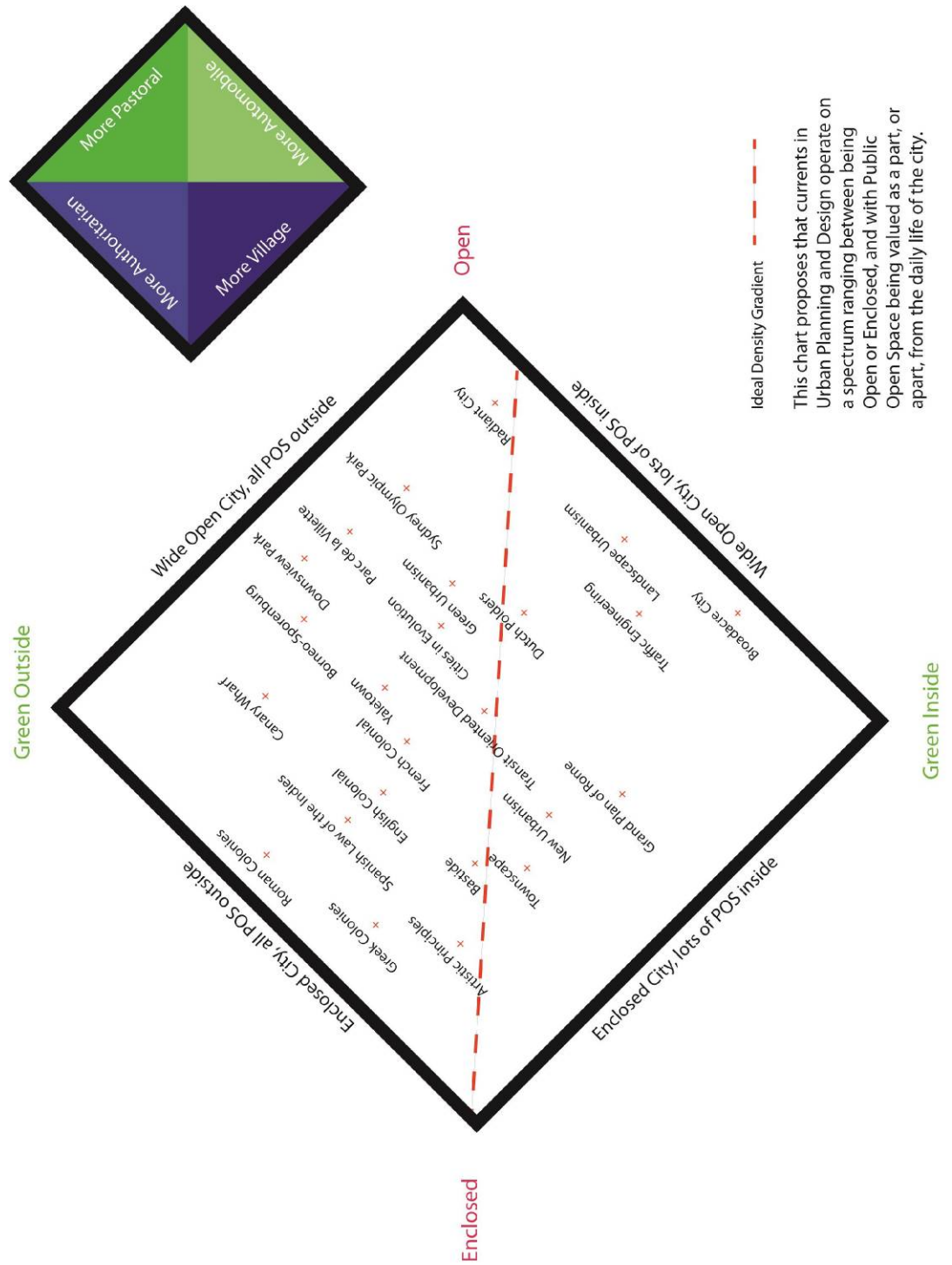
Figure 33 Spatial Axiom: Open and Enclosed Urban Environments

SOURCE: AUTHOR, 2014. THE DIAGRAM BEGINS TO SORT THROUGH THE COMPETING 'PREFERENCES' FOR URBAN ENVIRONMENTS. THE RED LINE ,'IDEAL DENSITY GRADIENT' *, IMAGINES* A GRADIENT WHICH MIGHT BE PREFERRED ACCORDING TO THE CURRENT, 2014, URBAN SENSIBILITIES.

The city/region must respond to the very real need for preparing the next generation of urban places for their high-density residents to be accommodated with public open space and other refuges. The debate cannot be centred on the aesthetic 'style' of buildings, the height or density of buildings, how many shops and shop windows must be at the ground plane, or whether one mode (car, bus, bike, train) is better than another. The region must include all these deeper matters of design, and not be derailed on just one aspect.

As the modelling for TOR will demonstrate, the debate should be centred precisely on: what are the regional goals, what urban fabric is required to achieve the goals and which mode of transport supports these goals. If the goal is low or primary economic activity based in low slung sprawl, then cars may be the best option; but then don't pretend to be interested in walkability and public transport investments. Vice versa, if the goals for the region are to demonstrate global best practices with a knowledge economy based in urbane, mixed-use and multicultural walkable precincts, then density and rail transport ought to be planned for. But the design must incorporate the fundamentals of making good public spaces that people will not only enjoy but will find safe and satisfying.

Below are three groups of examples of re-urbanisation, each unique in their emphasis, from around the globe. These are all highly dynamic mixed-use environments with slight to medium transport orientation, medium to high densities, and ecological urbanism – or Landscape Urbanism – in their programme.

Table 5 Examples of Re-urbanisation

Place	Type	Name
Parc de La Villette, Paris; Sydney Olympic Park, Sydney; Downsview Park, Toronto	Mixed Use, slight to increasing building programme, none to limited residential, Brownfield Parks.	Brownfield Public Amenity / Landscape Urbanism
Canary Wharf, London; Puerto Madero, Buenos Aires; Yaletown, Vancouver; HafenCity, Hamburg; Borneo-Sporenburg, Amsterdam; Edmonton Municipal Airport, Edmonton	Mixed-use, Brownfield, medium to high densities residential.	Strategic Urban Infill
Joyce/Collingwood, Vancouver; Pearl District, Portland; Parramatta, Sydney; Subiaco, Perth;	Mixed-use, Brownfield, Greyfield/Greenfield, high density residential.	Transit-Oriented Developments
Seaside, Florida; Poundbury, UK; McKenzie Towne, Calgary	Ostensibly mixed-use, walkable, human scaled, traditional town designs, fused grid, Townscape	New Urbanism / Theme park

2.4.1 MODERN CITIES AND REGIONAL URBANISM

Modern cities, in this sub-section, are discussed for their ability to combine their regional population growth with economic activity and transport accessibility. Though only four cities are discussed below, there could have also been many honourable mentions from around the world. These four, however, show a comprehensive strategy to demonstrate that building up, and not out, along rail public transport is the way of the future.

2.4.1.1 VANCOUVER, CANADA

Vancouver, British Columbia (BC), is a new-world example of transport infrastructure as a major determining factor in the growth of populations and real estate in the modern, rapid-communication era. Vancouver has never been a place to create a mass-produced product for export as an avenue of growth.[21] Rather, it is the act of receiving people, with a need to travel within its bounds and beyond, which has resulted in its urban expansion.

> …Vancouver's identity, its very economic survival, was to be premised on the viability of its status as an efficient thoroughfare for the movement of goods from and to the distant points it mediated (Walton, 2012).

> What distinguishes early Vancouver's economic history … is the extent to which the railway and real estate sectors in the Terminal City *(nickname for Vancouver)* overlapped. In return for extending its line westward twelve miles from Port Moody at the head of Burrard Inlet to Coal Harbour, both the provincial government and private landholders in the Granville townsite area gave generous bonuses of land to the CPR *(Railway company)* (McDonald, 1979 p.10-11). *Italics added.*

As Norbert MacDonald has noted,

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[21] Unlike Seattle, the closest neighbouring city, has Weyerhaeuser, Boeing, Amazon and Starbucks selling, respectively, lumber, airplanes, merchandise and coffee into the global market.

> …the very existence of its rail and steamship facilities shaped a whole set of expectations about the city's future. Thousands of migrants reasoned that with such transportation facilities Vancouver was destined for inevitable prosperity (McDonald, 1979 p.13).

Moving forward 100 years it is important to discuss the 1986 World Fair in Vancouver; it changed everything in Vancouver in two ways:

- there was suddenly a global window placed on the city through which the world could see Vancouver and from which the post-colonial Vancouver could see out; and

- the World Fair left a large swath of land ready for redevelopment which began the new era of urbanisation

As an example of the degree to which the newfound openness to the world was manifested, the real-estate opportunity of the swatch of land was taken up by Li Ka-shing[22] who was able to deliver a desirable product, housing in a secure country, for many of his compatriots leaving Hong Kong as Communist China took over. In this way Vancouver became a portal city (Boddy, 2004 p.18), much as Miami is to Latin America or Dubai to the Middle East and South Asia.

At roughly the same time as being awarded the World Fair, the city and province agreed to build the urban rail-transit system long overdue in the region which had rejected the limited-access freeway proposals some 20 years earlier. The result of this agreement was the SkyTrain: a futuristic[23], driverless, elevated, linear-induction motor, mass-transit technology which, despite not having the capacity per/hour throughput of a metro, had the promise of being a means of transport for cities and regions at less cost than an underground metro.

When the SkytTrain arrived in the 1980s, Vancouver was an urban area without limited-access, grade-separated and high-speed highways, unlike most of its peers in the

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[22] Reportedly the wealthiest persons in Asia 'Today's ranking of the world's richest people' " Bloomberg. http://www.bloomberg.com/billionaires/2014-05-23/ada/jaaaa Accessed May, 2014

[23] A trip was taken by the author, memorably in 1986, as a 12 year old during the fair.

new world. As such, after a few decades of growth without rail there was a somewhat tempered rational understanding that public transport access equated to real-estate dollars: access meant profit.

It was always envisioned that SkyTrain would be an effective tool in shaping the urban form of population growth and job locations. That it has done so successfully has been demonstrated as population within the service area has almost tripled (Newman & Kenworthy, 1999 p.221) as more residents choose to live in new neighbourhoods and reinhabit old neighbourhoods, with moderate infill, within walking distance of the SkyTrain stations. For example, Babalik (2000) researched global cities reporting that:

> Vancouver Skytrain and San Diego Trolley provided the clearest evidence of success in 3 dimensions: (a) stimulation of development in the city centre; (b) stimulation of development in declining areas; (c) change in the pattern of urban development (Babalik, 2000, p. 11, quoted in (Crampton, 2003 p.3).

And that furthermore:

> The most effective system in terms of shaping urban growth is the SkyTrain. The corridor that the SkyTrain runs through became the main development axis of Vancouver with a notably denser urban form after the opening of the SkyTrain. Development densities along the SkyTrain route have changed especially as a result of the rezoning plans of the municipalities. These plans increased the densities at station areas, and encouraged office and retail centres at stations. Some of the SkyTrain stations became the `new town centres' as proposed in the metropolitan development plan.[Babalik, 2000, p. 11, quoted in (Crampton, 2003 p.3).

From its founding until today, Vancouver has been a leading example of linking land use and transit to shape the population densities in a growing metropolis. The lesson Vancouver can teach is this: cities and regions must build rail infrastructure and strategically release land adjacent to maximise returns on investment. While the linkage of land and transport infrastructure makes perfect sense to almost anyone involved in land development, it is exceedingly rare in new-world cities that the infrastructure in question would be public-transport rail *instead of* highways.

2.4.1.2 TOKYO, JAPAN

After the cataclysmic shock of World War Two, Japan was fully engaged in a reconstruction era. This was not only a physical reconstruction, but a reconstituting of what it meant to live in a modern industrialised nation. There was seen to be no time to waste in modernising cities, industry, politics, culture and lifestyle. Change was inevitable so many chose to profit from the chance to live in a new high-rise residential tower near a convenient shopping complex with a very fast, if not high-speed, rail link into the city centre's high-paying technical jobs.

To meet the needs of this quickly urbanising city a new private business model was created. The model included buying up the variously configured plots of urban and agricultural land along a potential rail line, offering good terms and the first rights to real estate in the new development to the land owners, and laying down rail lines. Along these rail corridors were master-planned communities with new residences in land-efficient high-density blocks with shopping, schools and so forth. This created a series of highly liveable communities with private amenity and public services for the residents who also became loyal customers of the rail networks. The model was predicated on being able to sell the land for new residential units and to maintain high ridership, both of which returned a profit to the rail-oriented land developers. It had the effect of reducing the necessity to sprawl in low-rise automobile dependence. It also assumed the risk of design and construction of rail lines and removed the necessity to build excessive highway infrastructure (although it does have a relatively high rate of highway to person kms, please see Appendix J, Figure 184)

> The resulting "win-win" situation leads to financially viable investments and forges a close connection between rail systems and nearby real estate development that attracts tenants, investors, and transit riders. …Greater Tokyo's private railways have historically practiced transit value capture on an even grander scale, building massive new towns along rail-served corridors and cashing in on the construction, retail, and household service opportunities created by these investments. In both Hong Kong SAR, China and Tokyo, rail and property development has created a virtuous cycle of viable railway operations and a highly transit-oriented built form (Suzuki et al., 2013 p.6).

In total, these land and rail packages are 'the most sustainable pattern of regional development among any of the world's megacities' (Cervero, 1998 p.206). This should enable us to see that profit-seeking businesses and responsible civic-minded governments

following this approach can 'offer the best hope for creating the kinds of built environments that enable mass transportation to complete successfully with the private automobile' (Cervero, 1998 p.207).

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2.4.1.3 HONG KONG, SAR

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When the Communist war closed the door to and from China, British Hong Kong had to be completely self-sufficient. Waves of immigrants fled from the economic and cultural strictures of Communism; their first place of rest was Hong Kong. Though many mainland immigrants stayed and prospered the land area remained fixed. A unique combination of a limited land supply and strong rules regarding Floor Area Ratio[24], supplying an immediate demand and supply of density, was matched with the transit agency's ability to purchase land for its corridors and mixed-use developments, providing an assured patronage from co-locating of activity and residents. Together this has generated a world-leading example of combining rail and development packages (Zhang, 2004; Cervero & Murakami, 2009). This has been for the net profit of the transit agency:

> …"co-development"—development in which each sector brings its natural advantage to the table (for example, land acquisition powers in the case of the public sector, access to equity capital in the case of the private sector). The resulting "win-win" situation leads to financially viable investments and forges a close connection between rail systems and nearby real estate development that attracts tenants, investors, and transit riders (Suzuki et al., 2013).

The important lesson from Hong Kong is that with investment goals, strong planning to accommodate population and economic growth, high-capacity transport commensurate to the task and a limiting of land supply, it is possible to achieve a great deal of measurable positive transformation in an urban fabric. In the case of Perth or other automobile-dependent cities the land may never be as limited or the density so thickly distributed, but

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[24] "Hong Kong Planning Standards and Guidelines – Summary" http://www.pland.gov.hk/pland_en/tech_doc/hkpsg/sum/pdf/sum.pdf Accessed May 20 , 2014

if there are goals to be sought, Hong Kong does point to the economic benefits of following through on a plan.

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2.4.1.4 SINGAPORE

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Post-World War Two saw the rise in the strategic importance of the port of Singapore while at the same time a rise of Malay nationalism lead to the slow crumbling of yet one more pillar in the British Empire. After Singapore gained nationhood it developed as a low-cost assembly plant and trans-shipment port for several decades. By the 1960s the government saw that the only way forward was to plan strategically for high-density nodes in high-capacity rail transport corridors. It developed the Constellation Plan which denoted several nodes along lines, to work as a means to direct public transport-oriented locations for both residential and jobs growth:

> Subcentrering will continue to be the primary means of sustaining Singapore as a transit-oriented metropolis. Under the constellation plan, the four Regional Centres will function as mini-CBDs, taking Singapore commerce and industry to the already decentralised work force. .. .Plans call for centres to have varying degrees of self-sufficiency so that jobs and amenities are distributed as close to homes as possible (Cervero, 1998 p. 174).

An appreciation of the value of public space for enjoyment and the need for the island to absorb the humid climate's stormwater led to the setting aside of many strategic open spaces:

> Presently, Singapore's four Regional Centres are surrounded by vast expanses of open fields…most open space..will remain just that – open- as part of a system of protective green belts that retain natural ecologies and establishes clear edges between city and countryside (Cervero, 1998 p. 175).

As Cervero states, centralised planning in Singapore is comparable to planning for urban conurbations in most of the world (p.176), and a thriving economy is achievable within the constraints of 'lifestyle sacrifices' (p.177):

> It is important to remember that Singapore's intimate transit-land use nexus is the outcome of deliberate and carefully thought-out government decisions – decisions to restrain ownership and usage of the car; to build compact, transit-

oriented communities; and to ensure equality of access to housing, education and medical care (Cervero, 1998 p.176).

These four cities have achieved land-use and transportation integration by facing the opportunities of the future, planning to become a certain type of place, setting targets and achieving them. They were all land-scarce to a certain extent, but more to the point it is precise regional metropolitan planning which sets them apart from the others, crafting highly desirable urban settings.

In summary, the reasons that these cities were so successful are manifold but include: being of contiguous land areas conducive to regional planning, such as a watershed or delta area; land scarcity within a travel time budget; pre-existing population density; tolerances for mixing of land use; permitting the private sector to design and deliver, own and operate portions if not whole aspects of infrastructure; a commitment to rail over roads; and a lack of parking infrastructure to induce automobile ownership.

2.4.2   SUMMARY: CITY SHAPING

In this section we have referred to a wide array of sources on the expected positive impacts of planning for better human and ecological health.   Many people, from Lynch to Plato, Vitruvius to Duany, McHarg to Kennworthy, have tried to elucidate the best way to plan for cities. While some such as Wright and Howard have supported great swaths of low-density car dependency, others such as Corbusier encouraged architects to design very high density towers-in-the-park scenarios with mixed social and urban outcomes.

Several cities, beyond theories and establishing funding paradigms to deliver preferred outcomes, have had great success in leading the way for other cities to follow. Cities such as Vancouver and Singapore have consciously approached the future they wish for by investing in public transit infrastructure of sufficient capacity and altering land uses to appropriate scale to accommodate, mostly but not perfectly, their population and economic growth. It can be done in both the west and the east, under full democracy (Vancouver and Tokyo) or under other, benevolent, central command economies (Hong Kong and Singapore).   Purposeful city shaping for sustainability outcomes can be accomplished with the right targets, policy levers, market and leadership.

2.5 CONCLUSION TO LITERATURE REVIEW

We seem to know a great deal, but gain very little wisdom on how to proceed in managing automobile dependence.

We know there is a rise in global car use but that in select places in the industrialised OECD there is an obvious trend towards 'peak-car'. We know that different modes of transportation have different capacities per land hour and varied outcomes in terms of delivering desirable urban fabrics. We also know that there are a variety of reasons why Perth and other cities are automobile dependent but most are successful at being so due to diligent planning. It is not lack of planning that has created automobile dependence in Perth, our case study; it was a powerful commitment of government regulation and funding. We also know there are great examples from the past, and many projections of a future where automobile dependence is greatly reduced, but that all of these are being diluted. How best might we accumulate the knowledge and make an attempt towards a solution?

It seems from the literature on city shaping and urban design, land use and transport planning, and automobile dependence that there are plenty of commentators but that the message is not informing either the decision makers or the wide population. It could be said that there is a collective 'So What!?' response to the published data for this reason: **While creating a necessary vision, little of it measures the costs and benefits in any meaningful way with no details or plan of how to get to where we want to go.**

Meaningful information is required on dollars, yen, yuan, pounds, euros accounted for; the numbers of residences at what detailed and aggregate densities; levels of public services such as schools and hospitals, parks and parking places required; transport modes to support mobility; the level of third places and fine-grained street networks to support walkable accessibility; flow-on benefits including Costs Avoided and Value Captured as reasons to plan for not just Transit-Oriented Development but urban consolidation and potentially a Transit-Oriented Region.

Remedying this lack of detail is a method (chapter 4 sub-chapters) applying transport planning, highway engineering, strategic and long-range urban planning and landscape architecture as a master-planning discipline. It will use an approach similar to that used by

traffic engineers to create automobile dependence, to describe the interactions between land use and urban design which matches transport mode capacity to enable better urban outcomes that can approach both local and global goals. The method described in the Research Design and Results chapter provides a means to reveal the net impacts of land use and transport integration in a Transit-Oriented Region.

The results will be discussed in the various Results sub-chapters while the implications of the method will be examined in the Analysis and Discussion chapter.

First, however, will be a chapter devoted to the Research Design in which the methodology of an experiment to study this issue will be described.

3 - RESEARCH DESIGN

Designing a dream city is easy, rebuilding a living one takes imagination (Jacobs, 1958).

The infrastructure of urbanity as we know it will have to be reconceived, redesigned and reconstructed…(Weller & Bolleter, 2012 p.15).

THESIS QUESTION: Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?

3.1 RESEARCH METHODOLOGY

…it is fundamental for a technical science like urban design to make knowledge applicable to practice. …Design research, which is gradually taking shape within the field of urban design, is still in its infancy… (and) so is the field of research that is required for meticulous testing of design interventions (Jacobs, 2000 p.187).

This section will uncover the origins of this enquiry and ask: **How might one devise an experiment, replicable for different cities, to render clearly the impacts of policy choices in planning for urban futures?**

3.1.1 METHODOLOGY: PLACING THE PROCESS

This section will discuss the methodological grounding of the research. It will place the research within a spectrum of inquiry ranging from quantitative, scientific, positivist objectivity on one hand and qualitative, social science subjectivity on the other. This research will rely primarily on the quantitative side of the spectrum as the process and results are accounted in whole numbers. Where this research strays into subjectivity, the assumptions will be made transparent. The tactical and technical aspects will be described later in each model's 'method' section in Results, Chapter 4. In each methodology will be listed the advantages and disadvantages uncovered as the research was carried forward by the researcher. The methodologies are listed below.
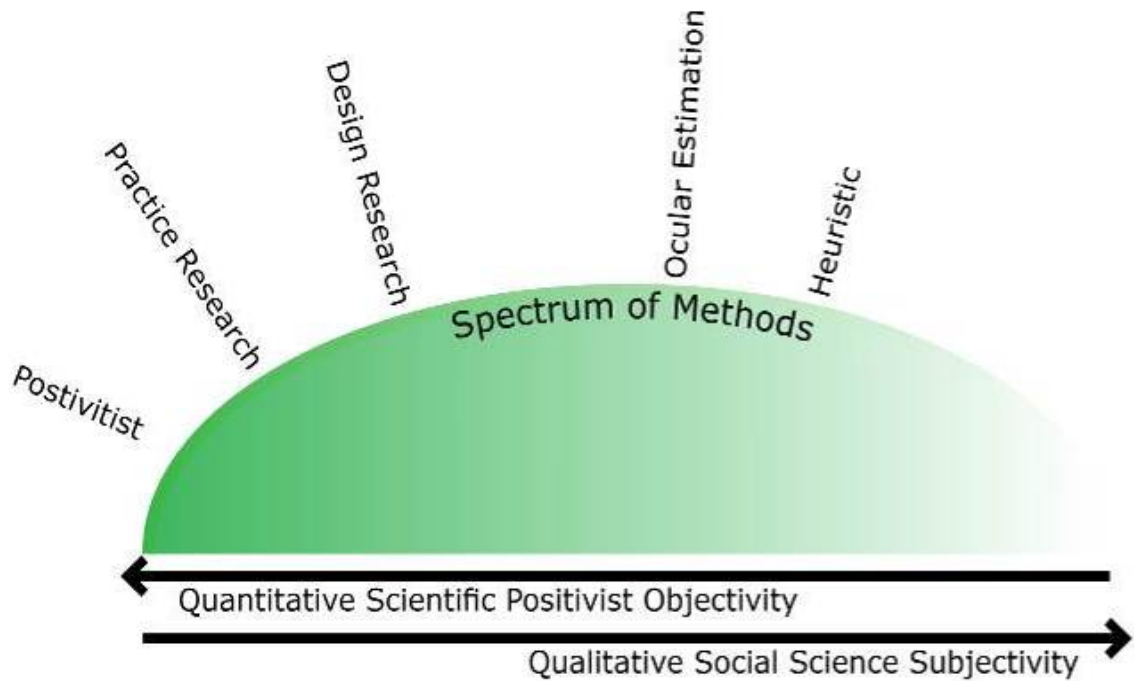
Figure 34 Spectrum of Methods

SOURCE: AUTHOR, 2014

POSITIVIST

The first methods used in this research are positivist to uncover 'logical and credible synthesis' (Deming & Swaffield, 2011 p.33).Though this research is speculative about a new future for urban transformation, it follows a similar approach that standard traffic engineering uses in calculating trip generation and parking ratios based on land use and metres of floor space per use.   The positivist method will be used in tracing District Structure Plans, a Metropolitan Regional Scheme, possible public transport alignments and other possible redevelopment areas to measure two-dimensional space. Following this method will be the methods of modelling and forecasting where and how the increased population will find residences and jobs within an amenity-rich, walkable catchment of public transport.

The advantage of this method is that it reveals actual numbers of cars and their spatial parking requirements, public transit components and the capacity per hour, residences and size of residences per person, work spaces in commercial and retail-shaped

floor plates, floors of buildings with heights, tonnes of carbon emissions abated, dollars of costs saved by not building car-dependent infrastructure and dollars of tax revenue from a broadened base, hectares of greenfield preserved as farm or forest. The whole numbers of identifiable quantities, it is felt, is will help decision-makers understand the ramifications of the many small and large policy settings and infrastructure spending choices they make.

The disadvantage of using any type of 'quantitative certainty' from a professional Standards Manual, or examining the experience of other world cities, is that it may lead to a *post hoc ergo propter hoc*[25] logical fallacy; this research will avoid false conclusions that a correlation is equal to a causation. Other cities have different driving habits, tree canopy cover to absorb carbon, shopping and working practices; they are not all alike. However, we are all humans wishing for the least amount of stress with the maximisation of profit in efficiency and many of us are now living in cities. We must be able to learn from the other cities, not to slavishly copy them but to learn from them, to indicate what is possible when intentional planning and design are at the core of how urban growth is structured.

D E S I G N   R E S E A R C H

Secondly, design research was employed to understand the question. Design research approaches the issues of metropolitan regional growth and transport provision as a design problem to be worked on via scenario iterations and testing prototypes. Rarely is design research brought to the questions pertaining to land use and transport integration at the metropolitan regional scale; this project will attempt to demonstrate the value of bringing such focus to the issues.

Design research is a method of investigation that sides with finding out rather than finding the already found (Lunenfeld, 2003 P.10)

Incorporated in this method is design thinking (Deming & Swaffield, 2011 p.38) which incorporates understanding needs, defining options, ideating scenarios, prototyping,

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25 Post hoc ergo propter hoc: Latin for "after this, therefore because of this" Example: If A happened then B happened, then to recover B again one must have A in place (Pinto, 2001).

testing and developing an implementable product. All of this happens in a revolving series of iterations without pre-judgement. Holding closely a developed idea is useful for a period if only to move forward in making a prototype. A core value in design thinking is being willing to redefine the initial understanding. This research seeks to understand the local and global situation, and uses a similar series of chained steps to develop a method which has been tested and prototyped after much iteration.
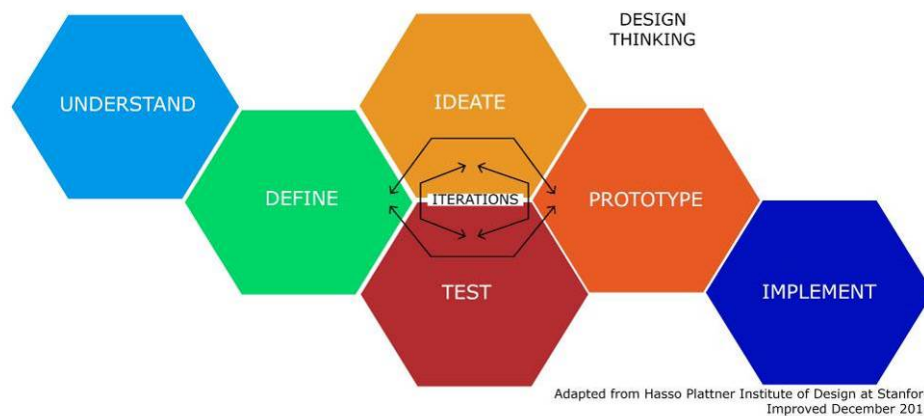
Figure 35 Design Thinking Diagram

SOURCE: ORIGINAL FROM PLATTNER INSTITUTE OF DESIGN, ADAPTED BY AUTHOR IN 2013

The research design method allows a creative approach to interpret the issue with an aim to prototype a solution for iterative refinement. The researcher elaborates on points to develop a novel and innovative option for the future. This is, in many ways, the opposite of researching a topic by following a linear process to the end of all possible points.

The disadvantage of design research is that there may not be a clearly repeatable experiment, but rather a process by which discovery may be made. The process may be described, but never quite attain the level of sophistication of a classically scientific experiment. The ramification of this is that were another researcher to attempt to re-do the process to verify the findings, the other may find very different results leading to other conclusions. However, in this is found the genius of design research; a process begins the evolution of a static 'fixed-on-facts' frame to a much more plastic and flexible 'options-seeking' mind.

P R A C T I C E   R E S E A R C H

The third method employed in this research was practice research, defined as

> "…an activity which can be employed in research, the method or methodology must always include an explicit understanding of how the practice contributes to the inquiry and research is distinguished from other forms of practice by that explicit understanding *(Rust, Mottram, & Till, 2007, p.11).*

To paraphrase the above, the method is not to 'do' the practice; it is doing the practice with an explicit understanding of how *the practice itself* is a tool of the inquiry as a means to a novel contribution's end. In this instance, the practice is one of using the tools of land use design (such as Urban Planning and Landscape Architecture) to examine the region as though it were a project to be designed as a physical possibility (Deming & Swaffield, 2011 p.245)

The advantage of the practice research method is that it permits skills from professional practice to be used in the research forum making a link from the community towards academia and vice versa. Having professionals in academia, hopefully, links transport's industry-hardened rigour to pure research while, in reverse, carries academic curiosity to an often indifferent professional practice. Professionals have frequently dealt with the same questions in practice and can bring insights which are not presented in academic journals.

The disadvantage of practice research is the chance that practice-led thinking about a project, i.e. delivering a complete scenario for implementation, is not what academic inquiry is traditionally focussed on. Likewise, a 'null-hypothesis' (Deming & Swaffield, 2011 p.122) is not a part of professional landscape architecture, urban design or urban planning as there are always relationships between social, ecological and environmental characteristics and the professional's role is to manage these interactions for a net benefit. As there are no 'null-hypotheses' in practice, it then becomes difficult to separate the need for objectivity from the need to create an argument for decisive action leading to subjective conclusions.

HEURISTIC

The fourth method employed was a heuristic method (Deming & Swaffield, 2011 p.35). Heuristics uses intuition, rules-of-thumb, experience, commonsense decision making; it is based on the notion that we must proceed lest there be no decision. It is akin to using one's intuition to find one's way around a new city, seeking a café near where people are congregated, or to find a public transport service along a major arterial; it begins the process of understanding with a possibility of being partially, or entirely, correct. This method was used so that portions of the overall methodology could be repeated in less data-rich (not collected) or data-restricted (not willing to share) locales.

The advantage to this method is that it can clear the obfuscation of jargon and statistics to describe what is evident. For example, if a public transport line appears to operate with many patrons who walk to shops after descending from the transport before arriving home, then that is a valid observation. Likewise, if a highway network has peak congestion after many collector roads and residential streets linked to single-family residential homes distribute their generated trips, then that is also a valid observation.

The disadvantage with heuristics is that there have been many rules-of-thumb which have been poorly informed or not completely thought through. There is a chance, as in other methods, of a *post hoc ergo propter hoc* logical fallacy which would lead to a false conclusion that a correlation is equal to causation; this stance will be avoided in this research.

OCULAR ESTIMATION

The fifth method adopted, ocular estimation, was used to quite literally 'go and see' the opportunities latent in the urban landscape. Ocular estimation is useful to 'ground-truth' different zones of the region and to witness first-hand the amounts of space, the traffic congestion, the spatial adjacencies, and the derelict or maintained character as a means to appreciate redevelopment potential along transport corridors.

While originally a method based in vegetation mapping when other techniques, such as aerial photography or digital remote sensing are insufficient, it is the best means to

describe effective data collection from in-the-field research (van Hees & Mead, 2000). While this research did not set out literal quadrats and count each 'species' found in the square, it did use a great deal of first-hand observations of on-the-ground urban environments. The advantage of this process is the building of knowledge and data from the ground-up as opposed to receiving data from a third party. The disadvantage of this, as a corollary, is that it relies on a subjective interpretation of the urban conditions to imagine what the place could become.

3.2 PARTICIPANTS AND BASE INFORMATION

3.2.1   PARTICIPANTS: PLACES WITH SPACE

'You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.' Richard Buckminster Fuller (Date and Source Unknown)

Presented below will be three models at four scales. The last two of these scales, the Regional and Local, will use the same model while the first two, Regional and Global, will have a model each, making three models at four scales. Though the three models could be considered as a nested series, leading from one to another thereby comprising one coherent model, this would not convey the process of discovery accurately.

Below are descriptions of the three physical areas used to test the theory of Land Use and Transport Integration in this research:

- Global cities– Model 1: urban fabrics as examples of design and policy outcomes
- Perth Metropolitan Region – Model 2: Land and transport capacity to achieve regional growth and sustainability goals
- Victoria Park – Model 3.1: an extract from Model 2 to show the implications, at a precinct scale, of up-zoning and transit service increases
- Stirling City Centre – Model 3.2: demonstrates the positive effects higher capacity transit services provide to aspirational re-urbanisation

These are the components of this research's experimentation. As a metaphor, these will be referred to as the 'petri dish' of living material into which a series of reagents were applied to gauge the reaction. This use of a biochemistry metaphor is purposeful; it aims to bring a certain 'scientific' process to the practice of urban design and planning, making the explicit method of this experiment all the more necessary. In this instance, the reagents will be the **elements** which are added to the city/region to create the chain reaction of events while reactions will be a list of the **changes** which occur in the city/region in this experiment.

Figure 36 A Petri Dish Experiment

SOURCE: 'HAND HOLDS PETRI DISH WITH BACTERIA CULTURE'. WWW.123RF.COM
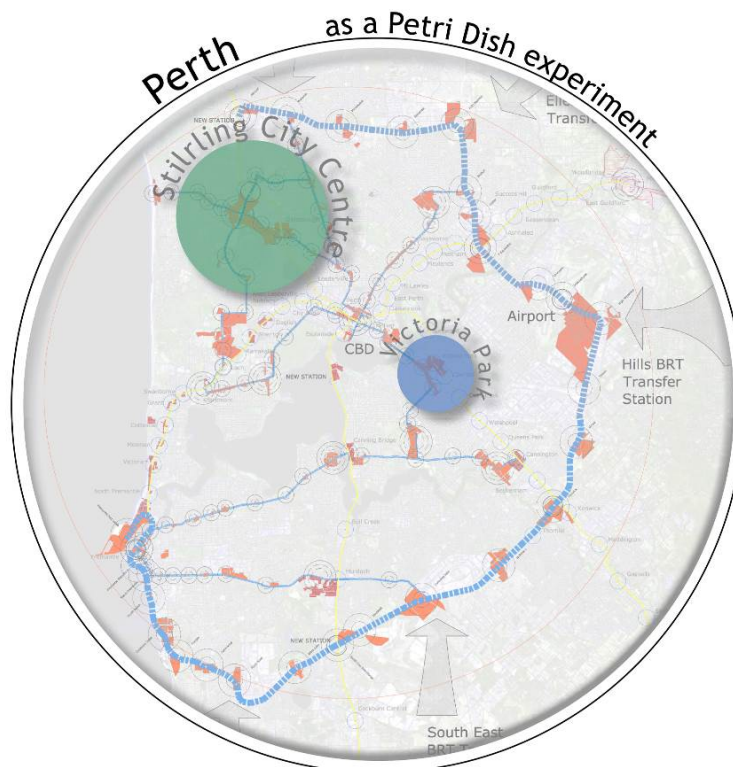
Figure 37 Perth as a Petri Dish for this Experiment

SOURCE: AUTHOR, 2013

3.2.1.1 THE GLOBAL SCALE – MODEL 1

The opportunities for transit-oriented developments rely entirely on many policy levers being pulled in unison. Without the pulling of the policy levers along with the re-zoning and public transport service levels there was little hope in activating the potential for the diverse lands along the transit corridors. However, there are many examples from around the world which might be used to illustrate the potential for either automobile or public transport orientation; this model employs these as examples.

Several global cities' neighbourhood scale imagery is employed, via Google Earth, to demonstrate the third model. This model illustrates the very real outcomes of policy choice and allocation of scarce infrastructure funding. There will be a wide array of city places, all at roughly the same scale, showing the influence of transport modes, parking rations, location, design and others.

3.2.1.2 PERTH REGION – MODEL 2

The Perth Metropolitan Region will be used as the experiment site to examine the Regional Scale. The Regional Scale is apparent in every urban environment; even city states such as Singapore and Hong Kong which appear self-contained in truth rely on labour, resources and the ecosystem of a much larger land area. Where urbanism ends may be where the last of its impacts are experienced (Belanger, 2013). The first of three models is used to describe the interactions of Land Use and Transport Integration at this scale.

The Literature Review section has a review of Perth's history of planning. Perth is growing quickly in population, calculated by the Australian Bureau of Statistics to possibly be 4 million, or even 5 million in the high range, by 2050 (ABS, 2011a). Currently, this population is significantly turning to the outer fringe car-dominated lands to find affordable homes, so the city is growing in overall urban footprint. Perth is already as automobile dependent as, for example, Los Angeles, California, with much lower population density, though it is less so than cities like Atlanta and Houston (Kenworthy & Laube, 1995). What its future could be is examined with this model.

3.2.1.3 VICTORIA PARK – MODEL 3.1

Victoria Park will be used to examine the neighbourhood scale. Victoria Park is an older inner city neighbourhood linked to the city of Perth by a viaduct which becomes the Albany Highway which, despite its name, creates a strong commercial corridor in Victoria Park. Victoria Park is between the city of Perth and the Curtin University campus, offering good centrality for many students and young professionals, and has many good urban bones which may be built upon.

Victoria Park is a case study of the potential effects of a transportation corridor. Victoria Park is operating as an area of redevelopment in these conditions:

- no true centre is possible as all the shops line the four-lane highway; it is a corridor primarily;
- the historic fabric with small lots and multiple opening is appealing to pedestrians as well as small enterprises;
- the corridor links two very strong attractors, the Perth CBD and Curtin University;
- it has a train station four blocks distant from the corridor which may be somewhat responsible for a percentage of the current redevelopment activity but not by design; and
- it is slated to be on the list as a potential route in the next 20 years of light-rail transport infrastructure.

Victoria Park is already reasonably accessed by several transport modes and it has the capacity to greatly increase the residential and commercial activity on lands adjacent to current and existing public transport lines. However, as it is a prime location in the matrix of evolving urban locations in Metropolitan Perth the market is providing homes without the benefit of an overall coordinated approach. Making the most of this market-led response will be a sub-text of the method and model for this area as the research demonstrates the policy levers to produce the desired/target urban fabric. Its potential for re-urbanisation will be explored in the following model.

3.2.1.4 STIRLING CITY CENTRE – MODEL 3.2

The Stirling City Centre will be used to examine the middle scale of urban fabric. The principal purpose of this model is to explore the impact the different public transport modes have on aspirational real-estate yields in the urban fabric.

The Stirling City Centre is one of Perth's best, or worst, examples of a car-dominated suburban shopping centre.[26] The Stirling City Centre has:

- an undersized road in an east/west direction and an oversized one going north/south;
- a series of strip malls and malls;
- several large-format single-enterprise shopping boxes;
- no discernibly safe pedestrian mobility;
- a heavy-rail train station which is uncomfortably accessed by foot; and
- the only green space is locked behind a chain-link fence

However, going forward, there is a very comprehensive 20 year program to redevelop this area into a light-rail serviced, mixed-use, twenty-four hour zone of living and working with a fresh running urban stream at its public-realm core. Due to the efforts in re-planning the area, it makes a very good case study of the potential transformation that high-capacity public transport and complementary land use policies combined with excellent urban design may have on this car-dominated area. Using the latest master plan and policies, the research will demonstrate the positive effects of implementing progressive multi-modal transport and efficient land use policy. The following model will uncover the potential for higher capacity public transport services to achieve the aspired re-urbanisation schemes.

3.2.1.5 CONCLUSION TO PARTICIPANTS

These three areas exist at different scales: global, metropolitan region and neighbourhood. These three were chosen because they are all potentially ready, at their scales, to become higher intensity urban areas with higher-capacity transport options spurring their growth.

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[26] It is evident upon looking in Google Earth or experiencing the spaces on the ground that there had never been an overall master plan at an early inception. Typically a master plan outlines activity zones with shared parking facilities; an overall traffic patterning including appropriately scaled intersections and signalisation; a plaza with a fountain and shade trees; and consideration for pedestrian movements.

The next chapter, Results, will elaborate how numbers can be achieved to calculate costs and benefits of attaining 21st century urban goals.

3.2.2   BASE INFORMATION: MEASURING THE LAND

3.2.2.1 MEASURING THE LAND – MAPPING

The research has attempted to make full use of publicly available planning documents, in letter and in spirit, to uncover what is politically and physically possible in redevelopment around potential rail lines. It was felt that to approach the case study urban region of Perth, extensive reading was required of what is currently planned.

Below is described the process of absorbing the extant documents and applying the methodologies outlined above.

EXTRACTING DISTRICT STRUCTURE PLANS:

In Perth, Western Australia, there are spaces already well documented as having opportunities for change, such as Curtin University, Canning Bridge, Fremantle's East End and Cockburn Coast. These spaces have well-developed and, in many instances, approved and publically accessible plan graphics ready to be viewed and downloaded. These are typically called District Structure Plans (DSP), Area Structure Plans, Official Community Plans or other nomenclature reflecting a general spatial outlay of land uses predicted to be effective at delivering a set of targets (e.g. population increase, economic activity). These plan graphics are typically in a larger file multi-page PDF format and if so a simple process of selecting the page, Document>Extract Pages, and saving as a single PDF document will extract the image file. This single sheet can then be saved as a .jpeg file which is a far easier file type to use in drafting.

INSERT .JPEG:

In AutoCAD, with the file prepared as per 'combining files' and all line work to scale and matching Insert>Raster Image in AutoCAD 2010 or Insert > Xref> Image in AutoCAD 2012 this .jpeg file and use the Align command ('al' in command line) (using two points – two clicks on known points, space bar, Y for 'yes' and space bar) from visible points of reference. Once these DSPs are loaded they are traced over on the appropriate layer for future work. There is little to be gained by reinventing work which other professionals have already elaborated and the public has come around to accepting. Only minor alterations

will be made to these DSPs in trying to arrange a region-wide master plan so that the research can move more quickly. The goals of the DSPs will be different from the targets established for this research project but the extent and general character aimed for will be generally respected.

There are many other places which can be ascertained as having potential for rail-oriented redevelopment by these two methods below. Such areas have not been reviewed for change by their LGA or they have been targeted for a radically different future than that deemed suitable for the future of Perth as outlined in the goals of this research (Stirling Highway, for example, being targeted for widening for cars alone). Within the goals of this research, then, the future of these other places is posited as being more compact, more complete with services and amenities, denser in residents and jobs, less automobile-dependent and much more oriented towards rail transit, cycling and walking.

However, to estimate the potential of these places, two forms of visual data collecting were employed: ocular estimation and Google Earth.

OCULAR ESTIMATION:

Ocular estimation (visual analysis) uses professional judgement and experience to view the potential for urban infill and redevelopment of the grey/brown field sites. Empty and derelict lots, areas of decay and underutilised places offer the ideal sites for re-urbanisation along potential new trail transit right-of-ways (ROW). The ocular estimation of this status involves walking, cycling or driving to and along the potential ROWs and taking photographs, taking notes and suspending all pre-judgement while imagining the potential for a very different future.[27] The dimensions of each lot (block in Australia) can be determined very accurately by using the AutoCAD files as listed below in 'Files'.

GOOGLE EARTH:

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[27] Disclosure: The Researcher has worked in no less than 5 'boom towns' in the design and construction industry. In such cities the rate of urban expansion leads to a critical eye for seeing new urban potential.

Google Earth can provide patterns to anyone looking for both urban history and future potential of urban areas. In searching for patterns along potential new trail transit right-of-ways one can see:

- missing bits of urban fabric – indicative of redevelopment potential (see below);

- lot patterns oriented towards or away from potential ROWs – indicative of lots which could be redeveloped without interfering with the character of the neighbourhoods beyond the initial zones of the stations and lines;

- height (from shadows) and mass (in relation to other buildings) which can be traced along particularly successful corridors and at evolving nodes. These places already are in a pattern of change and can provide much needed opportunity as places to intensify as they will receive far less negative reaction for the surrounding neighbourhoods;

- street patterns and widths which relate to an approximate ability to absorb height from density, through traffic (all modes), origin and destination traffic (all modes) and how it can interact with the surrounding neighbourhood delivering more than just a transit node, but also a community centre with many accessible amenities;

- previous tram lines and street widths which can be used to accommodate the required surface area for Light Rail Transit; and

- Google Earth's 3 Dimensional (3D) capabilities permit seeing clearly the grade differences between sites. This is especially useful to observe along the potential heavy rail line to the south of the Swan River or the grade changes along the Canning Highway.

From Google Earth a .jpeg raster file at various scales of the sites can be saved through the process of File>Save>Save Image. Using Google Earth as a source of satellite imagery does have issues, namely:

- The imagery is often slightly out of date;

- The imagery is often blurry at the edges and at large scale;

- The imagery is skewed with a roundness which makes accurate aligning via the method described above difficult. AutoCAD is not 'projected' and there is not perspective; it assumes the world is flat. This is a characteristic of the software as there is no need by the users of AutoCAD for earth rounding 'projection' in the design of a machine or over the size of a construction site.

3.2.2.2 DRAFTING IN POTENTIAL SITES:

With the .jpegs image files from both the District Structure Plans and Google Earth inserted and aligned as per the 'Insert' section above into the AutoCAD master file (see Master File p.207), the process now is to map the observable spaces which are Decayed Urban, Underperforming Urban, Deferred Urban or Brownfield Urban. All of this is determined by either observing first hand and/or by looking at the Street View on Google Earth. All those sites within a 500 metre offset buffer (1000 metre wide buffer) were linked together with an accurately drawn centre line of a new rail network as per the above.

DECAYED URBAN:

These are the bits and pieces of urban fabric which have been given over to the automobile directly, parking lots for example, or to auto-centric urbanism which is significantly defined by both cheapness of building material and cheapness of site planning. Examples are 'strip-mall' zones which have a front area reserved for parking, shed architecture with a pasted on façade (sometimes emblazoned with corporate icons) and few if any pedestrian provisions. Examples of these are car sales yards and fast food enterprises. Though these places may have a function and provide jobs and taxes, the land can be envisaged to provide more jobs, taxes, residents and services based in the condition as a transport corridor.

Figure 38 Decayed Urban, Albany Highway

UNDERPERFORMING URBAN:

These are the areas which could be significantly more valuable to the land owner, renting for higher rates and providing much more in terms of amenities and rates (taxes) to the community if it were to be redeveloped. Typically, these are sites with a low profile, one-storey building, are oriented towards to the prevailing transport corridor but are not creating enough draw to ask commuters to stop nor are they creating a node to which local residents are attracted and in fact may be eroding the sense of community in which the site sits. Examples of these are video stores, car rental agencies, furniture warehouses, tele-communications shops and, significantly, rental-property homes which face the corridor (arterial street). Though all of these uses have a function and provide homes, jobs and taxes, the land can be envisaged to provide more of each.

Figure 39 Underperforming Urban, Canning Highway

DEFERRED URBAN:

These are areas which are either still somewhat rural in character but will never be farmed for profits in the foreseeable future. These are large lots not as yet subdivided, or subdivided but without a purpose. Generally one finds these lands near to heavy rail, freeways or industrial parks. However within the bounds of Institutional lands and business parks there can be sites which have simply been overlooked, in reserve or otherwise, but certainly in a deferred state.

Figure 40 Deferred Urban, Kenwick Station

BROWNFIELD URBAN:

These are areas which once held industry or military complexes leaving behind a large swath of land with a mix of negative conditions including contaminated soils and water; poor access due to being 'off the grid' in terms of being interconnected to the urban fabric by road or rail; and high levels of fill which need to be moved before excavation can begin. However because they are unsightly these sites are far more likely to be desirable places to improve the look and feel of the neighbourhoods; often neighbours will approve of efforts to 'do anything' with these sites.

Figure 41 Brownfield Urban, Scarborough Beach Road

SURFACE AREAS

All of these types of sites, from Decayed to Brownfield, were drafted into the Master File to create a series of polygons which could be measured, dimensioned and mapped for further consideration in the master planning phase. Once an area was established and measured, its square metre volume of land surface was placed into an excel spreadsheet (see below). These square metres are important to find as space to craft a series of targets based on a regional requirement of the Australian Bureau of Statistics Population Projection increase of 1.8 million persons for regional Perth.

In Series B, Perth is projected to experience the highest percentage growth (116%) of Australia's capital cities, increasing from 1.6 million people at 30 June 2007 to 3.4 million in 2050 (ABS, 2011a).

If, as in Directions 2031 (Western Australia Department of Planning, 2011), forty-seven percent of all new residential growth is to be directed towards infill development, then this creates a legitimate need for 846,000 new residents. While this shows how many people need homes in infill, it does not show the square metres of land needed for these residents, where this land will be allocated and distributed or where they will work.

Once these new lands are drafted (see above) the experiment can now move into targeting these areas to see what sort of urban density, form, scale will be needed to accommodate these almost one million new residents.

The next step was to then uncover where the public transport services should be placed within the right-of-ways to best serve the majority of the surface areas suitable from the Mapping Potentials process.

3.2.3   ESTIMATING THE TRANSPORT SERVICES

In quantifying the capacity of each transport mode in its optimal performance, it is necessary to turn to several world-leading academic experts and professional practitioners who have approached the issue of mode share and mode capacities in shaping urban growth (Cervero, 1996, 2002; RTA, 2002; Vuchic, 2005; Litman, 2007; Vuchic, 2007; Parsons Brinckerhoff Australia, 2010; PTA WA, 2012c).

3.2.3.1 NEW RAIL RIGHT OF WAYS:

To be considered as a new Right-of-Way in this experiment, the basic requirements were:

- that there was an existing Right-of-Way (ROW), such as a road, freeway median or existing freight line;
- that there was a collector or arterial type of section along the road;
- that there be physical space on the road;
- that the ROW would link regionally significant Activity Centres; and,
- that the ROW had significant redevelopment potentials along the length of the line, at a spacing of 2-3 km along a heavy rail line or 500-700 metres along a light rail line

3.2.3.2 LEVEL OF SERVICE

The Level of Service (LOS) for sustainable public transport mobility was determined by this process:

Volume of land X Mix of use at grade X Permitted Height X Mix of use in 3D = Trip generation. (Tr)

Trip generation X target mode splits (M) = Volume required to move by Public Transport per day. (V)

Volume/12 hours of work per day = per hour Volume (Vh)

Mode capacity per hour (MC) >=< per hour Volume = Level of Service required

These mode capacity outcomes were then used to show how a modal type could best be used to accommodate them:

1. Less than 3000 trips per hour on an entire line of transport = regular Bus

2. Between 3000 and 8000 trips per hour on an entire line of transport = A Bus Rapid Transit type configuration

3. If the task was over 8000 trips per hour along a line, then a Rail-based type of transport was required being at minimum light rail up to commuter/heavy type configuration.

Therefore, expressed as an equation to find the mode of transport suitable to carry a targeted mode split with a specific per hour capacity:

$$V = Tr \times M$$

$$Vh = \frac{V}{12}$$

$$Vh = LOS$$

This forces a policy maker to recognise that certain modes of transport are best suited to certain load factors, such as V or Vh, and that land uses should respond to these opportunities or limitations. To render this simple, a spreadsheet was prepared. The capacities of different modes, operating under optimised (short) headways, are demonstrated by the following chart.

Transport Mode Capacities with common headways

	Bus	BRT (1)	BRT (2)	Tram	LRT (1)	LRT(2)	Subway	Commuter rail
■ Passenger/TU	60	90	90	90	90	90	100	100
■ Frequency(minute wait)	4	4	2	4	4	2	2	10
■ TU/Hour	15	15	30	15	15	30	30	6
■ TU/set	1	1	1	3	3	3	5	10
■ Passengers/ hour	900	1,350	2,700	4,050	4,050	8,100	15,000	6,000

Passenger Caapcity (y-axis: 0 – 16,000)
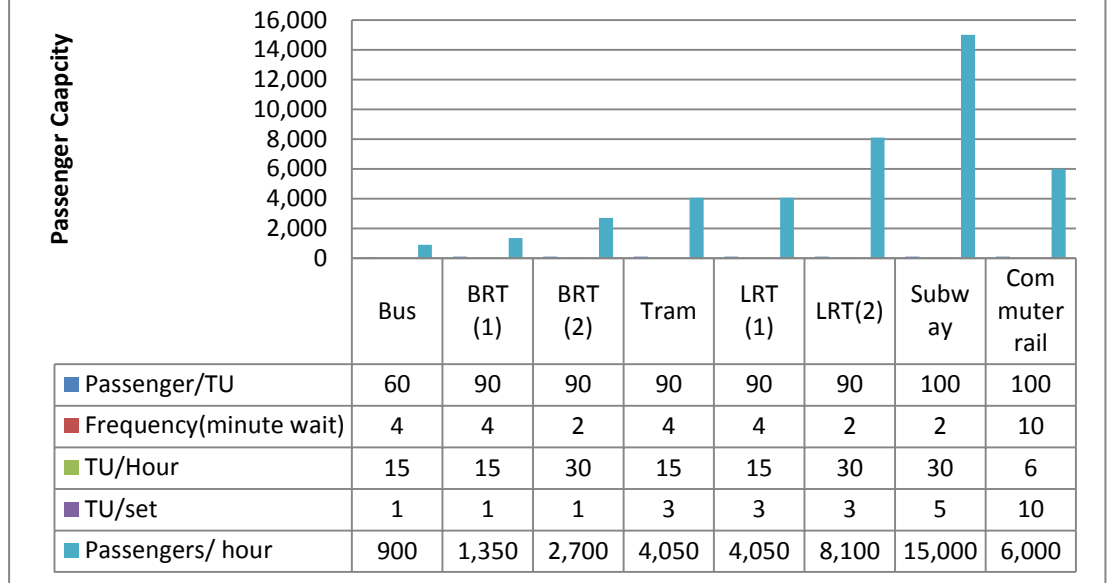
Figure 42 Transport Mode Capacities

3.2.4   RESEARCH DESIGN: QUANTITATIVE & QUALITATIVE

The goal is to uncover the target to achieve a balance of amenities for a set target of people on urban-infill transit-oriented land. This will provide more land inside the metropolitan footprint being used for: dignified housing; knowledge and service jobs with some light industry; and sports fields, urban agriculture and ecological reserves; and retain land outside the city in a wilderness, rural or semi-rural state. While high density is not the main objective, much higher density than is currently witnessed along public transport corridors and nodes will be the result of this experiment. This residential density will consist of low townhouses with towers of discreet heights arranged around varying proportions of public open space, commercial office and retail shopping spaces.

The research project is a mixed method, as listed above in methodology, though it is significantly quantitative. It is research based in numbers however it is not a statistical research.

3.2.4.1 QUANTITATIVE ASPECTS

Below are descriptions of the three physical areas used to test the theory of Land Use and Transport Integration in this research. These have dimensioned space which can and will change over the next fifty years. At question is the capacity of the land to absorb change and how it is best distributed to reach regional planning targets. The focus is on how best to be proactive in changing automobile dependence and transit orientation across the region. Exact measurements were taken of the redevelopment potential to then begin to assess the capacity of the land to provide for homes, jobs, parking bays, patronage, walkers, shoppers of goods in mixed-use precincts, carbon and VKT reduction.

3.2.4.2 QUALITATIVE ASPECTS

The research is mixed, with qualitative aspects, as a few subjective choices to make over the final alignment of transport routes, where the stops and stations and termini may be best located, which parcels of land are to be redeveloped within what radius of a transport stop, to what density and with which ratio of mixed use. The simplest response to these subjective questions regarding the public transport, in addition to the above sub-section, is that the routes will aspire to be:

- the straightest, that is, with the least number of corners which have these complicating factors: slow speeds as the trains must reduce speeds, high costs in terms of land for the radii, difficulties in construction and operation for all modes, and hazards due to operational uncertainty and leading to accidents;

- the cheapest with the least land to acquire from private holdings;

- where the right-of-way is most accommodating for multi-modal transport uses; and

- where there are parcels of land to be redeveloped (see Drafting in Potential Sites: 190).

The stations will be spaced according to the mode with:

- Light Rail Transit stations approximately one kilometre apart in faster running conditions or approximately four hundred metres apart in the slower operating urban conditions;

- Heavy Rail lines will stops only every two to five kilometres as best suits operating speeds and braking requirements.

Please also see the Appendix: Urban Design for Public Transport, Urban Design for Active Transportation, Transit Capacities and Urban Form and Urban Areas, Populations and Transport in 19 Cities, starting from page 444.

3.3 INSTRUMENTS

The original source files of the cadastral survey of the land had been considered unattainable. Having this information is important to this research as the precise dimensions or right-of-ways and areas are fundamental to knowing how much land is available along right-of-ways of sufficient width to accommodate a multi-modal approach to redevelopment. These land areas will form the locations of greenfield-conserving, walkable, transit-served, low-carbon areas of working and living in the Transit-Oriented Region.

The cadastral information, zoning, and other overlays were finally accessed in a file format, AutoCAD, which was the most useful for reasons outlined below. However it was necessary to make the AutoCAD data consistent across the Metropolitan Region by using techniques common in the design fields of Landscape Architecture and Civil Engineering:

- scaling the vector AutoCAD file to be correct in a real-world measurement;
- overlaying and fitting other vector files, in this instance the zoning and R-Code;
- fitting other raster images of other plans such as the many alignment options for light rail, heavy rail as well as local structure plans;

This will be further elaborated below under the heading AutoCAD onwards.

3.3.1 AUTOCAD

AutoCAD is vector-based, scalable and imminently the standard for professional drafting. I chose to use AutoCAD as it has these characteristics in relation to Adobe Illustrator and/or ESRI ArcGIS:

3.3.1.1 AUTOCAD VERSUS ILLUSTRATOR

Illustrator is a graphic vector-based software program, as is AutoCAD. Line and weight and colour are easily manipulated on a relatively simple file in Illustrator, but when large complex files of many layers and many zones (sites) of importance are contained within a drawing (zoomed to scale) the AutoCAD's system of layout tabs with viewports is far superior in the way in which layers may be serially 'frozen' (unseen) leaving only the

target information visible. In this respect, Illustrator would be far too clumsy a tool as there is no controlled scaling, to a specific scale of 1:20,000 or otherwise. Likewise, the crafting of separate sets of spatial data on sheets is not as easily performed in Illustrator and thus the consistent delineation of data sets will be harder to control than in AutoCAD. Lastly, because Illustrator is not dimensional it is *not possible to get accurate volumes* of spatial data; this is the data at the core of the research. The researcher will, however, turn to Illustrator to colour and produce finalised drawings which are consistent across the set, pleasurable and easy to read.

3.3.1.2 AUTOCAD VERSUS ARCGIS

ArcGIS is a high powered analytical and mapping tool. However, it is only as good as the data set one receives or creates oneself. It is very good at analysing what is given to it, correlating the data within the confines for which the data was collected. In this manner, it is ineffective for creating new data for future-forward projects for which there are only observed phenomena.

Furthermore, ArcGIS is not a drafting tool to design new futures. Though it does create maps, these are coarse in comparison to what is required for this PhD exercise. This experiment in specificity requires dimensioned inputs to export dimensioned outputs of verifiable square metres (m^2) to in turn create cubed metres (m^3) in a 3D model. This 3D model will then, in turn, be used to illustrate a transit-oriented region. In ArcGIS this would be a very time-consuming and laborious process. However, for shifting the data and output in one move, ArcGIS would be a preferred mode once 'tools' were written for such a process.

3.3.1.3 AUTOCAD AND THE RESEARCHER

It should also be noted that the researcher has been using AutoCAD for over a decade and is very proficient with its techniques for production. The researcher does acknowledge its limitations as being unable to register attributes, cross reference, correlate and create statistics. Unfortunately, there will have to be a measure of 'going back and forth' between an Excel spreadsheet, with targets (see 'Excel' below), and the AutoCAD file with the original core spatial data. The best characteristic of AutoCAD is that it can be

specific, explicit and accurate, scalable and dimensional. The outcome is an accurate reporting of volumes and distances as opposed to diagrammatic (Illustrator) and representational (GIS) in the other two programs, respectively.

3.3.2   FILES

Having received the AutoCAD files through the Western Australian Planning Commission (WAPC), the Western Australian Department of Planning (DoP) and colleagues at the Australian Urban Design Research Centre (AUDRC) in Perth, the researcher had to come to understand the content and larger contexts.

3.3.2.1 FILES BY NAME AND BY SOURCE

Western Australian Planning Commission / Department of Planning (WAPC/DoP): Building Footprint_Metro.dwg, Metro_Cadastre_1Ha.dwg, Metro_TPS.dwg, MRS_Boundary.dwg

Australian Urban Design Research Centre (AUDRC): 02 Easments+Lots.dwg, Cadastre stripped.dwg, Contours.dwg, mrscadhaded06.dwg

3.3.2.2 LAYERS

Understanding the content of the files began by using AutoCAD to open and explore what was drawn on each layer within each file. Every file, typically, is composed of layers which have specially grouped types of information drawn on them. For example, all like items fundamental to one bit of information should, ideally, be present on one layer so that this information may be isolated for examination and querying. By separating the layers with all like attributes together, the line types, pen widths (line thickness) hatches and other standard drafting symbols may be controlled.
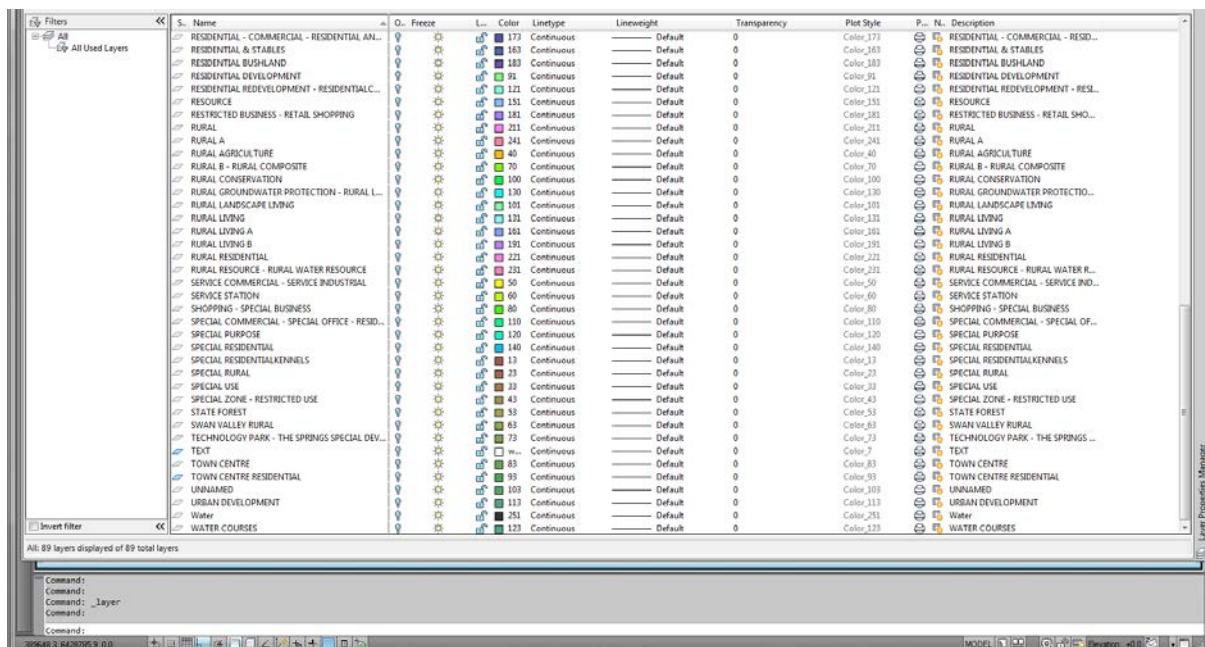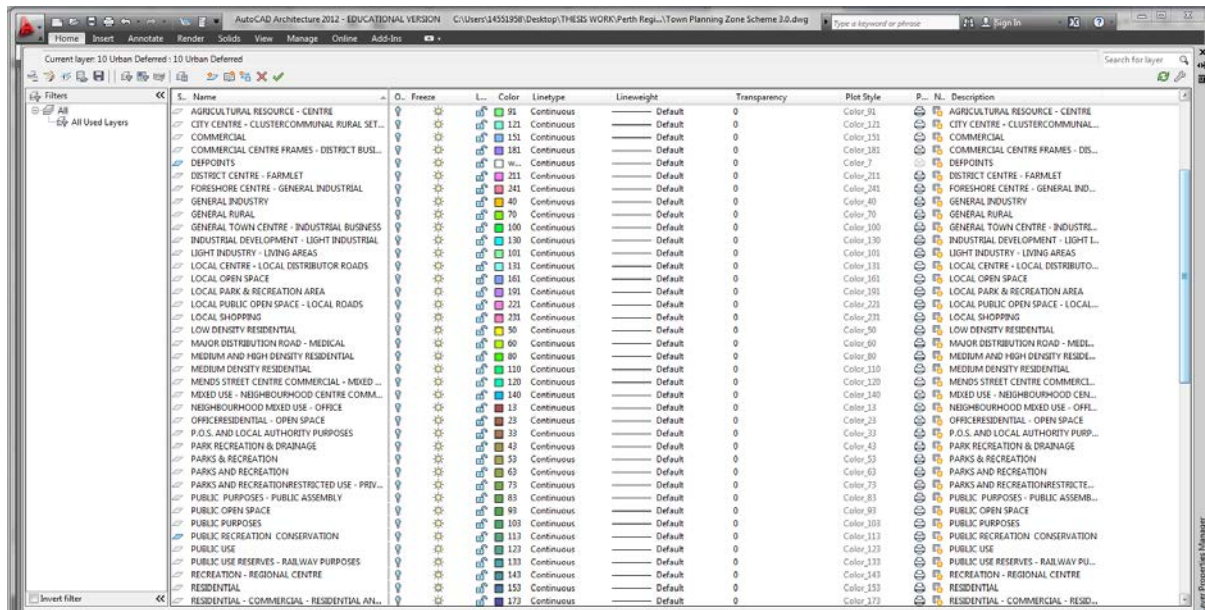
Figure 43 Example of Zoning Layers. Eccentric naming convention from the file 'TPS'

SOURCE: AUTHOR, 2012. LAYERS FROM WAPC FILE TOWN PLANNING SCHEME, OR TPS. THERE WERE MULTIPLE WAYS TO DESIGNATE PARKS, SINGLE FAMILY, MULTI-FAMILY, AND SO FORTH.

3.3.2.3 NAMING CONVENTIONS

Despite international efforts to regularise the naming conventions, the layers' name may, or may not, be indicative of what is drawn on it. For example, in the file titled "Metro_TPS.dwg", which showed the Local Government Authorities' (LGA) Town Planning Schemes (TPS) zoning across the Perth Metropolitan area, every LGA had a different title and definition for each zone. In some LGAs street Right-of-Ways (ROW) were included as Public Open Space, while in others they were not. In some instances large swaths of urban land were rezoned as Medium Density while in most others it was merely Urban. Trying to interpret what each layer meant and how a layer was similar or different was a task that required concentrated labour. The task was repeated again to be sure of a consistent process as detailed in reorganisation below. Google Earth Street View helped enormously in checking what was on the ground in many instances.

3.3.2.4 REORGANISATION

New layers were named, using the best of a standard naming convention, and information was moved to similar layers. This created a much clearer picture of the opportunities for redevelopment already created through legislation.

3.3.2.5 COLOUR RAMPS

Finding the correct colour to demonstrate the relative importance of a piece of data is fraught with problems: printers print in colour at different saturations (red becomes orange, or vice versa) or sometimes there is no colour printer available. To deal with these potential problems, a range of tones, hatches and pen-widths was used to prepare the drawings.

3.3.2.6 HATCH REMOVAL

Two files relating to the building footprints and to the zoning of the Central Perth Metropolitan Sub Region the files were entirely composed of large swatches of colour. The computer's Random Access Memory (RAM) and Graphics Processor Unit (GPU) could not cope with the amount of coloured area. To eliminate these large swatches (hatches) it was necessary to select the hatch, right click and select Generate Boundary from the dialogue

box. One had to be sure to have as the Current Layer the layer that one wants the new polygon (generated from the Generate Boundary function) to be appropriately layered.

3.3.2.7 ZONING AND R-CODE

In several instances it was required to reorganise layers so that data could be combined with other like data. With the zoning layers, it was necessary to create new layers corresponding to the typical zoning array in most major cities. The next step was to look at the polygons of zoning, reference to on the ground realities via Google Earth and place the existing layer onto one of the new layers which most accurately responded to that layer name in spirit or by name. This involved using the Layer Isolate (LAYISO) command to be sure to gather quickly all those polygons and hatch on that layer to move it to the new layer. The move was accomplished through the Properties Dialog box by selecting which layer it should appear on.

For the R-Codes (Residential Density Codes) it appears that there are two intervening issues with the data as it was received. One is institutional and the other may be institutional as well, or just missing. The first is that large areas of the Central Perth region were 'Unnamed'; that is, it was not specified to what degree an owner could build or rebuild on their property. It was assumed this meant that those areas had no redevelopment pressures and were not predicted, until a much later date, to have higher density than at present, remaining low to very low density. The second was that the data did not quite cover the needs of the experiment; that is, areas to the south and east of the study area were not represented by any data. Again, it was assumed that these areas have not received an R-Code as there are no density pressures based on large-scale redevelopments and so these areas will remain low density for the foreseeable future.

3.3.2.8 COMBINING FILES, CREATING NEW DATA

Polylines, polygons and points, as vectors in AutoCAD and GIS, can be overlaid to see through the data (roads, rails, lots and so on) and create new data related to the existing data. Drawing new data which lies accurately alongside existing data (polylines representing very real infrastructure, buildings, public open space) is the great strength of AutoCAD. AutoCAD enables designing to be simplified, dimensional, scalable and layered. The new

data, in this instance being new polygons and lines representing parcels of land to redevelop along new rail transit lines, is made possible and facilitated by the software.

That there is no data, on underground service lines for water, sewers and power, and other 'franchised utilities', has to be understood; this is not the only important data but gives a very strong indication, by looking at the data on the surface, of what lies underground. For example, if there is a cadastral parcel of certain size and accessed by a road surface of a certain dimension one can heuristically surmise, though not always accurately, that there must be adequate underground services.[28]

To facilitate viewing of all relevant data, seeing the relationships onscreen both locally to precise detail and generally across the region, it is important to be able to overlay the data by inserting one data set into the other, being sure to match each data set with similar units (command line UNITS), being metric and in metres to the same rounding. That they may not have the same x,y (latitude and longitude) origin can be very problematic, however with the move tool (m > spacebar) one can move the x-ref (external reference) into the correct place and then scale using the Align tool (al > spacebar). However, should the two files not appear compatible, it is important to reset the origin of each to a similar place, say, to the bottom left of the drawing area following these steps (View>Coordinates >Origin) and resetting this. It may require several attempts before success. While this resetting of origin does remove the original x,y coordinates one must use the new combined files as *one complete and coordinated data set which is accurate unto itself* and which is able to be properly projected once again if ever necessary.

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[28] Typically, in the initial phases of redeveloping a parcel of land underground services need to be upgraded in any event and the challenge is rarely insurmountable. However, that there may not be enough 'services' to a lot may in fact prove to be the first and last reason to move towards a distributed energy, water and waste system. This is especially the case on the large parcels of land where the scale of the developments will make them affordable, recouping costs over the medium term and avoiding cost of oversizing services, within the project's scope.

X-refing one data set into another does have problems, namely, file sizes which require the computer to be able to process (render) over and over again, with every pan or zoom, the complete amount of data whether visible or not. These rendering requests require not only large amounts of Random Access Memory (RAM) but also that a great deal of this RAM is dedicated to the Graphics Card. It also requires that the processor can work hard, preferably from several cores so that the tasks are 'split up', and that the whole remains cool over an extended amount of time. To overcome shortfalls in these specifications, as not every computer is created to perform these complex rendering functions, it is often necessary to reduce the number of polylines, polygons and points. This is accomplished by a combination of, *from a copy of the original file*, deleting whole areas of data (outside the study boundary) or deleting whole 'layers' of information which is unnecessary for the experiment (such as some text or symbols layers or duplicates) or removing large swatches of coloured 'hatch' to become simply outlined polygons (right click on hatch, select Generate Boundary). By this process one can begin to create many multiples of megabyte reduction in file size which, while some data is lost, the performance of the computer enables the experiment to proceed. Much as one needs a safe boat to explore the ocean in Marine Science, one needs a computer able to navigate the files. At times, as sea conditions limit a marine experiment, so does the computer's ability to process (render) files limit this type of experiment.

To insert an x-ref (external reference) one simply follows the Insert > Reference > Attach and selects the target file.

All of this process, while time consuming, is necessary to create a Master File or a set of Master Files.

3.3.2.9 MASTER FILE

Due to the extreme complexity and the sheer numbers of polygons created by, especially, the cadaster (block and street pattern) and lots (individual parcels of land) which alone accounted for thousands of lines, polylines and splines, it was necessary to keep relatively simple AutoCAD files free from 'heavy' x-refs (external references) .

When necessary, the separate files would be rationalised, that is re-saved with a similar name and reduced by deleting large portions of either area or layers or both. In this way the inserting of an x-ref was made easier and easier to operate.

The Master File was forced to become several master files which required some, but not extensive, interplay to remain up to date. However, this portion of the method for this research may be hard to replicate precisely as there was a precise set of plays memorised by the researcher which relied on a deep understanding of how to use AutoCAD.

3.3.2.10 CONCLUSION TO INSTRUMENTS

With all of the techniques employed, below, the research then sought to trace areas of potential redevelopment along transport lines in AutoCAD:

- receiving the files,
- processing the files,
- removing unnecessary information,
- combining files,
- inserting raster images of WAPC documents,
- creating new data sets,
- looking at the cadaster and Google Earth for a Ocular Estimation of potential land of redevelopment,
- and finally using the best of available global research into how to estimate the requirements of an integrated public transport system.

The square metre results and kilometres of rail lines were then placed into an Excel spreadsheet in which the modelling could occur. The modelling will be described in the Results sections below.

3.4 PROCEDURE AND TIMELINE

The procedure involved a great deal of iteration; it was not a linear process. Access to the AutoCAD file was ultimately imperative to be able to have numbers with which to model. For several months the research was proceeding with an Illustrator base of the Metropolitan Regional Scheme. While interesting graphics were obtained from the MRS base map, no specifications of dimensions, areas, volumes or lengths could have been

accurately counted via this process. However, by using the MRS base map the researcher became much more aware of the opportunities latent in the physical layout, infrastructure and planned growth of Perth.

3.5 ETHICS AND LIMITATIONS

There were no ethics requirements for this research on the materials presented here. There was an ethics approval from Curtin University for an online survey, however, as the results of this survey are not being presented in this work, it is not relevant.

There were limitations placed on the survey data from the Western Australia Planning Commission (WAPC) for the cadastral information used for Models 2 and 3.1, and these have been complied with.

Restrictions were placed on the outcomes of the Model 3.2 as this work was accomplished under contract for the Stirling City Centre Alliance, a local government planning authority under the auspices of the WAPC, however in the contract it was made explicit that the researcher was to use the model and outcomes as a part of this doctoral research project.

Google Earth allows researchers to use their imagery so long as one is not defaming, preparing a pyramid scheme, or otherwise trying to profit from its use. See Google Maps/Earth Terms of Service: http://earth.google.com/intl/en/license.html

3.6 CONCLUSION TO RESEARCH DESIGN

This chapter 3, Research Design, had set as a question: **How might one devise an experiment which is replicable for different cities to render clearly the impacts of the policy choices in planning for urban futures?** To answer the question a suite of high-level methodologies were elaborated as being suitable to search for meaningful details and measurements as described in the findings of chapter 2, Literature Review.

Using a methodology which included Positivist, Design Research, Practice Research, Heuristic and Ocular Estimation the research has set out to examine several participant sites. The sites chosen are in the Perth, Western Australia, metropolitan region including the region itself. There is also a wide variety of global cities' sites as examples of urban conditions stemming from policy, design and choice which have had significant positive, or negative, urban outcomes. All of these sites needed to be measured in different ways suitable to the context of the research, and so several background measuring tools were elaborated, including methods to measure the land for capacity, transport service and for amalgamating raw AutoCAD data with current planning efforts across an entire metropolitan region.

The experiment's grounding was thus prepared for the next chapter, Results, wherein the method of each model will be described, formulas shared, assumptions made clear and the charted results labelled.

4 - RESULTS

THESIS QUESTION: Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?

This chapter will ask: **What are the policy levers available to planners and politicians and how do we measure their impact in a meaningful way?** Three models were developed, based on the Literature Review and Research Design and devised to produce a replicable, adjustable, transparent method for understanding the choices, aggregate measurements of space and importance of urban and transportation goals being linked.

This research will present a flexible (user may change assumptions) and transparent (assumptions are made clear) methodology to prepare the metropolitan region for local design solutions to resolve increasingly global problems about car dependence.

The models build on tiers of investigation: one leads to the second and the second leads to the third and so could be taken as one complete 'method'. However, they are useful as separate models and outcomes for these reasons:

1. A Global model, **1**, is about policy options trade-offs. It is global in its examination of the relationships between the factors which lead to, or away from, desirable transit-oriented, walkable, mixed-use, dense, amenity-rich, and green urbanism. This model uses a series of pull-down tabs to select a scaled amount of a 'lever' which, when added up, relate to a Google Earth satellite imagery bank and Street View to present real-world images of what such levers produce. It assumes no judgement on the variety of urbanisms the model produces, but does prepare the model's user for what may be reasonably expected from applying, consistently, such policy levers. This model informs the process of deciding which levers to be pulled in the following models.

2. The second model, **2**, regarding the regional metropolitan scale, is aspirational and looks for region-wide opportunities and capacity to house anticipated population growth.

This method/model uses measurements for the whole Perth Metropolitan Region in over one hundred possible redevelopment areas.

3. The third model, **3.1**, is built as a part of the regional model of Model 2. It will use the model to show how a neighbourhood, Victoria Park in this example, may be re-imagined depending on where on the spectrum of global urban examples it is desired to be placed over the next decades.

4. The fourth model, **3.2**, looks at real-estate yields in light of different transport provisions and examines the aspirations of city shaping. It will reveal how different degrees of policy application lead to very different urban outcomes. This model uses a precinct, Stirling City Centre, with ambitions to become a transit-served 24 hour mixed-use area functioning as a second Central Business District of Perth, to illustrate the benefits of higher order transit provisions.

The methodology is summarised in the following diagram. In its totality it is one method, but this method does not produce one result. Rather, it is a suite of methods to understand the dynamics of land use and transport relationships which, as individual components, can provide a picture of the forces supporting and limiting a Transit-Oriented Region.
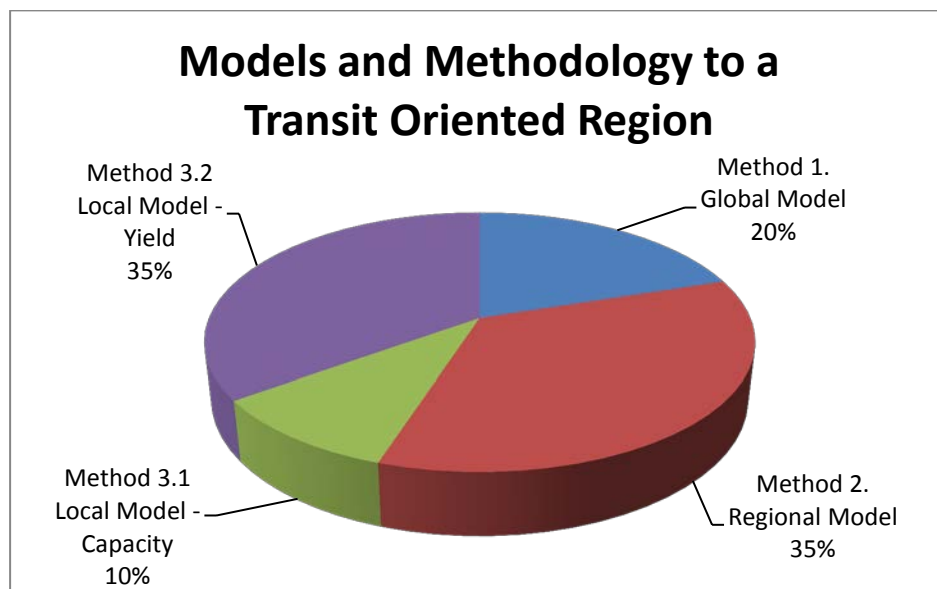
Figure 44 Methodology diagram by per cent of quantity

Source: Author, 2014

4.1 RESULTS: THE GLOBAL SCALE **MODEL 1**

The first model is called The Global Scale as it looks at places, lived-in neighbourhoods, from around the world as instructive examples of urbanity. It begins the conversation on what type of city one may aspire to live in. If one idealises Paris, New York, Portland or other cities it is important to know what levels of service are present (such as high public transit accessibility and great walking destinations) which make the place appealing, without delving into 'style', from a variety of perspectives. All cities have options and priorities for the betterment, or detriment, of the urban fabric and need to better elucidate the overall vision for sites and precincts and neighbourhoods.

4.1.1   INTRODUCTION TO THE GLOBAL SCALE: MODEL 1

As the process of uncovering opportunities in the Perth Region, discussed below was carried out it became evident that a fundamental first step had been overlooked. The first question was 'What type of city does Perth want to become?' The same could be asked for any city in the process of growing, changing and investing in transport networks. While difficult to comprehend the entire surface of a conurbation, it can perhaps be illustrated at a visual scale which is repeatable and consistent with other cities for comparison. All cities will have made policy choices regarding land use and transportation provision, including the choice to *not* make choices and retain the urban fabrics they have inherited, with physical urban fabric outcomes available for the world to see via Google Earth. What was then prepared was a coherent 'choice option', or 'policy lever', model which produced an 'answer' linked to folder in Google Earth for 'like' comparisons of real, existing, urban fabrics.

This will be useful in first helping to sort out the 'policy options' for re-developable sites along the public transport corridors in Perth, and indeed anywhere in the global urban domain.

Hyperlink to Global Scale Model Folder:
https://www.dropbox.com/sh/wzexr5s7ang038g/AAAj0r1h6Q_C8hyh0nmM25BTa?dl=0

4.1.2   ORIGINS OF THE GLOBAL SCALE: MODEL 1

For most urban development there are a series of policy and design levers to be pulled to create walkable, leafy tree-lined, transit-served, dynamic and mixed-use, high-density and high-amenity places. These places are not re-created by preparing a list of 'nice-to-haves' and neither are they effective if any one or two of the following indicators are missing. If the location is wrong, or the scale of the project too small, the parking ratio too high, the mix of uses at the ground-plane is oversubscribed, or the public transport service is the wrong mode for the location, then the outcomes of the project will not be maximised.[29] To clarify how one indicator has a bearing on another, the preparation of a 'spectrum of urbanity' was required to exhibit the range of options.

A new model was created which uses simple addition and division to give numbers in a range of 1-4, or 1-5 in two instances, to reflect where on the spectrum a certain type of urban fabric is in the case of the existing examples, and could be in the case of new planned areas of growth.

The relatively simple method – using addition and division – developed to present this model belies the days and weeks spent being 'too smart' in trying to make complicated what need not be complicated. The researcher attempted several means to add weighted values to all the possible indicators and to present the formula in several different long division formats, but essentially it was reduced to very simple adding and subtracting for these reasons:

- The world is already full of mathematical formulas few in government – planners to politicians – can either comprehend or have time to comprehend or which are useful in any meaningful way. While this may seem pessimistic, it has been observed that high-level strategy decisions are made on persuasive arguments rather than formulas.

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[29] For example, the successful T.O.D. Subiaco in Perth has been criticised as being 'undercooked'. The density could have been much higher given the walking distance to inner city locations and capacity of the commuter rail station to support many more daily trips.

- This added transparency to the model. One can insert a number, thereby changing a factor, and view the result in whole numbers which correlate with a selection of global urban fabrics represented, again, by whole numbers. How this works will be discussed in the Method section below.

There are many manifestos, articles, books, presentations from urban and transportation scholars, but missing from the collection are the simple and pervasive engineering 'standards' which provide most of the 'reason' for the way most urban land is constructed. There needs to be qualitative certainty about the benefits of any approach over and above the standard engineering one to convince an engineer of the efficacy of a different approach.

The two reasons given above explain why this model was made simple, rational and positivist, but don't describe the deeper origins of the model which are:

- First, the impact of a useful, simple, transparent formula may have on decision makers in seeing options before approvals. Often it may appear that the development proposal, or application, is all there is: development or no development. Yet there are levers to be pulled at several levels on any given development as local governments actively try to achieve stated 'sustainability goals'. Being able to pull these lever options, impacting on each other, will be illustrated in this model.

- The second origin of this model's method comes from protracted private negotiations over a project's details and public engagement regarding the community's future. Often the negotiations have to do with questions of density or height, or with transport problems such as parking or intersection capacity or local school upgrades. In either public or private dialogues there needs to be a clear understanding that when a place is rezoned to higher and better land uses there will be transport impacts exceeding the current situation. Likewise, when a new transport scenario is presented, there will be increased access with impacts on land-use uptake and certainly on land prices, with flow-on effects regarding who lives where and distances to places of work. Understanding the impacts one set of issues has on another appears, unfortunately, to be in professional silos. There may be agreement that there are impacts, but they are rarely quantified or even qualified. In these situations the best possible scenario is transparency. Communities, their politicians, civil service and development groups need to have a way of objectively understanding the impacts of policy settings to make informed decisions. This model will help illustrate the policy and design options.

- The third origin is based in the desirability of streets, neighbourhoods, cities and regions to be places we love and love to walk in. We admire certain places, like Paris or Barcelona, but how do they compare with the scale and fabric of a proposed urban redevelopment? Could we ever build these types of walkable, mixed-use, transit-serviced urban places again? If we like

them, why do we build even one more parcel of automobile-dependent urbanism? How then do we describe in real terms the actual trade-offs made in these desirable walking environments to live like that? For many people the lack of parking, say in Paris, may at first seem unacceptable but when combined with the benefits of not needing a car for much of the time the pay-off of living in a car-reduced, transit-oriented, mixed-use environment becomes clear. This model will help illustrate the global city fabric an urban development may aspire to.

The resultant model from these origins will be described below.

4.1.3   GLOBAL CITIES MODEL'S METHOD

Given the time and funding, the Global Scale Model could be rendered into a Visual Preference Survey of the preferences of lay-citizens, professionals, politicians, financiers and so forth. This could reveal compelling data.

Though urban fabrics are difficult to assess comprehensively – how much of any one factor is the result of culture, economics, politics, religion, trends, or personal choices will remain elusive – there are standard items that government-led policy settings can control. While planners, architects, politicians cannot always control micro- or macro-economic swings, personal tastes, new banking practices and mortgaging regulations or others, cities and regions are generally able to control and plan for these factors:

- Location, being the location prioritised within the region for redevelopment, typically accomplished through a permissible zoning of sorts

- Area, being the physical area of up-zoned land – giving large parcels more potential redevelopment – in a local structure plan

- Density, being the number of residents and jobs mix to create 24 hour activity, bringing other amenities (shops, parks, schools, public transport) closer to more people

- Public Transport provision, being the capacity of the public transport network adjacent to a project to support a percentage mode split per hour or per day

- Parking Ratios, being the mandatory number of car parking spaces per land use

- Mix of Use, being the allowed rate of mixing between residential, institutional, commercial and retail

- Design, being the degree to which the transportation hierarchy focusses at the ground plane - detail regarding pedestrian and cyclist priority

and finally what this all amounts to:

- Urban Fabric, being both the visual 'appearance' and function of the place which is appealing and connotes a way of being. Though it comprises measurable quantity of intersections, street widths, building heights and surface parking, these are but means to *improve* the overall Urban Fabric.

While more indicators could be added to this list, and the model can certainly support others and remain just as robust, these are some of the primary statutory and strategic planning items which can be controlled by most local governments.

4.1.3.1 SCORING

With these indicators established a scoring chart from 1-4 was created, and in two cases 1-5, to comprise a spread from 'base case' to 'best practice'. Even a 'base-case' scoring scenario, which may be equivalent to a highway-accessed strip-mall of small dimensions on the outskirts of town, received a score of 1 so as to demonstrate the thresholds at which the positive effects of 'better practice' begin to have their effects.

Via the scoring chart, of 1-4 or 1-5, there is a ranking of each 'quality' under each heading. Automobile dominance in outer suburban areas of single-use zoning with high parking ratios and a small redevelopment area would score poorly while a large contiguous area[30] in an inner or city centre location with high transit access and a high mix of land-use and safe walking environments would score highly. These could be weighted, however this will unnecessarily complicate the process as the point of the chart is to be simple and transparent.

With each indicator given a score from a drop-down menu, the result led to the multiplication of the score and division (divide by number of indicators:7) to give a whole number answer which corresponds to an Urban Fabric 'answer' (see Figure 44 Formula to LUTI Policy). The fabric number would then correspond to a hyperlinked folder of Google

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[30] This model assumes that the best of intentions for high-quality design will prevail in providing excellent urban grain and fabric in large lot assemblages. High-quality design will include plazas within interconnected street grids and great public realm interfaces including multiple openings, awnings, step-backs in the massing and so forth (Gehl, 2001, 2010).

Earth places which take one around the world to see what other places look similar, given the choices made in the drop-down menu.

4.1.3.2 MISSING VARIABLE

We may know we want a particular urban area to be walkable and appealing, but what other variables are necessary to make a place work as idealised? How dense and mixed use, with how low a parking ratio to induce walking, does a place need to be before a regular bus should be replaced with a Bus Rapid Transit (BRT), or a BRT with LRT? When does an LRT not fit the capacity requirements of a genuinely highly dense 24 hour place? Or what if a plan for an area accounted for everything except making the place walkable? What would be the impacts of the choices made, and where are similar urban environments?

To solve this, the mathematics were reverse engineered for each of these questions and a folder of hyperlinked Google Earth places was devised to relate the corresponding outcome.

4.1.3.3 LIMITATIONS

The folder of hyperlinked Google Earth places was decided on at the discretion of the researcher and based on personal observations at many of these cities or by reputation. Ideally these places could be selected as representative environments by a group of persons even more familiar with these particular cities. Furthermore, it would be better to obtain the actual data on mix-of-use and parking ratios, pedestrian counts and fatalities, density and accurate location description to assign the corresponding whole number to each Google Earth 'place'. However, given the limitations and the timeframe, this was not possible in this research.

4.1.4   EQUATIONS TO GLOBAL CITIES MODEL 1:

UF[1234]	Urban Fabric	PT[12345]	Public Transport

L^{1234}	Location	PR^{1234}	Parking Ratio
A^{1234}	Area	M^{1234}	Mix of Use
AD^{12345}	Activity Density	D^{1234}	Design

7=Seven known Factors (the other, eighth, is being solved for)

Solve for missing variable. One example looking to find UF, Urban Fabric, might look like this:

$$UF = \frac{L^{1234} + A^{1234} + AD^{12345} + PT^{12345} + PR^{1234} + M^{1234} + D^{1234}}{7}$$

Or, if solving for Public Transport the equation remains the same but with *PT* in the place of *UF*. This works for the other variables as well.

FORMULA TO LAND USE AND TRANSPORT INTEGRATION POLICY
Using Google Earth locations to demonstrate urbanism on continum of Land Use and Transport Integration

Scoring Chart

Score	Urban Fabric	Location	Area h	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1	Car	Outer	25	20	Car	RTA & RTA +	Single	Car
2	Transit	Middle	50	40	Bus	RTA -10%	20% mix	Multi
3	Walking	Inner	100	80	BRT	RTA -20%	30% mix	Shared
4	Walk +Transit	Centre	200	100	Light Rail	RTA -30%	40% mix	
5					200 Heavy Rail			
	Urban Fabrics are changeable along the variable listed to the right. What type of environment is desired?	Centre can be new in any area IF over four hunderd thousand (400,000) sq.m GFA	Area size	Residents and jobs as Acvity Density over 24 hours	Frequency, duration, speed, reliability, and capacity.	RTA + includes excess parking adjacent	Ground Plane Net Total from dominant LU	Car= Car dominant and reliant. Multi=Footpaths and cycleways. Shared= all mode priority.

Workbook

Solve for the Missing Variable: What is there, what is missing? Parking ratio? Design?

URBAN FABRIC
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
4	4	4	5	5	4	4	2

LOCATION
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
3	3	1	4	4	3	1	2

AREA
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1	1	1	1	1	1	1	1

ACTIVITY DENSITY
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1	1	1	1	1	1	1	1

PUBLIC TRANSPORT
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1	1	1	1	1	1	1	1

PARKING RATIO
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1	1	1	1	1	1	1	1

MIX OF USE
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1	1	1	1	1	1	1	1

DESIGN
Urban Fabric	Location	Area	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1	1	1	1	1	1	1	1

Results

Solve for the Missing Variable: Which Urban Fabric is aspired to?

Urban Fabric	Location	Area h	Density /h	Public Transit	Parking Ratio	Mix of Use	Design
1 Google Earth Link	1 Google Earth Link	1 Google Earth Link	1 Google Earth Link	1 Google Earth Link	1 Google Earth Link	1 Google Earth Link	1 Google Earth Link
2 Google Earth Link	2 Google Earth Link	2 Google Earth Link	2 Google Earth Link	2 Google Earth Link	2 Google Earth Link	2 Google Earth Link	2 Google Earth Link
3 Google Earth Link	3 Google Earth Link	3 Google Earth Link	3 Google Earth Link	3 Google Earth Link	3 Google Earth Link	3 Google Earth Link	3 Google Earth Link
4 Google Earth Link	4 Google Earth Link	4 Google Earth Link	4 Google Earth Link	4 Google Earth Link	4 Google Earth Link	4 Google Earth Link	4 Google Earth Link
			5 Google Earth Link	5 Google Earth Link			

Figure 45 Formula to LUTI Policy, snapshot of the model's spreadsheet

4.1.5   MODEL OF THE GLOBAL SCALE: MODEL 1

The following is an account of how to operate the model.

DATA COLLECTION

Step 1: Understand the site. The first process is to understand the details of the urban grain and fabric (see Definitions p.17) of the physical spaces considered for redevelopment and the further impact area of the land-use change or transport service provision. This will mean looking through existing planning documents, legal 'gazetted' plans and other policy papers at several different tiers of government to find the relevant policy which may affect the proceedings. At this stage one needs to research changes to standard parking ratios, transport provisions, mix of land use alterations, 'up-zoning' for higher density and other statutory planning changes.

The next stage is to go to and from the site by public transport so as to get a feel for the options and ease of travelling there first hand. Next is to take photographs and notes regarding parking, density that can be seen and estimated, the activities and the mix of use as well as the 'design' of the place, by walking through the area and evaluating its safety. While this may be a somewhat subjective process, purely objective evaluations may miss the sensory aspects of a first-hand data collection.

If the proposed site of urban development is under construction, conceptual or at early stages then use what is available from the graphics and written proposal or consider what one would prefer to have happen on the site. Is the site to be for car-free and low rise-projects, or a set of high density towers with standard parking provision in single-use zoning?

Lastly, prepare a visual catalogue of the site with notes and aerial views from Google Earth. Keep these available as a resource to justify your choices in the scoring, as outlined below.

SCORING AND OUTPUT

Step 2: Apply your assumptions. We all have our preferences for places: for example; some like plenty of parking, some like walkable streets, some like both. In most

situations the operator of the model will only be looking to solve one or possibly two of the missing variables which create the types of places we like. Having identified the variable(s) under question (i.e. density necessary to justify light-rail transport) choose the vertical heading line to begin the process of applying ones assumptions/preferences to retrieve an output in the red box, Step 3.

One needs to populate the other boxes from the drop-down options ranging from 1-4 or 1-5 which correspond to the policies, first-hand observations and the visual catalogue from step 1. A scoring chart is provided at the top of the page for guidance on the value to select (i.e., an area of over 200 hectares receives a 4 while a small site of 25 hectares is a 1).

Once all the selections are made, an output will be generated in the red box. This whole number by itself is interesting (that 4 is higher than 1), but essentially it is neutral and without meaning. The whole number is only an output; what the output means in relation to other similar sites around the world is revealed in the Results section below.

RESULTS

Step 3: Apply the result. Taking the output number in the red box from the scoring sheet one then has to manually click on the hyperlink in the results section which corresponds with the output from the Scoring section. For example, if Public Transport had been the missing variable (if one weren't sure what mode of Public Transport is appropriate given the other on-the-ground facts or choices) from an urban development project and it was found to be 3, then click on the hyperlink under Public Transport in the box labelled '3'. This will then lead the operator directly to a Google Earth folder in which there will be a selection of places to be viewed, as described below.

GOOGLE EARTH

Step 4: Explore the sites revealed from the Results. All the global 'places' within the hyperlinked folder are known either through first-hand experience or by reputation as being on a continuum of urbanity. They may not be prime examples of a particular type of urban environment, as few places are ever alike or perfectly one thing except themselves, but they do illustrate the options of existing built environments in ways which demonstrate a breadth of recent and historical urban fabrics.

To use the folders: Upon clicking the hyperlink, the Dropbox server should directly take the operator to Google Earth. If it does not this is because the free software of Google Earth has not yet been installed. Install at:

http://www.google.com/earth/download/ge/agree.html) or if the file type is not linked to the programme (C Drive >Programmes (x86) > Google>Google Earth>Client>Googleearth).
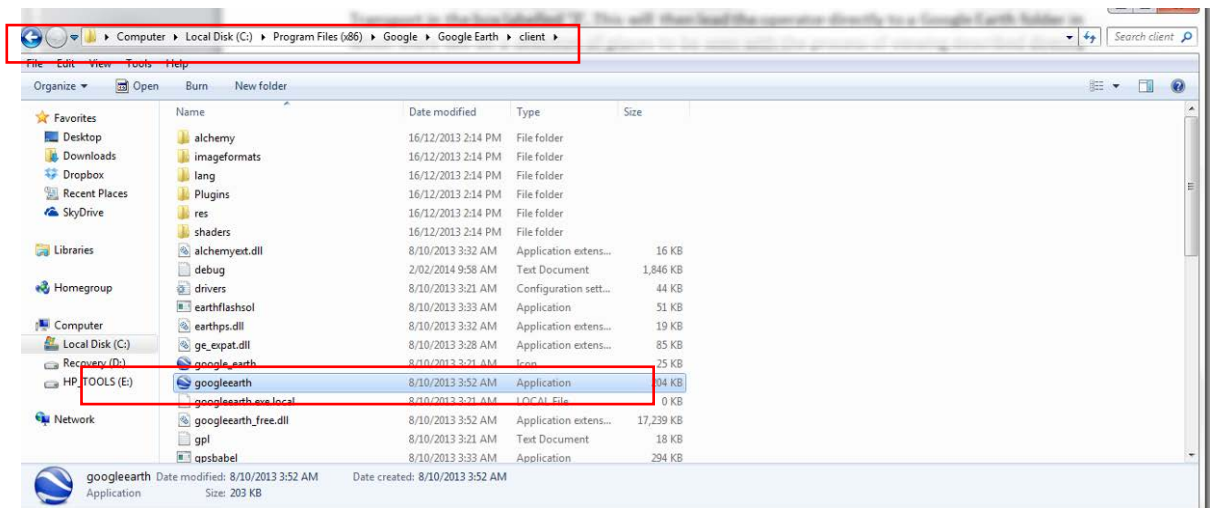
With the folder named 'Urban Fabric 1, 2, 3, or 4' loaded in Google Earth, there comes preloaded a sub-folder to be opened before the characteristic push-pin is presented. Each item is labelled as 'CITY Sub-area' (for example, HOUSTON Woodlands). Each of these places has been brought to approximately the same distance from the earth's surface (1000 metres above the surface) and at a scale of approximately 1:3500 on an A4 sheet.

One needs a modicum of experience at looking at aerial photography to be able to interpret the highways, railways, stations, parking lots, building footprints, parks, formal sidewalks and informal footpaths and other. By so looking at this scale the fabric and the grain can be interpreted. One of the great advantages of using software such as Google Earth is that it is free, useable, accurate and democratic in its operability – everyone can participate – and that the operator may zoom into places and even use the Street View function to see better the 'urban grain' of the places. In zooming in and seeing the grain, the operator may then decide if they 'like' the place, if it is a place they would wish to live or work in and feel proud to take a visitor to their city.

In this way, asking whether someone 'likes' a place or not, the Google Earth folder functions as a rudimentary Visual Preference Survey. However, the point of this model is *not* an aesthetic appreciation of 'preferences'. Rather, it is to gauge if the functionality of the spaces is what they desire based on their mix of uses, parking ratios, public transport service, density and perceived safety. By assessing the functionality, one can then begin to more accurately plan for what type of 'urban fabric' one wants in the project or prefers for their neighbourhood.

To reprise in table format, the steps are:

Table 6 Steps to Model 1, reprise

Steps to Model 1		
	What	Outcome
Step 1	Understand the site.	First is to understand the details of the urban grain and fabric of the physical spaces considered for redevelopment and the further impact area of the land-use change or transport service provision.
Step 2	Apply your assumptions.	Having identified the variable(s) under question (i.e. density necessary to justify light-rail transport) choose the vertical heading line to begin the process of applying ones assumptions/preferences to retrieve an output in the red box, Step 3.
Step 3	Apply the result.	Take the output number in the red box from the scoring sheet and manually click on the hyperlink in the results section which corresponds with the output from the Scoring section (Step 2) to find the online folder of Google Earth places, as per Step 4.
Step 4	Explore the sites revealed from the Results.	The point of this model is *not* an aesthetic appreciation of 'preferences'. Rather, it is to gauge if the functionality of the spaces is what they desire based on their mix of uses, parking ratios, public transport service, density and perceived safety.

4.1.6   RESULTS OF THE GLOBAL SCALE: MODEL 1

The results are to be generated by the operator /user for their ability to estimate the levels of transport service, parking ratio, mix of use density and so forth they desire in their large to small, inner to outer urban precinct. Were the timeframes longer with this research, the researcher could have taken this demonstration model to the public to calibrate it further and gather results.

4.1.7   CONCLUSION TO THE GLOBAL SCALE: MODEL 1

The implication for the model is threefold:

- There is a debate (see p.155) over the best way to plan for our communal, open, pluralistic urban environments. This model may help to resolve the conflict between 'style' 'density' and 'mode' as it shows that it depends on the needs, goals and aspirations of the locales within the cities.

- The model can demonstrate a way forward in developing the fourth urban fabric (5.1.1 Delivering Perth as a Fourth Stage Urban Environment) with the types of variables clearly enumerated for their positive, or negative, effects on the development of sustainable human habitats.

- The global comparisons are of equal-sized areas, at least in the first instance before the operator/user zooms to street level, and comparison between cities may be made for their strategic goal achieving functionality.

The implication, therefore, is that a model such as this can give greater clarity and transparency to the multiple small moves which go into building the dynamic, modern, goal-oriented urbanism which is spoken for.   While this does not resolve the finest details it does point to which details of construction, policy, financing, fabric and grain will need attention in a planning process.

For example, were a local government eager to have a Light Rail Transport (LRT) service in their jurisdiction, this model points to the specific areas of policy and planning to be addressed before a legitimate application could be lodged for funding. Without having made the land-use changes in the correct places to a sufficient land area-scale, it will be hard to justify the economics of mass transit.

While it is correct, to paraphrase Robert Cervero, that 'mass transport needs mass' there are other aspects which need policy and planning to support mass transport. These include:

- higher residential and jobs density;

- reduced parking provisions (to induce other means of transport);

- a diverse mix at the ground floor of publically owned services (post offices, recreation centres and schools for example), privately owned amenities (shops and cafes as examples), and professional services (dentists, doctors, lawyers) to shorten most distances for more people;

- slow vehicle speed on interconnected streets with safe crosswalks to promote pedestrian and cyclist activity in an overall location which is desirable or becomes desirable due to the excellent planning and design of the urban fabric.

Though precise formulas are not easy to provide, this model demonstrates the coordination of factors which must be carefully managed to create the type of city and region desired. Using this model, urban designers, policy writers and decision makers may begin to understand the interaction of the factors while also placing their project within a global best-practices spectrum.

4.2 RESULTS: THE REGIONAL SCALE - **MODEL 2**

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).

This research will present a flexible (user may change assumptions) and transparent (assumptions are made clear) methodology to prepare the metropolitan region for local design solutions to resolve increasingly global problems about car dependence. To overcome several of these disconnects this research will undertake the following in this model, the Regional Scale Model 2:

- Analyse the capacity of land, in volume and persons, to accommodate higher activity densities with each change in public transport levels of service;

- Calculate the public transport mode capacities, in persons per hour per lane, to serve compact polycentric region policies;

- Enumerate the direct and indirect economic costs and benefits of high-capacity public transport and walkability as a part of the growth of opportunity in reduced car dependence.

To be even more specific, the outcomes will demonstrate the ideal polycentric locations and scale of building floor plates to create:

- Floor space for the green economic service, knowledge and technology economy to be located;

- Precincts in which walking to local shopping and local employment work together with higher public transport access to places which are less resource consumptive;

- Quality places which are more likely to be resilient and desirable in their ecological and climate appropriateness within a walkable scale.

Hyperlink to Regional Scale Model:
https://www.dropbox.com/sh/tue36puw1avd7ze/AACZYw_WfEAQwqzNUTERNrUWa?dl=0

Ideally, The Global Scale Model 1 will have reported that the preferred planning paradigm is one for a higher density, mixed-use, transit-oriented, walkable, parking-reduced set of neighbourhoods across the region. To partially satisfy the output of Model 1, Model 2 aggregates the local land surface area in two dimensions (2D) – from sites across the metropolitan region which : a) are adjacent to current or potential rail lines, and b) have redevelopment potential. Model 2 then provides a method to estimate, in three dimensions (3D), the built urban form with a mix of uses and preferred dimensions to a residential unit or a retail or commercial work space to provide a number of residences and work places around the redevelopment sites.

The product of the model can be used to clearly see the trip generation and parking requirements (though ideally far less than advanced by the 'standards') as well as indicate results of lowering of Green House Gas Emissions, reductions in Vehicle Kilometre Travel, Value Capture Potential, Costs Avoided, Health and Productivity gains and other benefits from planning for a polycentric Transit-Oriented Region. As this model aggregates from the local and accounts upwards towards the regional; it is also used for measuring the benefits for a particular site of being re-urbanised (as will be explored in Models 3.1 and 3.2) or for a particular line of rail-based re-urbanisation. In this way the costs (of rail construction, difficult density decisions, and social infrastructure provisions) may be placed alongside the benefits at a variety of scales.

As stated, this sub-chapter discusses future transport and land use options for an urban region to achieve the stated, rhetorical goals 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), being for a compact, walkable, polycentric comprehensive re-urbanisation. However the detail provided in this model enables us to view a future based on rail and Transit-Oriented Development in creating a less automobile-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 (BRT) lines are proposed through the outer suburbs as a way to link these areas to the Ring Rail and existing heavy rail lines,

although these results are not discussed due to space limitation. This is then compared to a car-based future where residents and jobs are sprawled outwards from the road-based network. The results should be of interest to any city concerned with 21st century goals (UNEP, 2012c), including public transport planning, urban rejuvenation, lowering collective burden on the environment while improving a city's high quality of living.

This three transport-mode plan for Perth includes heavy rail, light rail and bus rapid transit to 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 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 infrastructure and development sites is presented below.

Note: All of the red polygons of rail-based redevelopment as seen in Figure 46 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 to between 4 and 10 storeys.

Figure 47 A future Perth of a highly connected networked of rail lines and urban development

4.2.1   METHOD TO REGIONAL SCALE: MODEL 2

4.2.1.1 RATIONALE

The methodology has many steps to be explained; suffice it to say that this paper responds to Robert Cervero's call for clear accounting on the social costs and benefits associated with any infrastructure project (Cervero, 2003).

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

4.2.1.2 STEPS

The method developed for this paper aims to locate ideal transit-served development plots, ascribe a land use mix and floor heights and to calculate population and employment 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 what the benefits are of creating new neighbourhoods around transit stations which are walkable, mixed use, amenity rich and desirable places to live.

CURRENT PLANNED LAND REDEVELOPEMENT

Step 1: To help answer these and other sub-questions the researcher 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 professional planners and visionaries which will serve as a foundation and rationale for 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 considered as well, giving more coherence to where rail might want to serve (see below). AutoCAD, a drafting software, 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. See 'Base Information: Measuring the Land' p 188 for more information on this process.

Step 2: It was then important to check the various proposed rail alignments for sufficient dimensions in the cross-section to support low-floor Light Rail or conventional heavy rail carriages, see Figure 47 below. See 'Estimating the Transport services' p.195.

A 500 metre buffer was placed alongside these lines to delineate the areas for discussion. Only the land areas within or reasonably adjacent to this buffer were under consideration, not all of Perth. AutoCAD was able to dimension the RoWs as presented in the base plan.
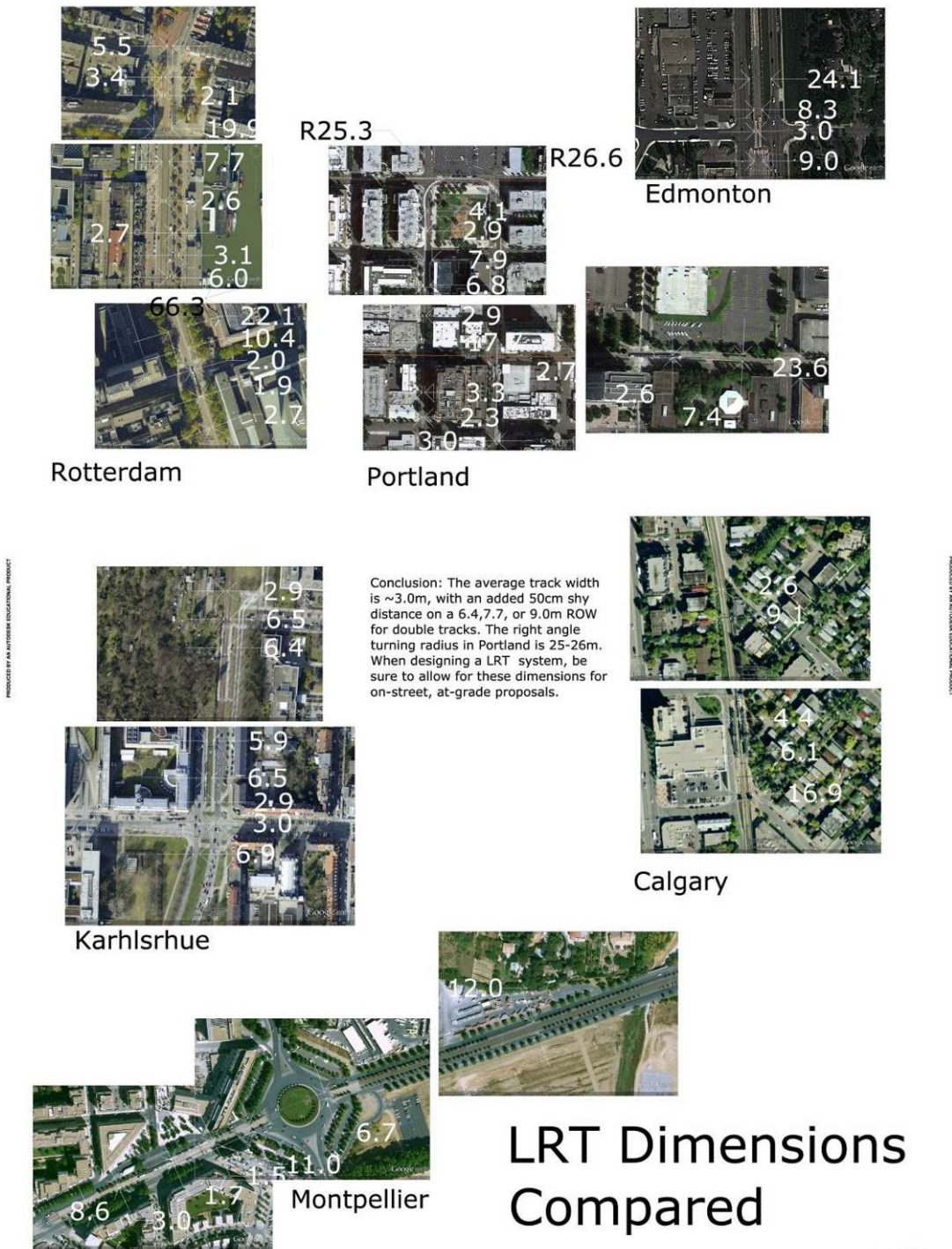
Figure 48 LRT dimensions compared from selected cities.

SOURCE: AUTHOR, 2012. INTERNATIONAL LRT RIGHT-OF-WAYS COMPARED
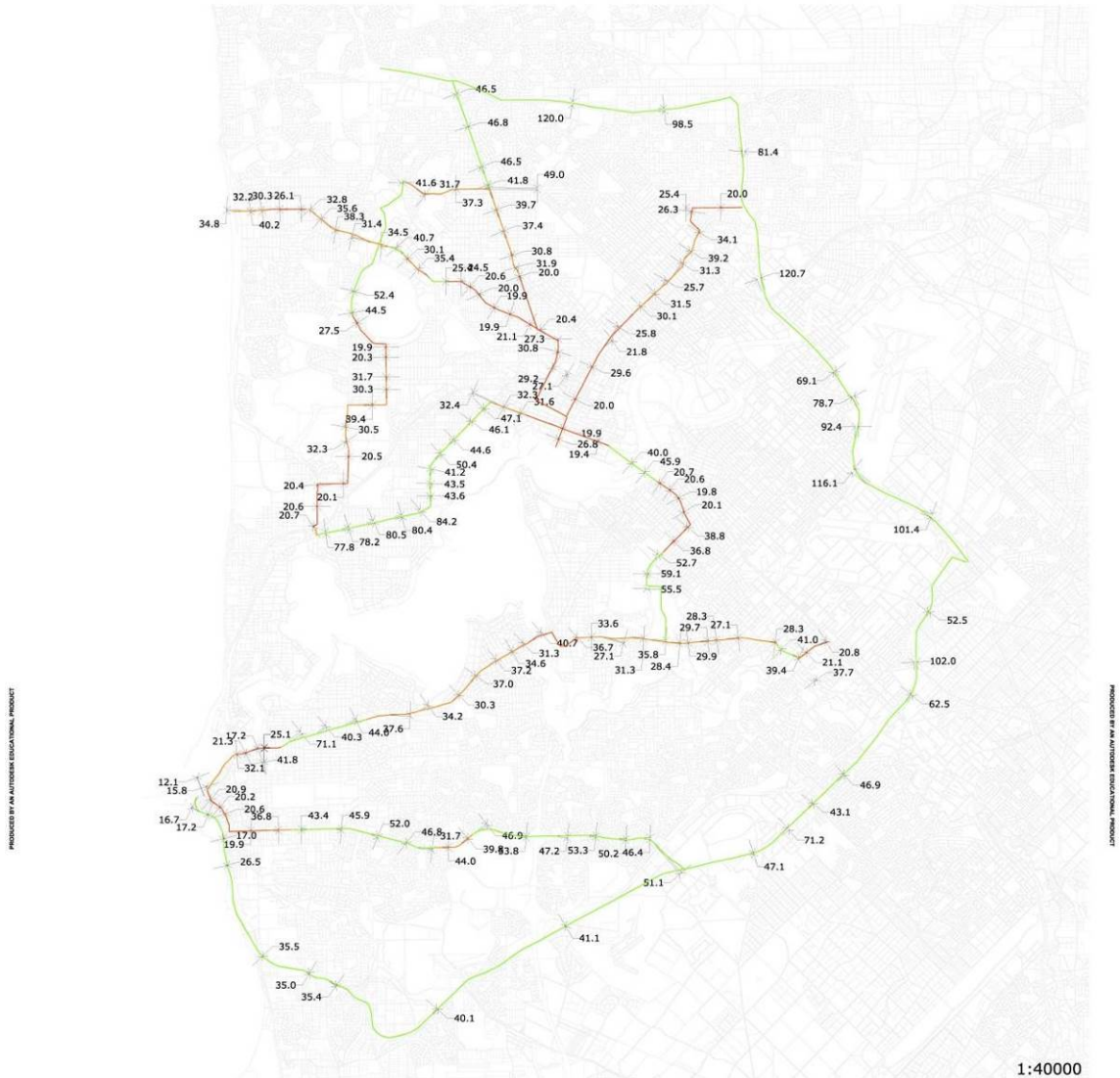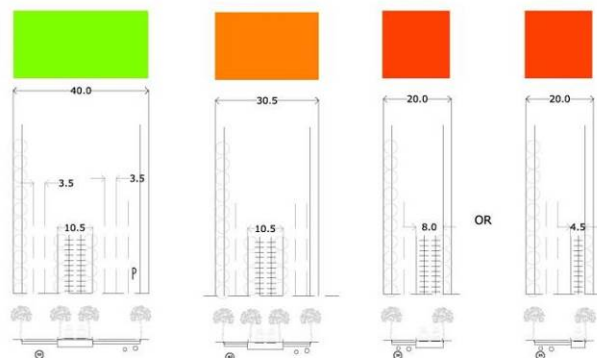
Figure 49 Right of Way Dimensions and the LRT in the street

SOURCE: AUTHOR, 2012. POTENTIAL RAIL RIGHT-OF WAYS IN THE PERTH REGION

Step 3: The third step was to see how large areas across the region were already zoned for use (see below) and for density according to 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.
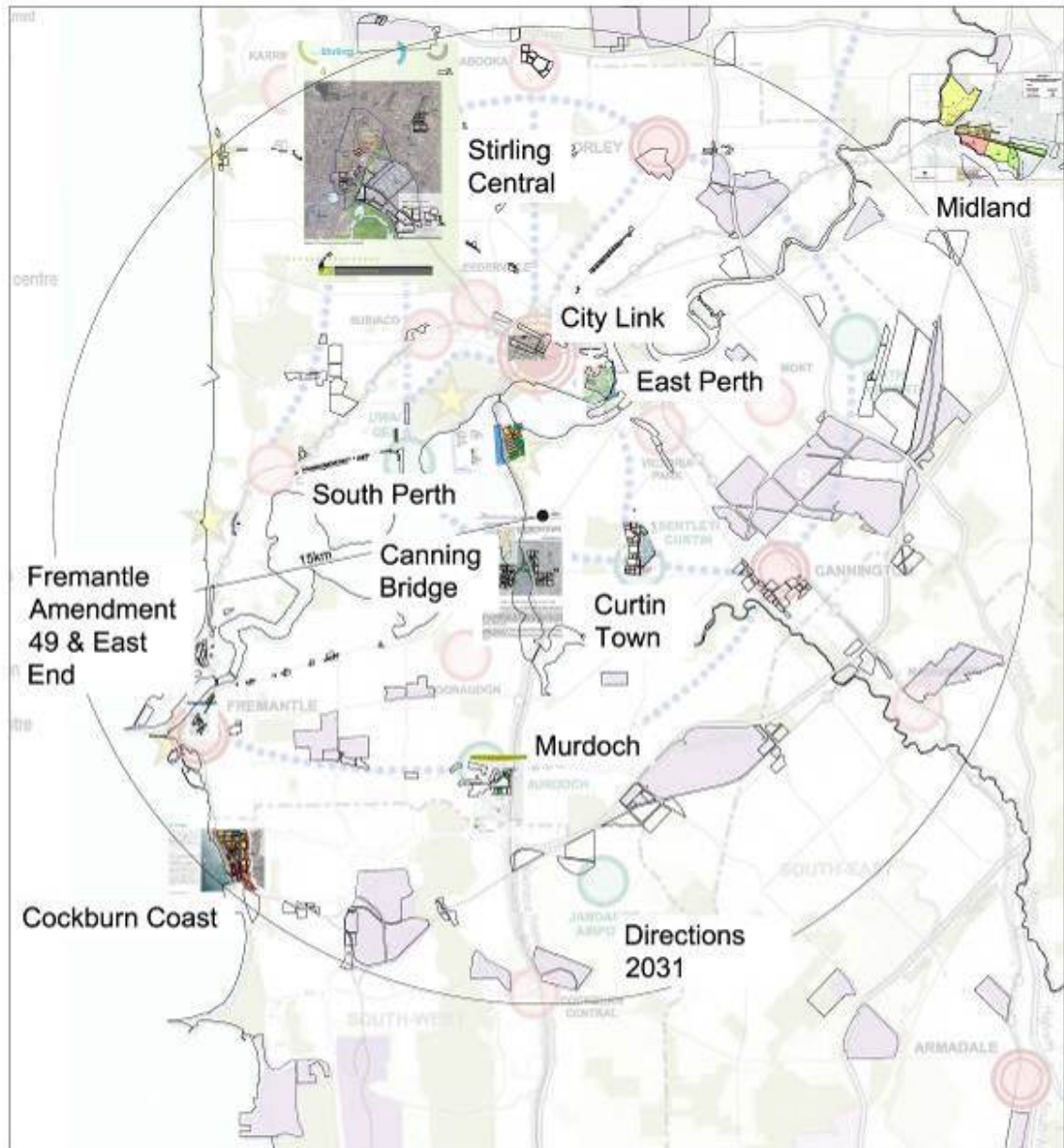
Figure 50 Planned areas of expansion

SOURCE: AUTHOR, 2012. LAND USE PLANS OVERLAY OF THE PERTH REGION

METROPOLITAN REGION SCHEME
PERTH WESTERN AUSTRALIA

Legend
Medium Density
Mixed Use
Commercial
Industrial
Low Density
Public Service
Urban Deferred
Parks
Rural
Water
Water Resource
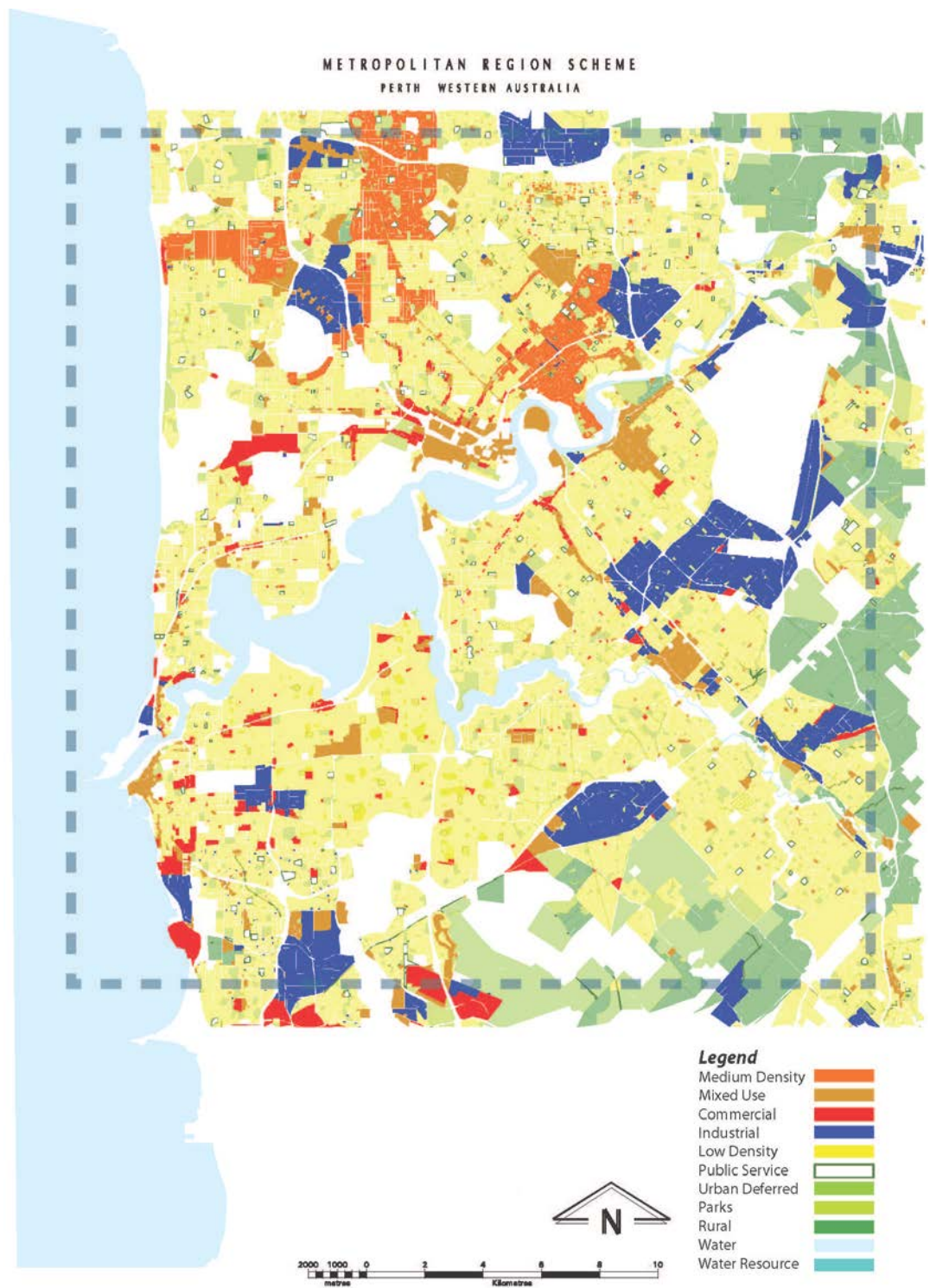
Figure 51 Local Planning Scheme

SOURCE: AUTHOR, 2012. FROM WAPC FILES.

Metropolitan Perth R-Codes

Figure 52 Residential Codes (R-Codes)

SOURCE: AUTHOR, 2012. FROM WAPC FILES. DARKEST AREAS ARE MOST LIKELY TO SUPPORT DENSITY AND MIXED USE

Step 4: There was lastly an 'objectively subjective' process to look for brownfield (ex-industry), urban-decayed (car yards), under-used (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 below). All these sites, as traced, were given a potential station location within their bounds, a name and a place on a list re-developable areas 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, station precinct and transit line to come to the totals presented in the results.

Table 7 List of available land types for urban infill

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 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 for 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.

METROPOLITAN REGION SCHEME
PERTH WESTERN AUSTRALIA

Current Passenger Rail
Future Heavy Passenger Rail
Future Light Passenger Rail

Legend
Medium Density
Mixed Use
Commercial
Industrial
Low Density
Public Service
Urban Deferred
Parks
Rural
Water
Water Resource

N

2000 1000 0   2   4   6   8   10
metres   Kilometres
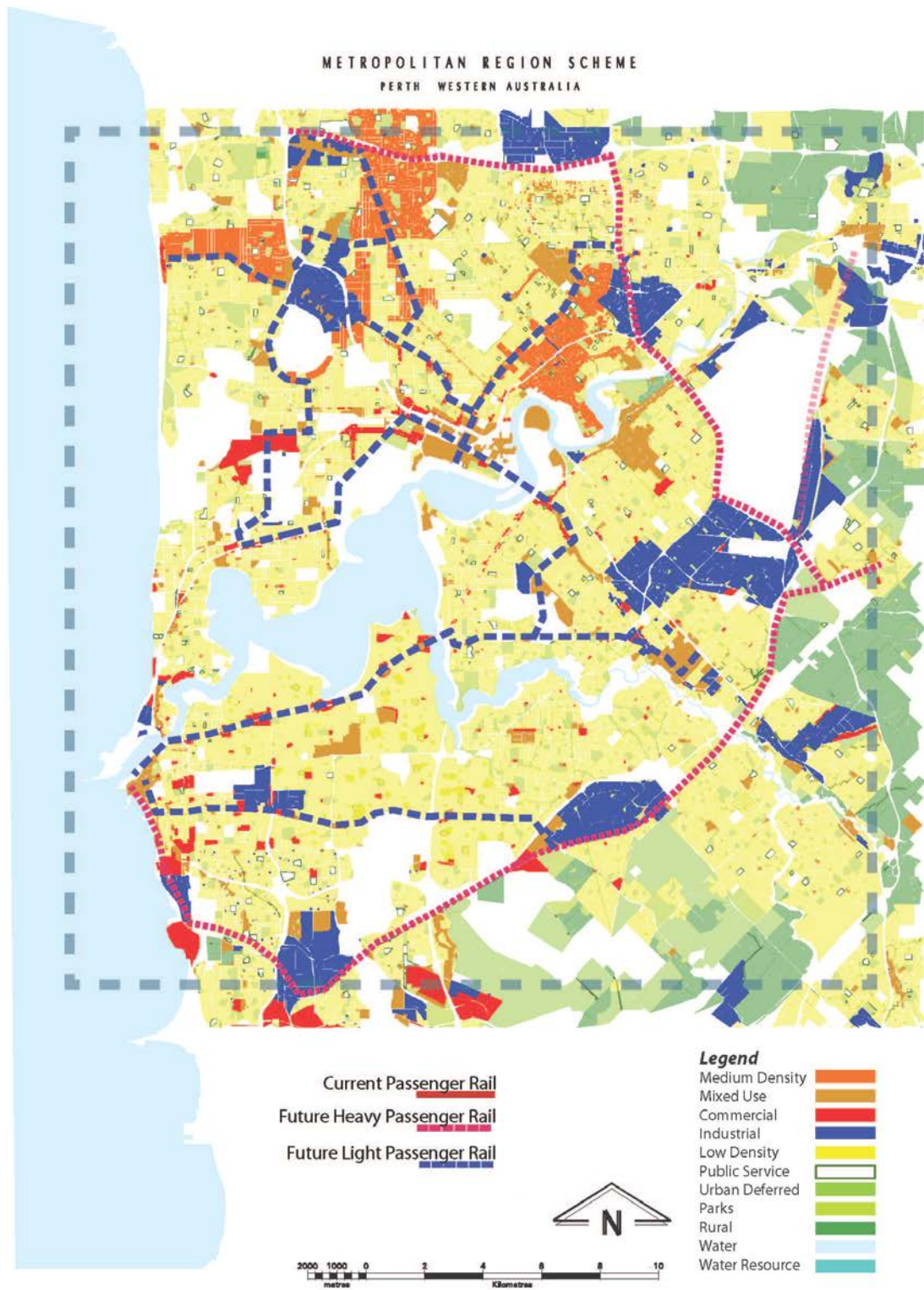
Figure 53 Current zoning and land optimal rail routes to leverage latent opportunity

Metropolitan Perth R-Codes

Future Heavy Passenger Rail

Future Light Passenger Rail

R80	R20
R40	R10
R30	R5
R25	R2.5
	Unnamed
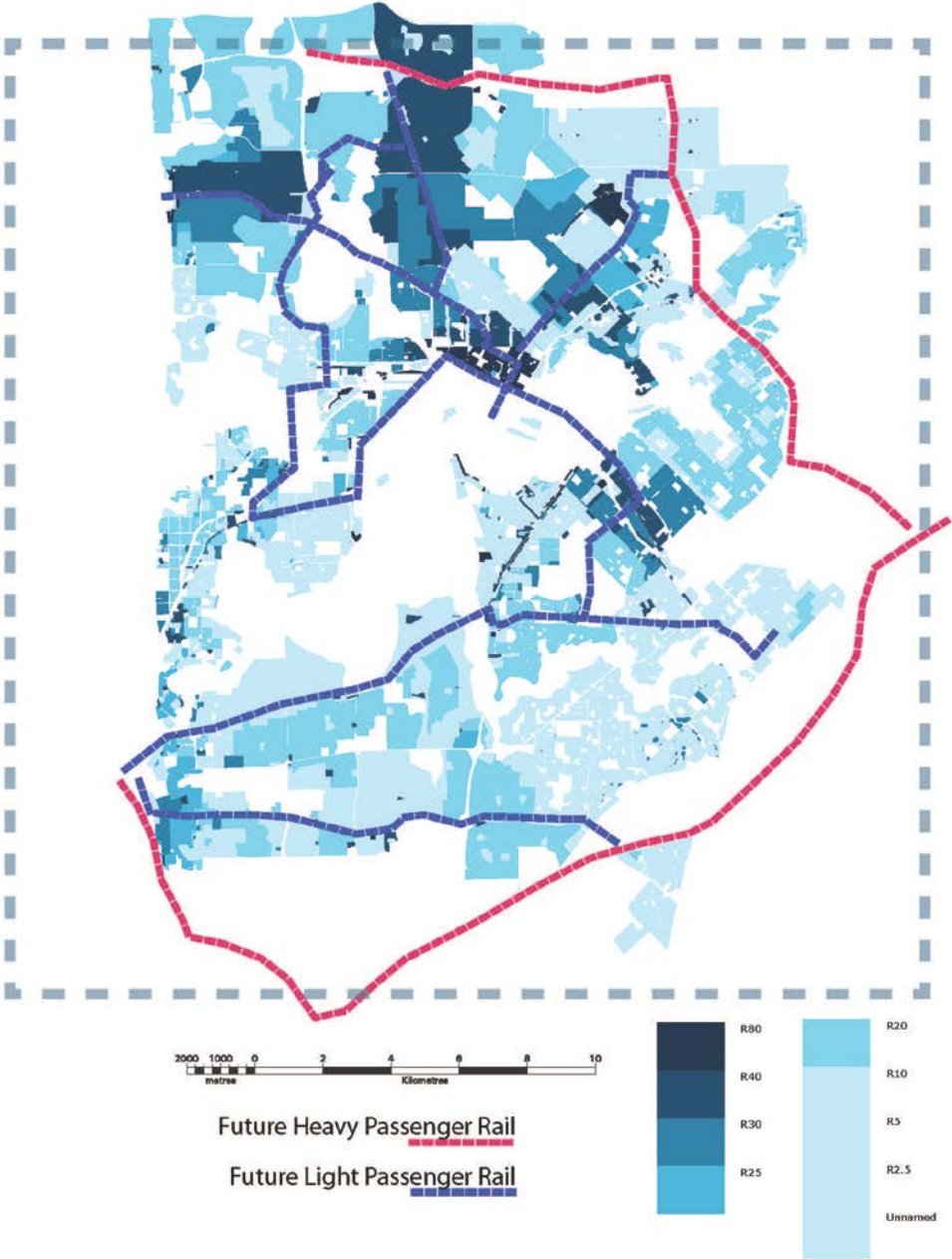
Figure 54 R-Codes and land optimal rail routes to leverage latent opportunity

Step 5: The land, which was both close to rail current or future and likely to be redeveloped, was measured to the nearest square metre, 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.

Note on Land capacity, 2D Space

At each potential station there is a land surface, this is the 2D space. This is not the absolute space at each station; otherwise they would all be roughly the same measuring the area of the 400 metre radius circular ped-shed. Were this a 'tabula rasa' approach such a motion towards complete restructuring would be appropriate. However, each station has characteristics, such as a slope, a historic building, highways, lot alignments, surface water and so forth which led the researcher to calculate the polygons of re-developable area at each station. An example from the Southern Circumferential Line (SCL) is shown below, with several stations having almost no re-urbanisation potential, such as Waterfront station in Fremantle, while others have large land potentials extending beyond the 400 metre radius, such as in Canning Vale.
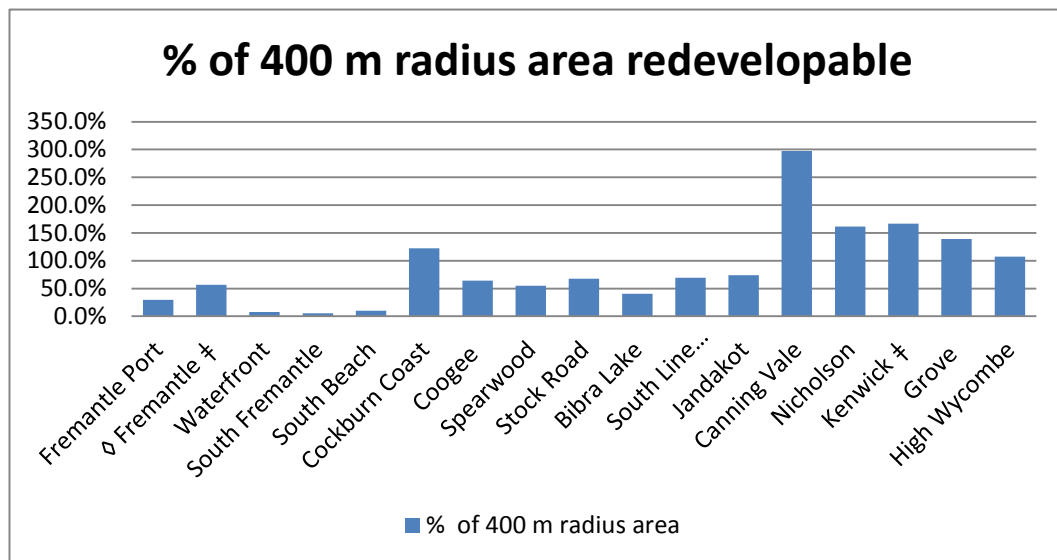
Figure 55 % of 400 m radius area developable

Note 1 Land Capacity, 2D space

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

Table 8 Maximum heights for rail transit serviced urban land redevelopments

- a station precinct site was less than 40,000 m^2 in size, or 4 hectares, the maximum height allowed on that size was 5 storeys;

- for building sites over 40,000 m^2 but less than 100,000 m^2 the maximum height was set at 6 storeys and

- a station precinct's redevelopable area over 100,000 m^2 was permitted a maximum of 10 storeys.

In this step an 'IF' proposition was created in the spreadsheet stating that IF a parcel of land was below a certain threshold of size, constrained due to an environmental or cultural/heritage factor, then there would be a height limit (of 4 storeys) on this site. This would thereby respond to, though perhaps not satisfy, communities' concerns for overbearing, out-of-scale building heights. Likewise, if a site of potential redevelopment is very large a collection of taller buildings (with a maximum of 10 storeys) with appropriate setbacks and public open space would not overburden the site.

If there was only a small area available, it suggests 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 may still contribute to the regional growth but stay proportional to their extant urban form.

Note on Density, 3D space

Density and high towers *per se* are not the explicit goal in this research. The target is to achieve a balance of amenities for an optimum amount of people on infill transit-oriented lands across a metropolitan region with little to no outward automobile-dependent low-density sprawl. This will, ideally, illustrate the opportunity and the scale of the challenges ahead of all cities.   This process will demonstrate the reason to leave more land outside the city in a wilderness, rural or semi-rural state with the latent land inside the city being used for dignified housing, knowledge and service jobs, light industry and beneficial sports fields, urban agriculture and ecological reserves. While high density is not the aim, it is correct to assume that higher density, and better designed density, will be the result of this experiment. This research does not propose a status quo plus a little bit, but rather an achievable aspiration of higher density nodes strung like pearls on a necklace with multiple mutually beneficial outcomes. This density will consist of low townhouses with towers of discreet heights arranged around varying proportions of Public Open Space, Commercial and Retail (see definitions above).

Note 2 Density, 3D space

Step 7: A mixing of uses was aspired to with the remainder of the land. As widely agreed in current literature, and aspired to in current planning practice, to achieve higher-order sustainability a high-degree of mixed land uses are desirable. This brings more destinations closer to more people and shortens the trip to and from a destination. Ideally, more trips become a walk or bike trip within one's own neighbourhood which allows a higher population density, furthering the case for higher-order transit service provisions (see below) .

Table 9 Three Principal building types used in this paper

Types of building floor space 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, elevators, water and sewer service provisioning, parking requirements and traffic generation.

Note on Singular Land Use Types

As we look forward to a Transit-Oriented Region it is important to recognise that, overwhelmingly, the international discussion in the literature on this matter   calls for combinations of these aspects:

- higher mix of land uses
- 24 hour neighbourhoods
- walkability
- ecological responsibility
- green technology
- transit-oriention
- placemaking
- moderate to high density (35 to 300 persons per hectare)
- perceived density

To mix land uses, the next step was to divide the area into percentages ranging from mostly Residential to mostly Commercial but always with some portion of Retail and Public Open Space. These land uses are described below:

Residential	In this experiment it is assumed that the average Australian household is 2.5 persons and that the average Australian home is 250 square metres meaning each person uses, as a standard, 100 square metres for dwelling (eating, sleeping, entertaining) purposes. This makes an easier calculation when formulating achievable regional targets; it includes homes for singles, couples, elderly, itinerant backpackers, Fly In Fly Out workers, and all other forms of habitation. That 100 square metres is far in excess of the world's average is not debated here. Perceptions of requirements for living space are an ideal topic for research at a later date. (See Further Research at the end of this paper)
Commercial	Commercial is space intended primarily for production. This is in opposition to 'consumption' as one finds in Retail. Production includes other terms such as Light and Heavy Industrial, Institutional including universities, schools and hospitals, typical commercial such as professional offices and services.

Retail	Retail includes consumption activities such as clothing stores, grocery stores, eateries, pubs, equipment sales, rental agencies and others including large format 'big-box' shops in situations where they are willing to occupy a 'urban' site in the transit oriented neighbourhoods.
Public Open Space	Public Open Space includes sports fields, trails, ecological reserves, re-established ecosystems, space for urban agriculture and passive park space. These four land uses were arranged in different ways, see below, reflecting a range of residential, commercial, and retail mixes along with varying rates of Public Open Space allocation.

Note 3 Singular Land Uses

Table 10 Land use mix by development types

Name	Residential	Commercial	Retail	1.00 (Check)
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

For examples, a redevelopment site found appropriate to be Residential would comprise, mostly, 90% housing with only 10% devoted to small-scale retail such as grocery store, corner stores, laundry, café, bar and so forth. Residential +Mixed would have less residential and 15% commercial /institutional space, within its overall 3 dimensional area, such as offices for dentists, doctors, accountants and/or institutions such as health care centres, recreation centres, schools. This mix of land use is for the remaining percentage after 25% of all land uses were set aside for Right-of-Ways and Public Open Space as per Step 5, above.

Land uses then can be further allocated according to the physical context of each site. For example, if the site is largely deeply situated in a residential area then a relatively small mix of commercial and retail is appropriate to meet the needs of the immediate project and serve the surrounding neighbourhoods. It is important not to allow too much commercial or retail activity deep in a residential area. There are many examples where excess commercial space, wrongly distributed, can actually weaken a neighbourhood as can too much, or too little, retail.

For the purposes of this model, Institutional and Light Industrial will be included in Commercial as a land use type due to the similarity in floor-plate sizing, parking, access and egress standards.

See Methods below for "Table 8 Land use mix by development types" page 249 for a breakdown on the Mix-use Types developed and employed.

Note 4 Mixed Land Uses

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 one person per 50 m^2 for residential (ABS, 2012c), 25 m^2 for retail, or 20 m^2 for commercial space (Hillier, 2001; Western Australia Department of Commerce, 2012). The numbers for retail and commercial were averaged upwards to 40 m^2 and 50 m^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 calculating the benefits and costs that may be accrued over the next 50 years.

Step 9: Traffic and parking rates were derived from the Roads and Traffic Authority of New South Wales multiplied against per metre or 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 0.9 parking stalls, each commercial 100 m^2 was to produce 10 trips per day and have 2.5 parking stalls per unit while retail units of 100 m^2 were expected to produce 50 trips per day with 5.1 parking places per unit (RTA, 2002 p. 3-3, 5-4).

COST AVOIDED

Step 10: The total Cost Avoided was calculated by multiplying 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)by the figures for costs avoided per dwelling provided by Trubka ($378,553) (Trubka et al., 2009). (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 56 Table of Costs Avoided in Trubka et al.

Source: (Trubka et al., 2009)

The dwellings numbers were calculated after a lot by lot search for space in new and current rail station precincts along the proposed and current rail transit lines. The dwelling numbers are the result of dividing the net land available into land use types which best suit its context (Table 7 p.246) and multiplying by the maximum number of floors (Table 5 p.239).

Trubka 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 made by making the infrastructure already in place work harder to support the increase in population.[31,32]

VALUE CAPTURE

Step 11: With the next generation of transport projects, cities will require land to be zoned and parking to be reduced to take best advantage of the demographic changes. The real estate market needs to function freely but with a series of simple to implement and 'nothing hidden' charges to help pay down the expense of the public transport 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 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 are derived from several possible funding streams. Many of these streams exist already (MRIF, land tax, parking levy as identified by McIntosh 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 existing properties the Value Capture fund could be even larger. The numbers are conservative as they only take account of development occurring in up-zoned land adjacent to rail transit. None of these funds will begin to deliver the estimated result until the land is rezoned, the real-estate market takes up the opportunities and the units are under construction.

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[31] The current capacity of the underground services is upgraded on a regular half to full century schedule.
[32] 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, refer to the papers cited in the Bibliography.

Method to establish Value Capture potential:

- Using the same dwelling numbers as 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 precincts and multiplied by a 10% 'rate', tax, applied to the increase in the properties values: (520,645 X $500,000 X 0.1 X 0.1). This equals 1% of the dwelling units' value being applied towards a Value Capture ring-fenced fund. If this were applied just once on each dwelling, at initial sale, 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 it applied as a special lower rate per year, 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 (Realcommercial.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 driving demand. It is calculated on 250 working days per year. This number does not reflect existing parking and could therefore produce a greatly increased 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. To repeat, it is preferred this volume of parking is not built.

- A \$5 per day charge on all new <u>retail</u> parking spaces could raise \$297 million <u>per year</u>. Pricing parking reduces 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. Again, it is preferred this volume of parking is not built.

- 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. These dollars are not available unless the land is rezoned and the transit service genuinely desired enough to be considered a part of the house / job location's benefit.

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, perforce, need further modelling to consider the pace of development and the dampening effects further taxes might have on higher density housing.

CAPITAL COSTS

Step 12: Martin (2011) described the costs of constructing major transit projects in *Reviewing the last decade of public transport infrastructure projects in Australasia.* Building <u>heavy rail</u> 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) Interestingly, the Southern Rail in Perth cost $17 million/km to build.

Regarding 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.

FLOOR AREA RATIO

Step 13: Floor Area Ratio is the ratio between the gross area to be built on and 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.[33] 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.

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[33] 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/

To reprise the steps, the following table has been prepared:

Table 11 Steps to Model 2, reprised

Steps to Model 2		
	<u>What</u>	<u>Outcome</u>
Step 1	Current Plans for Land Development	Map what has already been planned for. Overlay all of these to begin to understand the pressures and also the alignments of plans.
Step 2	Preferred Rail Alignment	Map where various options for rail options lay.
Step 3	Current Zoning	Map the current zoning
Step 4	Places for Infill Development	Where are the additional easy wins for infill especially close to rail
Step 5	Gross and Net Developable land	Measure the optimal lands, remove RoW , setbacks and POS
Step 6	Building Heights	Apply a maximal height that is *politically* feasible in these locations
Step 7	Land Use mixes	What mix of uses balances homes, jobs, shops, POS is ideal for each site
Step 8	Person Activity	Calculate the numbers of people this should accommodate and offer jobs for
Step 9	Traffic	Calculate the number of trips this should produce. Also,

	Generation and Parking	calculate for awareness (preferably not applied) the 'standardised' parking numbers.
Step 10	Costs Avoided	Calculate the benefit to levels of government of not having to build new low density residential by reusing existing infrastructure
Step 11	Value Capture	Calculate an approximate benefit to levels of governments from a suite of passive and active value capture from rising land and property values
Step 12	Capital Costs	Calculate the approximate cost to build the rail or bus infrastructure
Step 13	Floor Area Ratio	To give a more accurate sense of the 'scale' of the redevelopment across the sites as a proxy for measuring 'change'.

4.2.1.3 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 this: 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[34]. These developments would occur only in the red polygons of Figure 46 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. This will form a Transit-Oriented Region.

4.2.1.4 LIMITATION

The inherent limitations to this model are manifold. First, it is speculative connoting a limitation on plausibility, especially that of the adoption of a long term funding commitment to railways over highways. Second, it is subject to many objective – positivist - measurements which may or may not be accurate, especially in regards to land area potential to be re-urbanised, parking reductions, height limits and so forth. Third, much of the outcomes are premised on the ability for any of it to be built by developers. Fourth, the outcomes of co-benefits are entirely premised on a very small slice of the available literature selected for its relevance to Perth, Australia.

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

4.2.2   THE REGIONAL SCALE: MODEL 2

A snapshot of model, from the spreadsheet, looks like this:
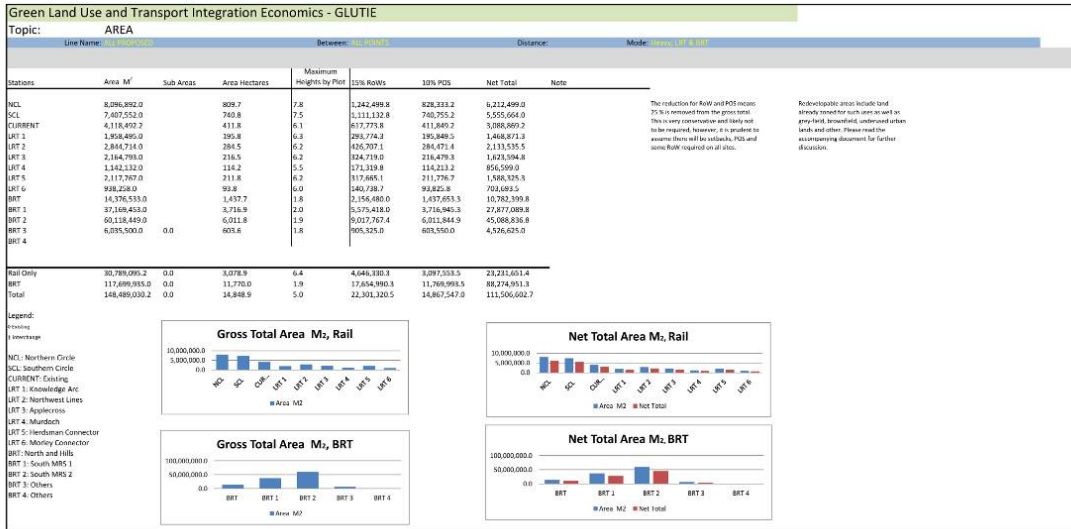
Figure 57 GLUTIE Model, Area.

SOURCE: AUTHOR, 2014. THIS IS THE FIRST OF THIRTEEN SHEETS.
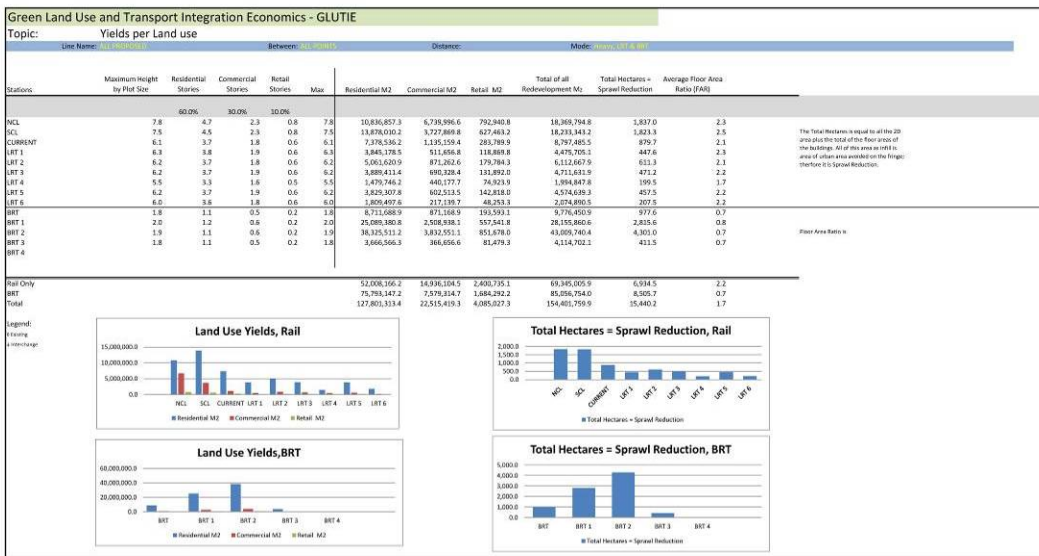
Figure 58 GLUTIE Model, Yields

SOURCE: AUTHOR, 2014. THIRD OF THIRTEEN SHEETS.
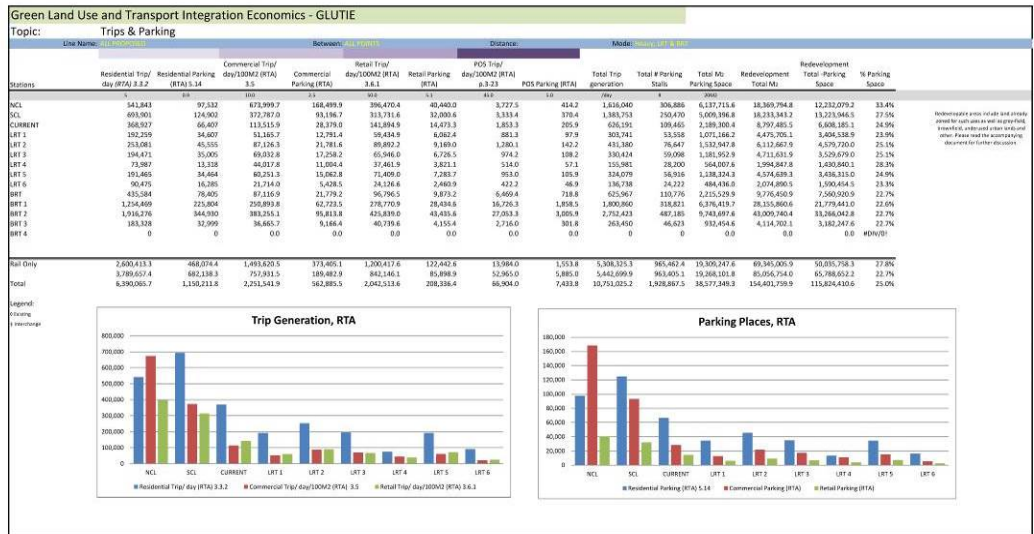
Figure 59 GLUTIE Model, Trips and Parking

SOURCE: AUTHOR, 2014. FIFTH OF THIRTEEN SHEETS.
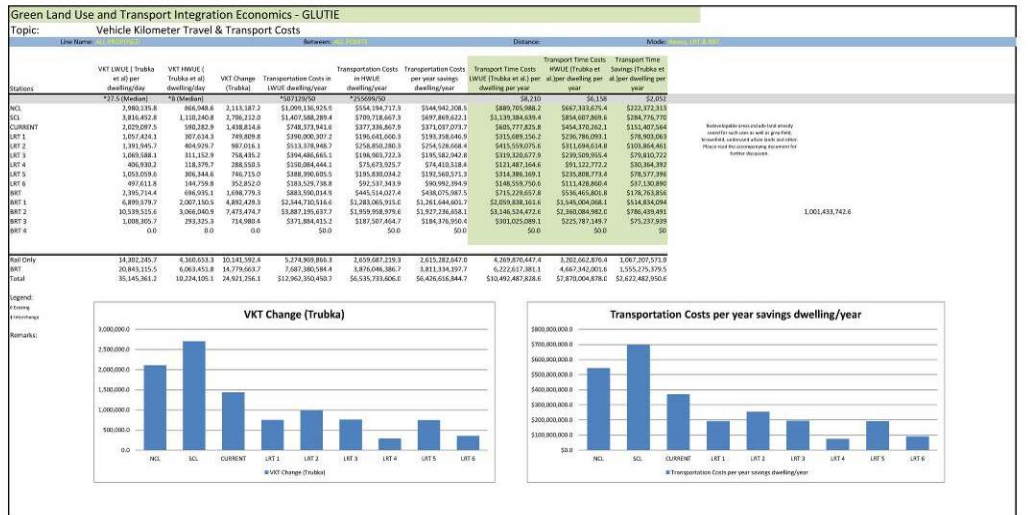
Figure 60 GLUTIE Model, VKT and Transport costs change

SOURCE: AUTHOR, 2014. ELEVENTH OF THIRTEEN SHEETS.

4.2.3 EQUATIONS TO THE REGIONAL SCALE: MODEL 2

4.2.3.1 THE TRANSIT ORIENTED REGION FORMULA

In urban design, programming is widely used to calculate sufficient capacity for the activities planned in a space. For example, bedrooms have a capacity for persons; the amenity is a bed and a closet. Dwellings have a capacity; the amenities are beds, washrooms, kitchens, cupboards, couches, and windows. Commercial buildings have a capacity; these are lifts, stairs, parking office space and adjacent public open space for lunch. Neighbourhoods have a capacity; the amenities they rely on are parks, shops, jobs, parking, transit, schools and libraries. Cities (urban systems) have a capacity; this is travel distance, travel time, jobs, dwellings, open space, public services including police, fire brigades, schools and water/sewer/power (underground) services. When any of these are deficient, none of these spaces can reach its potential. However, with proactive efforts any urban region may comfortably accommodate high numbers of people so long as amenities are provided. Amenity provision must accompany population growth, and amenities should be offered where the most number of people might access the services – this holds true for sewers, police, public transport, schools, parks and so on.

To properly understand the relationship between what is aspired to and what is required to achieve goals, it was necessary to create models to measure different aspects of a sustainable urban form and fabric.

C	C=Capacity of urban fabric to absorb increased population	G	GHG savings (tonnes of CO_2)
A	Area	Cs	Carbon sequestered equivalent
POS	Public Open Space	VC	Value captured from 1% stamp duty and parking charges ($)
A^1	Area minus POS; setbacks; right-of-ways for utilities, internal roads and surface parking	CA	Costs avoided from infill versus sprawl ($)
H^{123}	Maximum allowable height on an area due to precinct size	He	Health gains from walkable Environment ($)
M^{123456}	Possible ratios of mixed use	Pr	Productivity gains from walkable environment ($)
Y^{123}	Yield of real estate	VKTc	Vehicle Kilometres Travelled change
U^{123}	Units (residential or workspace)	TC	Transport cost savings
S^{123}	Size of units (residential or workspace) per person	M	Mode expected to be appropriate per precinct or corridor
R	Residents	PSP	Public service provisions (schools, libraries, recreation areas, hospital beds)
J^{12}	Jobs	L^{1234}	Length of mode line
Tr	Trips expected from units	Co	Cost to construct public transport line
Pk	Parking expected from units		

Expressed as equations, the model may be presented thus:

$$POS = A \times 0.1$$

$$C = (A - E) \times H^{123} M1^{123456}$$

$$C = Y^{123}$$

$$U^{123} = \frac{Y^{123}}{S^1}$$

$$R = \frac{U^1}{S^1}$$

$$J^{12} = \frac{U^{23}}{S^{23}}$$

$$U^{123} = G, Cs, VC, CA, He, Pr, VKT_{C,} TC, M, PSP$$

$$CO = L^{1234}$$

=Gross Land Available (gross)
=Net Land - (POS + Utility ROW + Setbacks)
8 =Permissible Height
70, 20, 10 = Mix of Use 2D - surface plane
70, 20, 10 = Mix of Use 3D - through mass
C = Capacity of the land
Pr = Capacity - Parking ratio

CHECK: Is Transport mode correct for transport task due to new trips from development?

Projected trip	Tr	20,000 per day
Mode capacity	M_c	10,000 per hour
hours of major transport task	H	10
% mode uptake	M	15%
$Capacity_c$ of land inverse of transport capacity	C_c	(Tr * M_c)*H* M = $Transport_c$

Y C_c * 24m(per car bay)=Yield increase

U Yield = Units [123]

Jobs, Resident Units = Jobs and Residents (24 hour activity)

People in high walkable re-urbanised environments =

- •-GHG Reduction
- •-VKT Reduction
- •+Health improvement
- •+ Infrastructure of opportunity
- •+Costs Avoided
- •+Value Captured

Figure 61 TOR Formula with hypothetical units

The relative 'transport orientation' of a region may be described by a formula such as this:

$$TOR = \frac{(\text{UF} \times \text{Y}) \times M_c}{UA}$$

Transit-Oriented Region = (Urban Fabric * Yield)* Mode Capacity/Overall Urban Area (km)

A more conceptual diagram of a TOR may look like this:
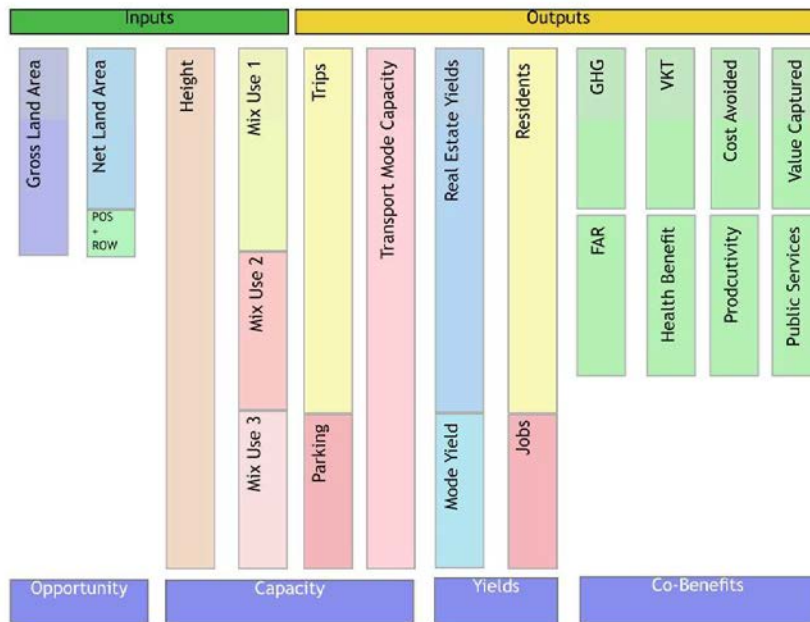
Figure 62 TOR Formula Conceptualised

4.2.4   RESULTS FROM THE REGIONAL SCALE: MODEL 2

4.2.4.1 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 metres (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 metres (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 metres (10 hectares). This will provide retail spaces for almost 80,000 workers, and commercial office space for over 400,000 workers while reducing 1,164,000 tonnes of GHG from transport-related activities per year, saving 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.

Table 12 Benefits of transit investments

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

- redevelopment of ideally suited sites to house the changing demographics,

- new housing providing for a lower carbon lifestyle, lower greenhouse gas emissions and lower Vehicle Kilometres Travelled,

- improved local air quality,

- providing for urban forms which are more conducive to walking and cycling,

- enabling the current infrastructure, already built, to provide more service,

- avoiding costs to households and state/local infrastructure costs,

- improved social amenities such as recreation, medical and educational facilities in close proximity to residents,

- protection and maintenance of ecosystem services at the urban fringe of farm and forest,

- value capture to pay down capital rail expenses,

- increased global competitiveness,

- incentives to build less single occupant vehicle infrastructure, and

- participation in the growing, globally significant shift from car-based cities to a more rail-based future.

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

The total number of residents and jobs attracted to these rail-based locations can absorb around 30 years of Perth's present expected growth without another car-dependent house or job 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 rates).

The costs of construction for the rail systems that would catalyse these changed urban development patterns have been estimated 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, is 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, which 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 when redevelopment of middle and inner city locations occurs 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.

4.2.4.2 OUTCOMES OF ALL PROPOSED TRANSIT IMPROVEMENTS

This section will make a very large assumption – 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. See 5.2 above for a list of all the types of redevelopment places.

For a plan map of all the redevelopment areas, in red, along the current and proposed rail lines, see below.
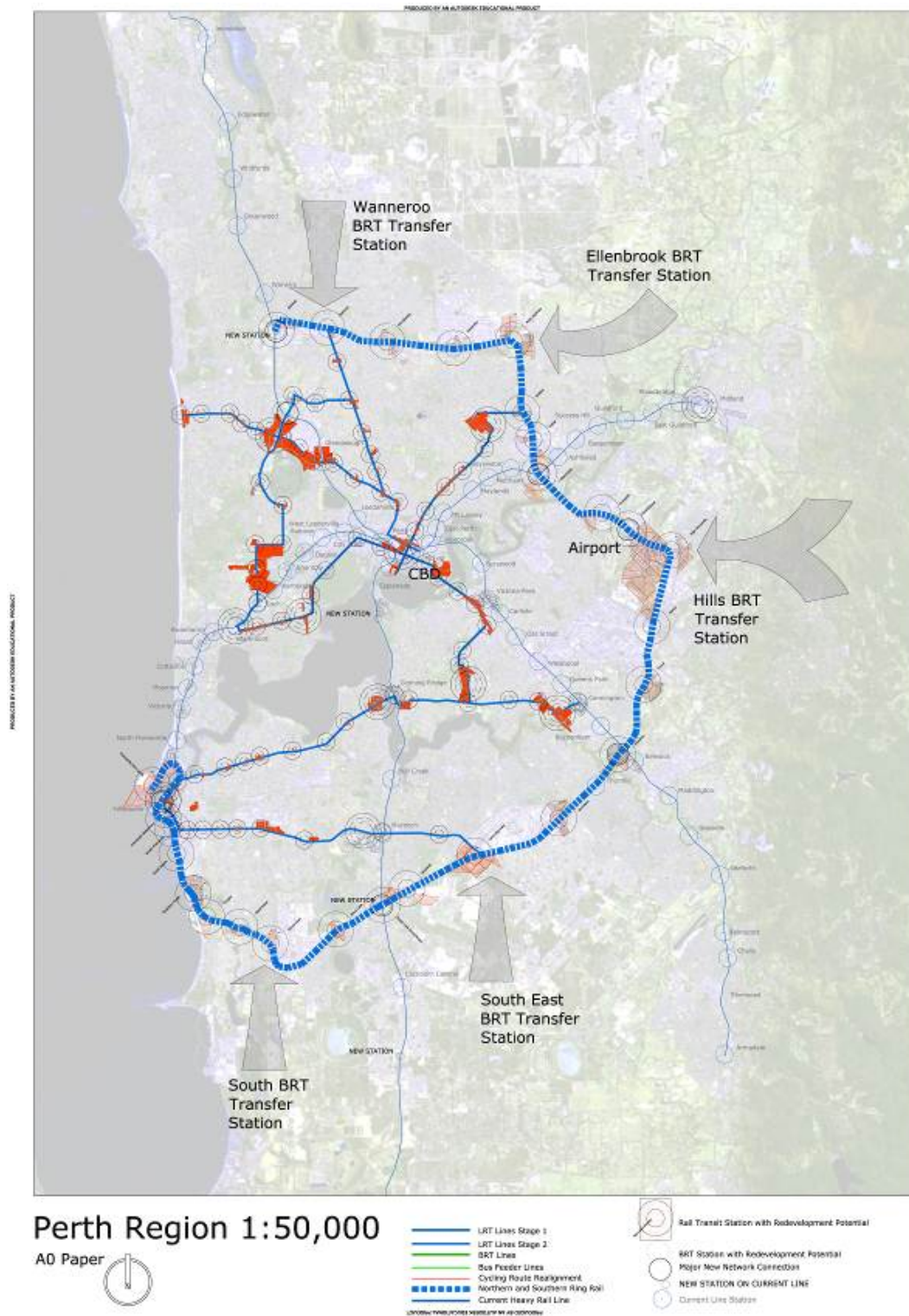
Figure 63 LRT network (solid blue) with SCL, NCL (dashed blue) with existing lines in light blue. Development pods are in red.

Figure 64 BRT lines in green and Heavy Rail line in dashed blue

TRANSPORT AND LAND USE CHARACTERISTICS

The proposed transport and land use surrounding the new train stations of this network will make 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 of extending the reach of the rail system will be to make the car a less than optimal transport mode, which has multiple flow-on effects including reduction in GHG and VKT, and better health outcomes, while creating walkable compact and complete communities.

TOTAL AREA BY MODES OF TRANSIT AND SEPARATE LINES

The total net area, in the red columns, represents 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 and so forth. The gross area is represented by the blue columns. Two notable things are present 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 land for the LRT lines must be selected from land to be redeveloped inside the exiting urban fabric; and two, there are large increases in land available along the BRT lines due to the potential for amalgamation of large areas 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 hectares for developing walkable transit-served communities.

Net Total Area M$_2$, Rail
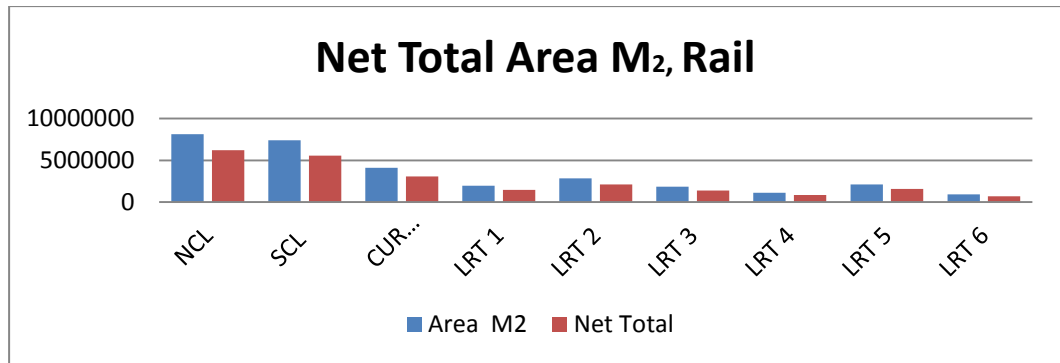
Figure 65 Developable land across the Perth region near future transport lines

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.
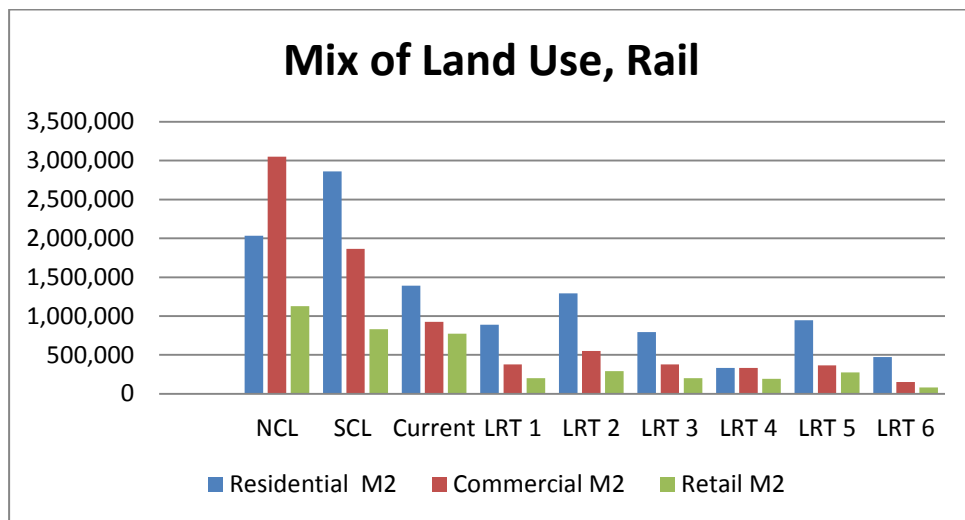
Mix of Land Use, Rail

Figure 66 Mix of Land Use

LAND USE 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 heights 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.

Land Use Yields, Rail
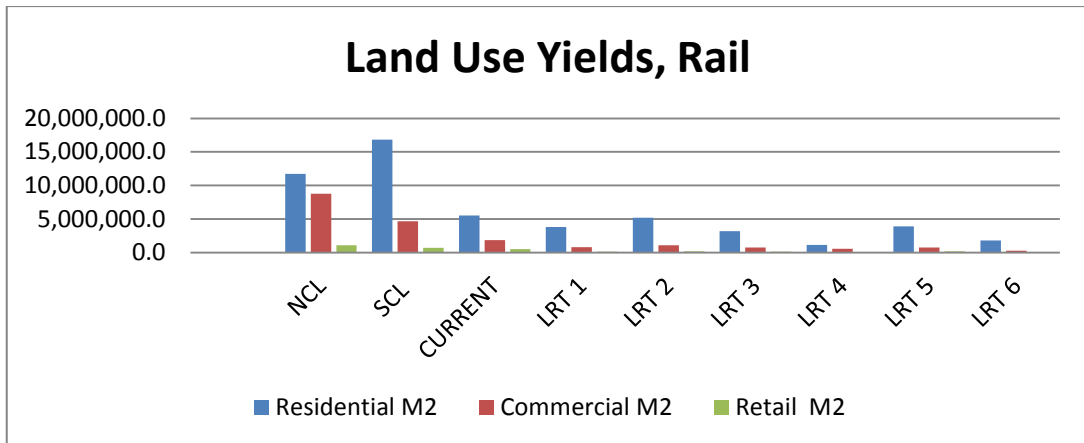
Figure 67 Land Use Yields

PERSON ACTIVITY BY MODES AND LINES

The NCL is envisaged to be 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 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 third of the population may 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, are 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.
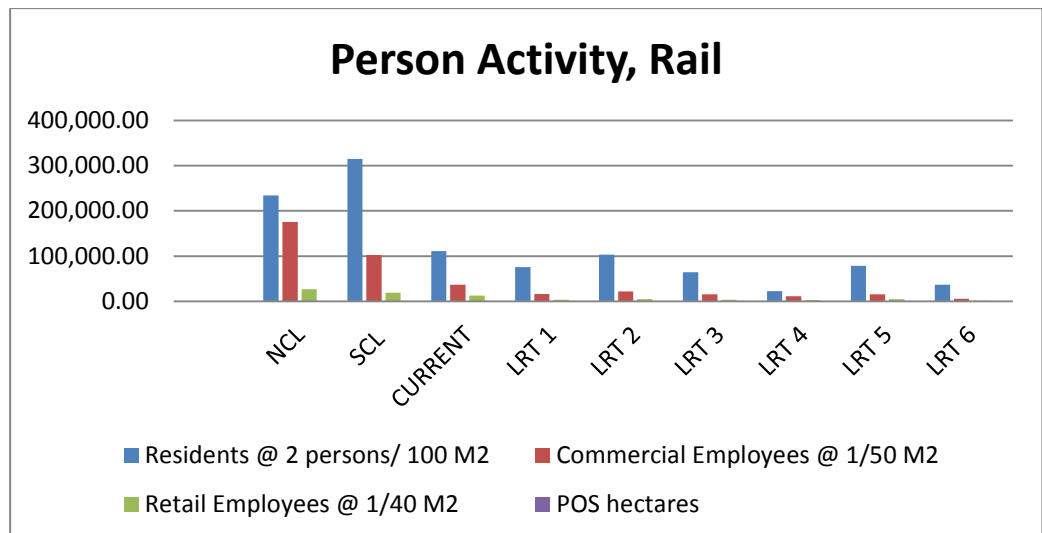
Figure 68 Numbers of person activity

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 many trips 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 have to devote in the order of 34 % of all space to parking the car. In straight numbers the area required would be 25,717,876 m^2 which is much more than the original amount set aside, 4,596,622 m^2 for Right of Ways from the gross land area. At 34% this will lead to unabated induced driving with consequences for transit use, walking rates and the ability to effectively and affordably redevelop many of these areas as envisaged.

Trip Generation, RTA

Residential Trip/ day (RTA) 3.3.2   Commercial Trip/ day/100M2 (RTA) 3.5
Retail Trip/ day/100M2 (RTA) 3.6.1

Parking Places, RTA

Residential Parking (RTA) 5.14   Commercial Parking (RTA)   Retail Parking (RTA)
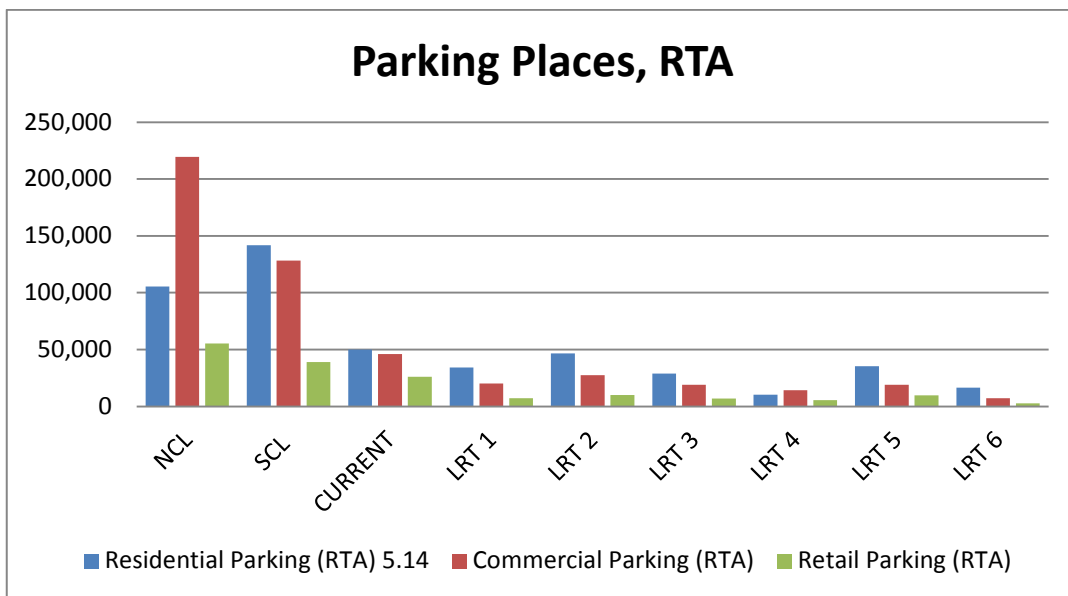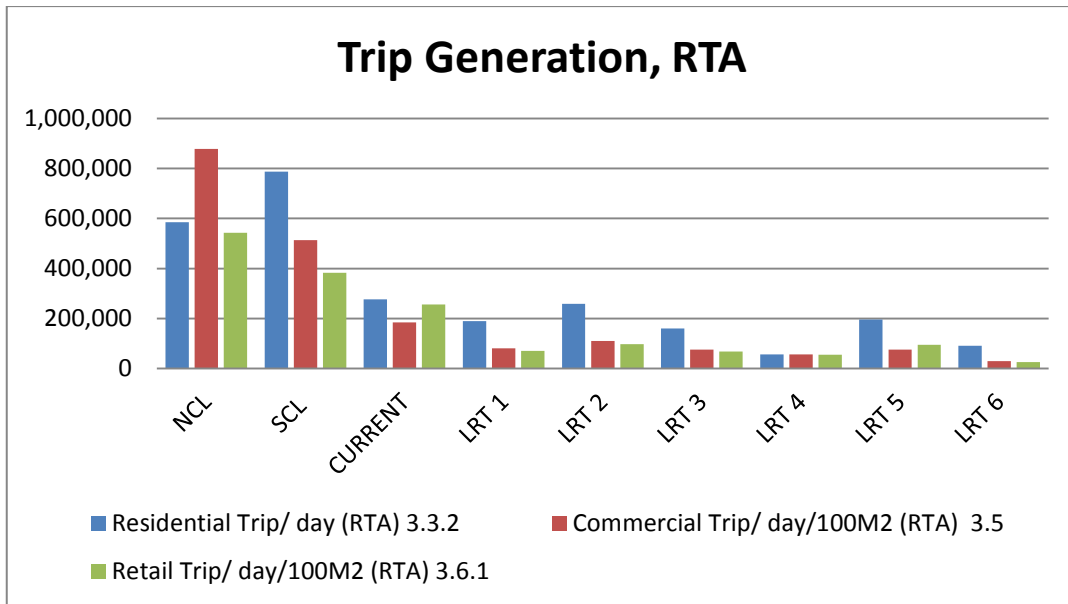
Figure 69 Trip generation and parking numbers

YEARS OF HOUSING SUPPLY

The entire proposed 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 (Table 5 List of available land types for urban infill) 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 would be to a maximum 10 storey height, but only in precincts which can accommodate that height (Table 6 Maximum heights for rail transit serviced urban land redevelopments). The average Floor Area Ratio for rail-based transit-oriented precincts is 2.3.
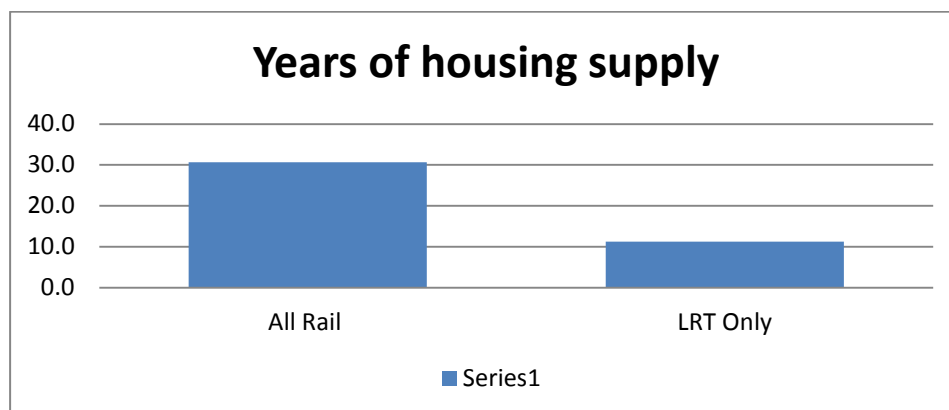
Figure 70 Years of Housing Supply on all rail and BRT land redevelopment

The policy on new residential developments in Directions 2031 states that 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[35].

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[35] 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 up-scale Western Suburbs) which may not be seen in today's urban fabric as opportunities but are very fixed in their current use. Perth, Fremantle and every city that has existed have flourished by an ever-changing evolution of lands from one use to the next.

Percentage of Targeted Infill
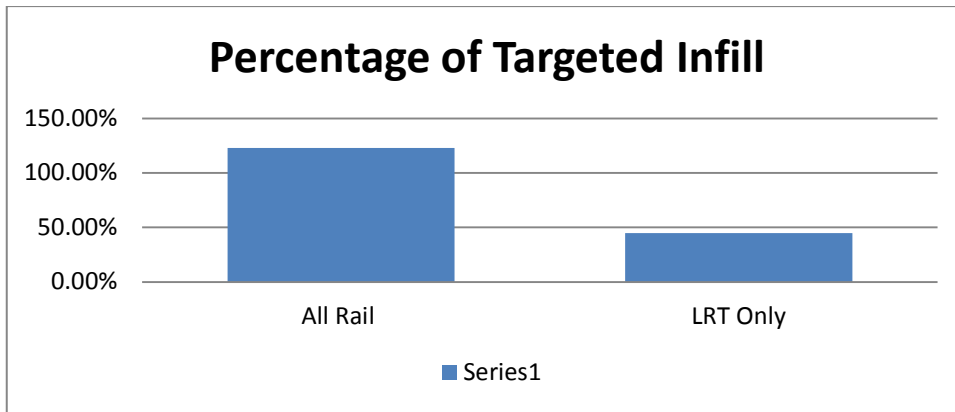
Figure 71 Percentage of targeted infill (Directions 2031) achieved

GREENFIELD AREA SAVED, SPRAWL REDUCED

The total floor area of built form, with POS and Infrastructure already left to the side in each station precinct, is equal to 7,591 hectares 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).

Total Hectares = Sprawl Reduction, Rail
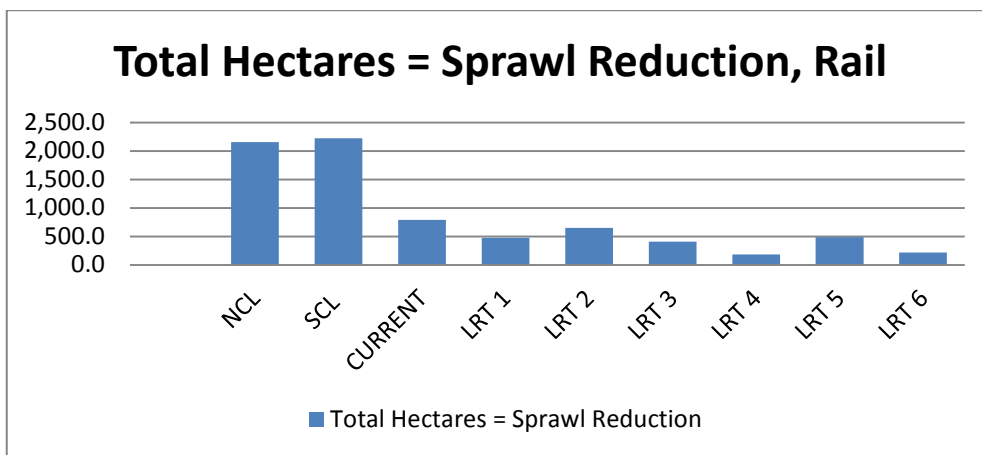
Figure 72 Sprawl Reduction from a region of transit-served communities

INFRASTRUCTURE COSTS AND COSTS AVOIDED

The total cost savings accrued from tying into and upgrading existing infrastructure as opposed to building new sewers, water and electricity infrastructure 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 costs are eventually passed onto new homeowners, the $50 million can be seen as making housing more affordable and increasing homeownership or as money to be reinjected into the local economy by residents.

The total cost avoided could be in the order of $9 billion dollars. This will be $9 billion in costs avoided from transport, health services, greenhouse gas reduction and infrastructure including schools, hospitals, fire stations and police services (Trubka et al., 2009) 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.
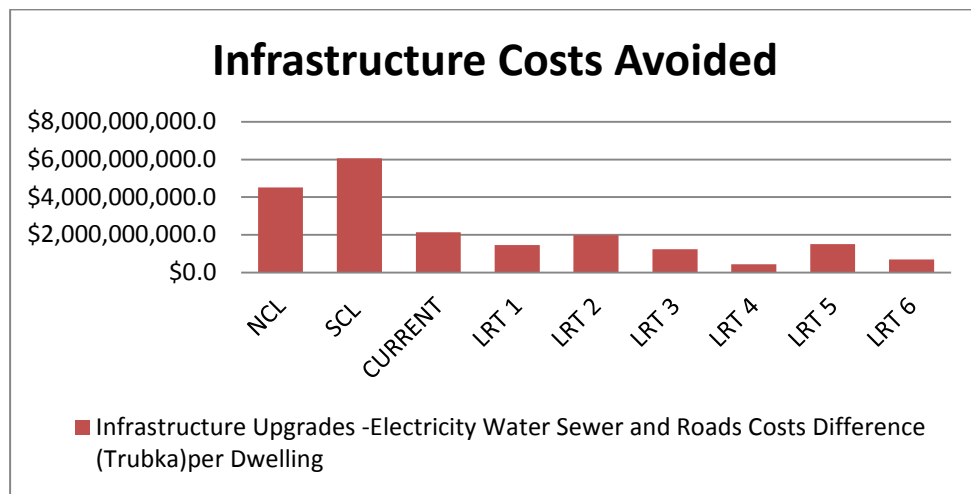
Figure 73 Dollar value of infrastructure costs avoided over 50 years

Total Cost Avoided (Trubka et al) per dwelling/year (over 50 years)
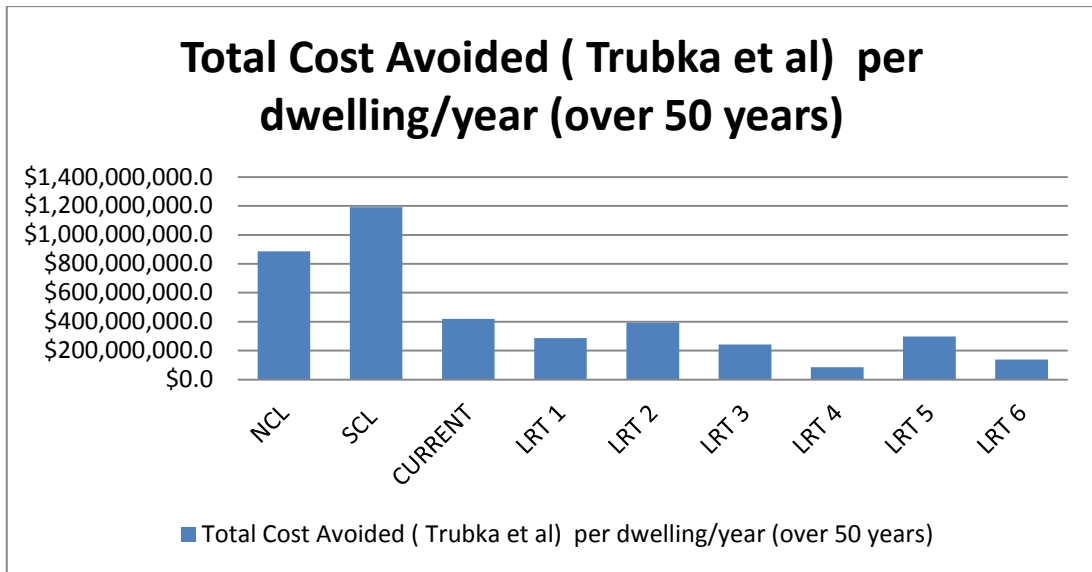
Figure 74 Total costs avoided per year

TRANSPORT COSTS

To break down the total costs into transport costs alone the first chart looks at Vehicle Kilometres Travelled per person aggregated across all precincts along a transit line. From rail-accessed transit-line redevelopment 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.
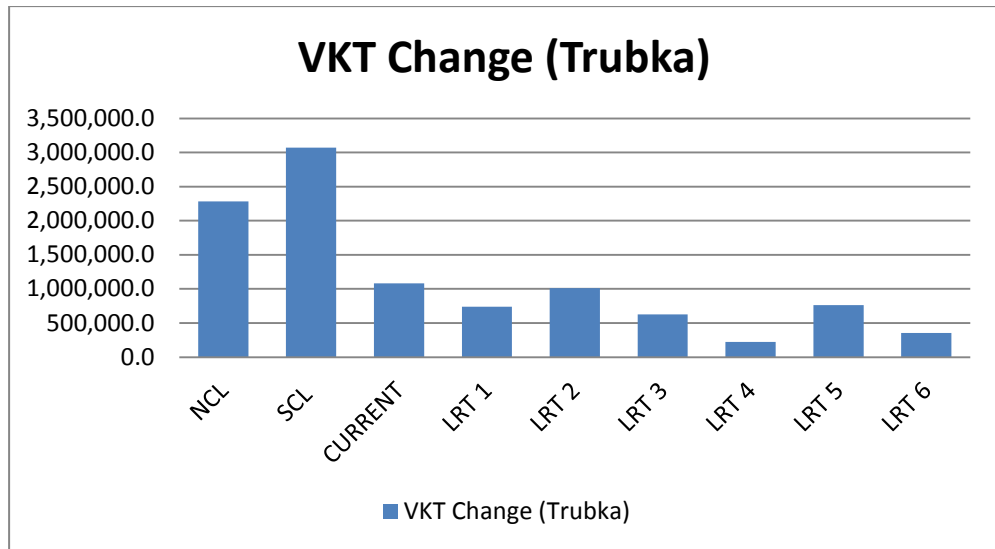
Figure 75 Vehicle Kilometres Travelled change

For example, along the NCL, we can expect over two million fewer kilometres of vehicle travel from the total residents and jobs *per day* due to persons living in high versus low walkable neighbourhoods.
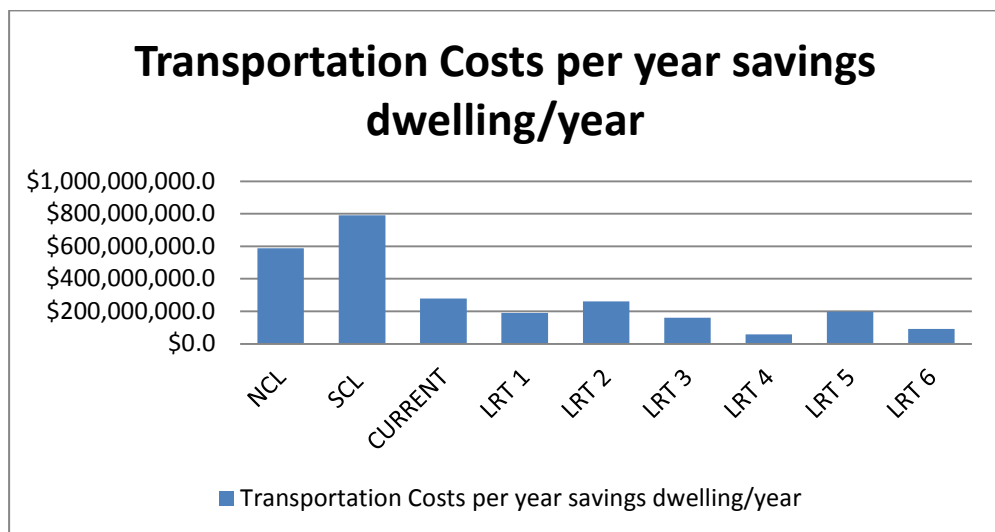
Figure 76 Transportation Costs across Perth Region

The lower chart shows the total costs saved by rail transit line. In total the costs saved from living close to rail transit-oriented developments are in the order of $2.6 billion *per year*.

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 saved. At a rate of $23 dollars per tonne from the Australian Clean Energy Future this equates to almost $22.62 million which could 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.

Transport related GhG Per Dwelling prevented in Tonnes per year
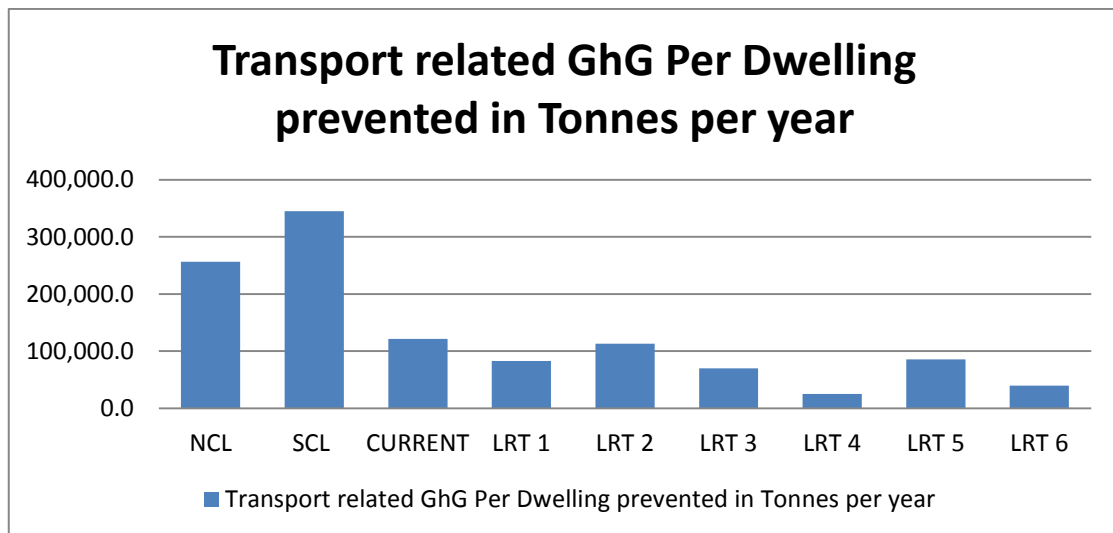
Figure 77 Greenhouse Gas reduction across Perth from TOD development

PHYSICAL ACTIVITY COSTS

It can be estimated that walking rates will increase to above BAU, but perhaps not reach historic pre-automobile levels of physical activity, by living closer to daily needs within walkable neighbourhoods and by walking to and from the transit stations at either

end of a work, school or shopping trip. For all the proposed transit lines across the Perth region the potential is in the order of 609,000 more kilometres walked per day by newly housed residents living in TODs. This is equal to walking only an extra 0.6 kilometres per person per day which is entirely reasonable. The calculated direct benefit to the healthcare system of this additional walking in compact transit-served environments is approximately $44 million *per year* as it delays the onset of obesity, diabetes and other illnesses related to inactivity.

The total benefit to the economy of having a much more active and healthy and therefore productive workforce living in walkable urban environments is in the order of $402 million dollars *per year*.
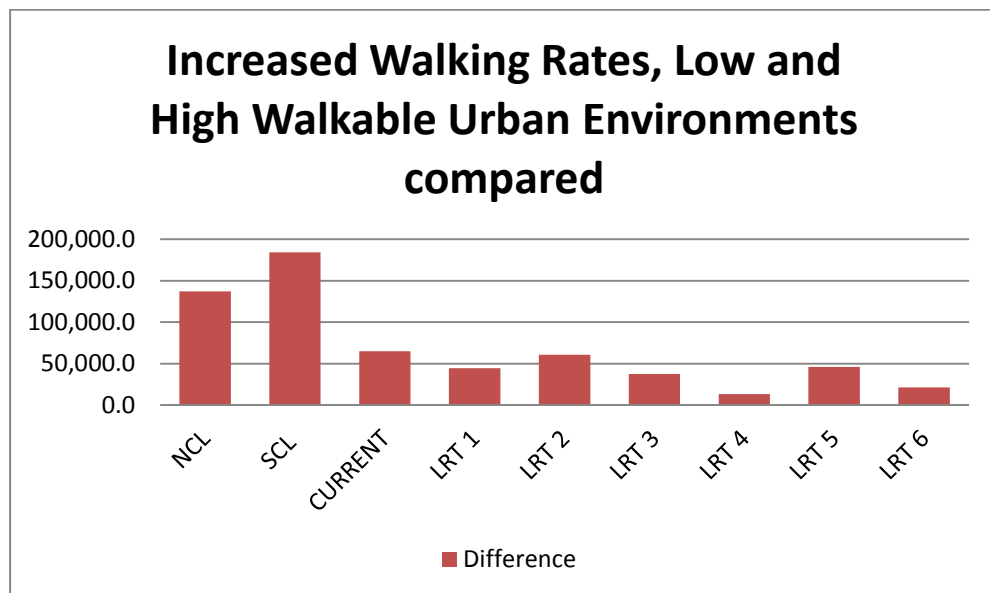
Figure 78 Daily Walking Rates in km per day

Health Care and Productivity dollar values, Low and High Walkable Urban Environments compared
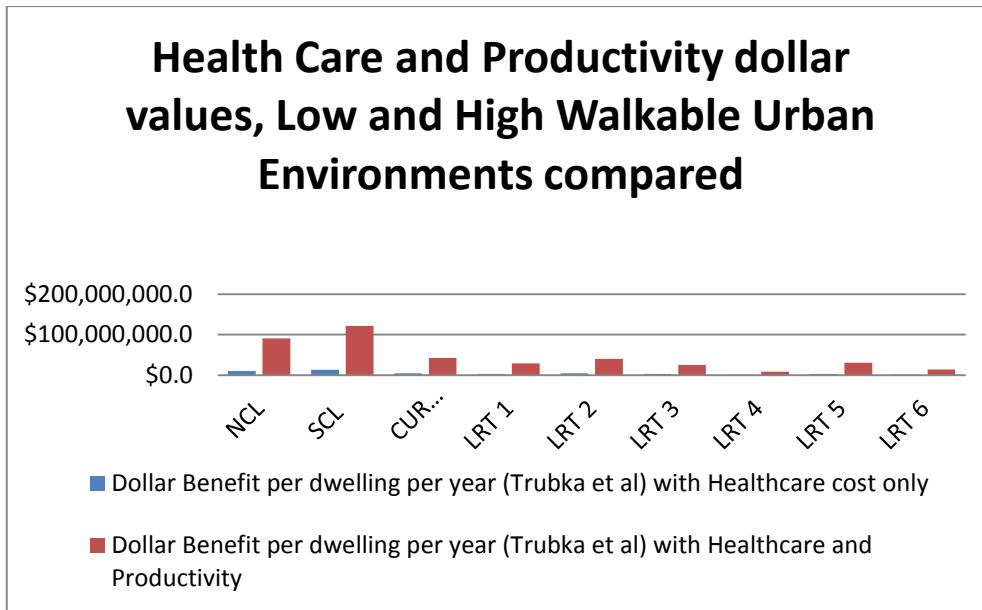
Figure 79 Healthcare and Productivity dollars

COST RATIOS FOR ALL MODES AND SCENARIOS CONSIDERED

The total cost of building all these transit lines will be a significant. dollar amount. However, if over $7.5 billion in Cost Avoided is compared with $4.4 billion to construct the same kilometres of rail transit (Martin, 2011 p.11) it does begin to make the overall case for rail transit. However, it does not consider maintenance and operational costs of the transit network which are ongoing, alongside the continued benefits of being a global city. The expected up-zoning along the transit lines into Transit-Oriented Developments becomes a sound, long range and visionary investment for governments to consider.

Cost Ratios

	Avoided & Captured	Capital Expense
■ Dollars	$7,630,919,894.1	$4,416,000,000.0
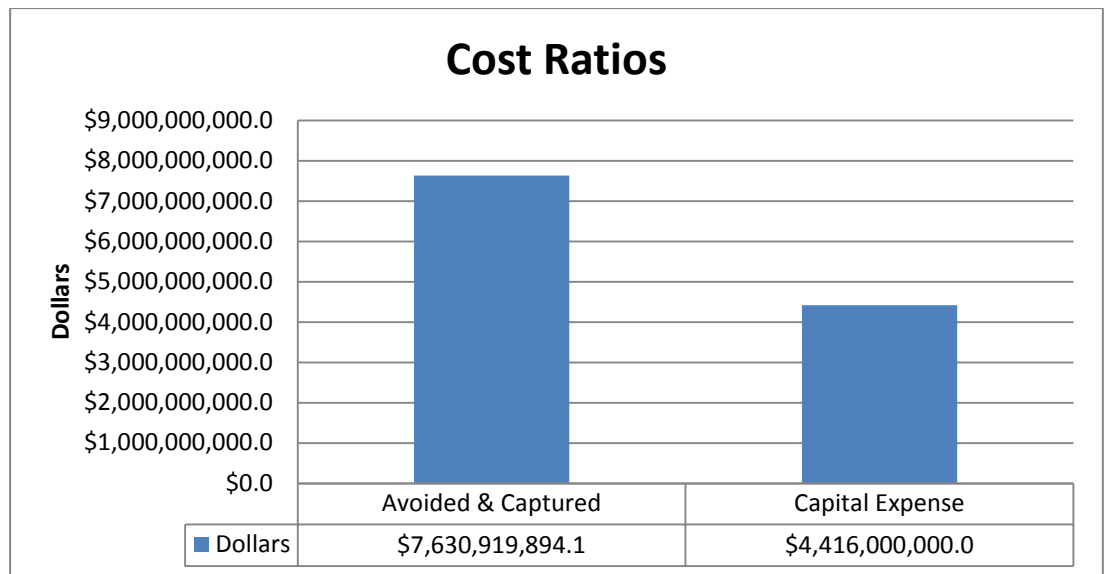
Figure 80 Costs avoided and Value Captured contrasted with Capital Expenses

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

4.2.5   CONCLUSION OF THE REGIONAL SCALE: MODEL 2

As Robert Cervero said, '… only through a full accounting and weighing of social costs and benefits' (Cervero, 2003) can we say that the cost of constructing 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 findings of Trubka et al. (Trubka et al., 2009) are applied to 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 up-zoning similar to the proposed scenario of this paper, then there is a strong case to be made for the rail and bus investments. Investments in the transport network will be for the next generation of residents, providing spaces to live, work, shop and play with a car-reduced lifestyle. This paper demonstrates the benefits 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 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 take a major step forward in achieving regional and national 21st century goals while remaining a competitive and liveable city.

4.2.6   GRAPHIC PLANS

To better understand the large scale opportunity, but also operation, a series of birds-eye and plan graphics were prepared. These are presented below.
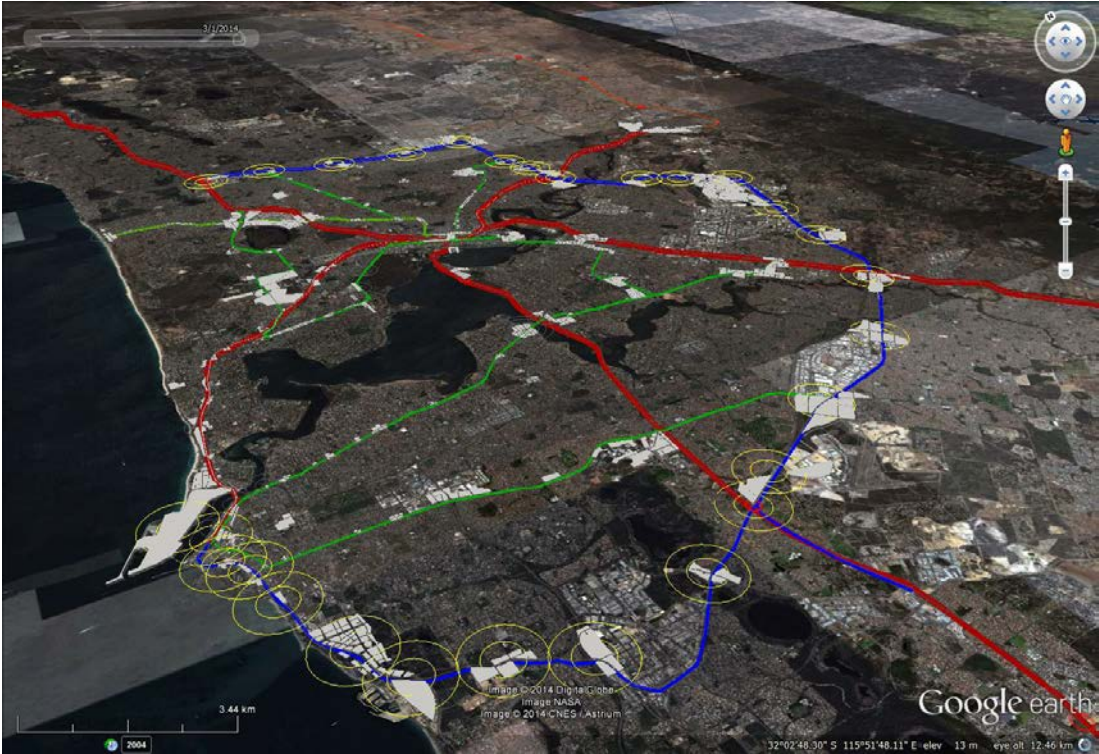
Figure 81 Perth from above

REDEVELOPMENT PODS IN WHITE WITH HEAVY RAIL LINES IN BLUE AND LRT IN GREEN LINES

Figure 82 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.
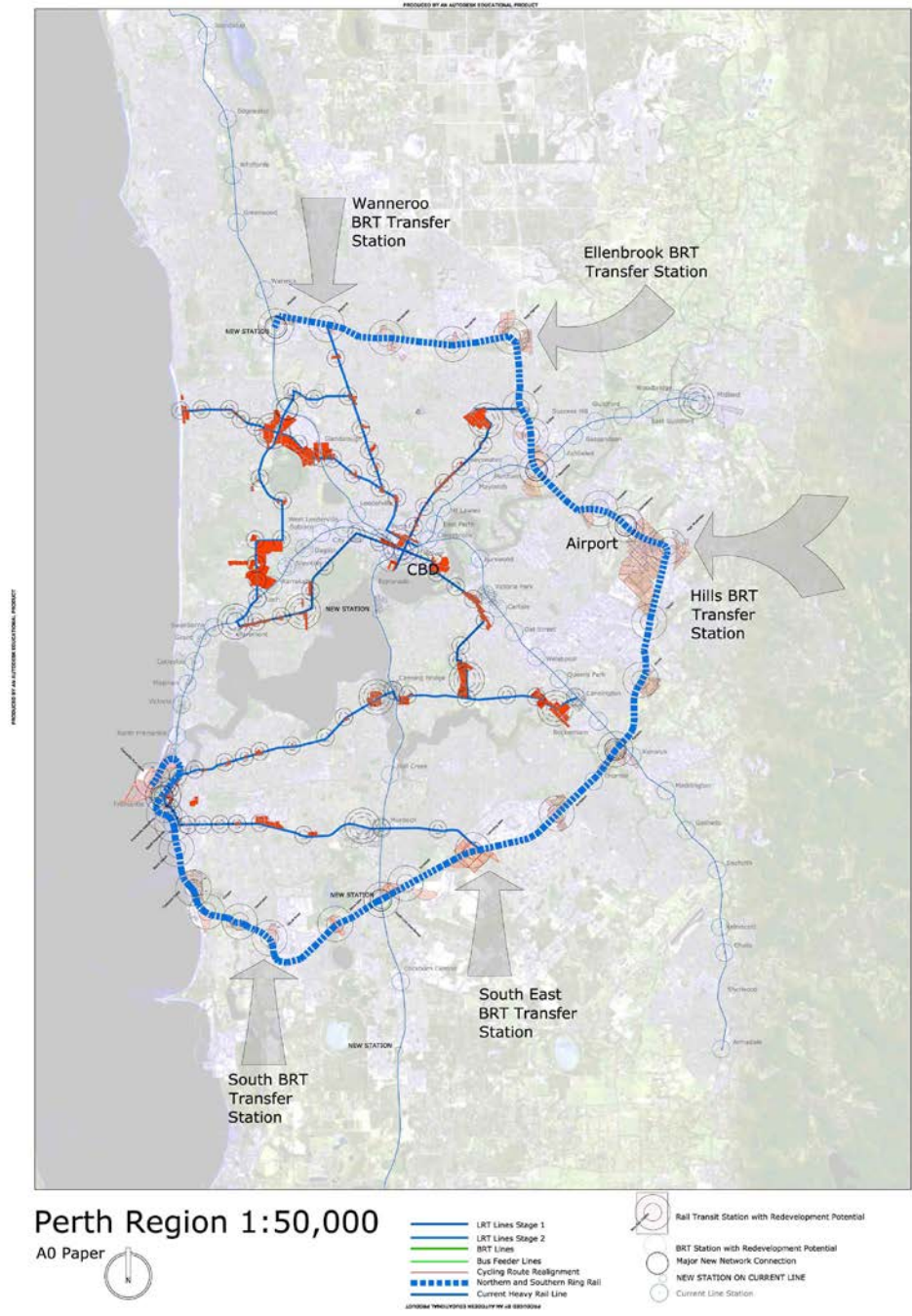
Figure 83 Perth: Ring Rail (Blue, dashed), LRT (Blue, thin), Land Re-Urbanisation (Red)
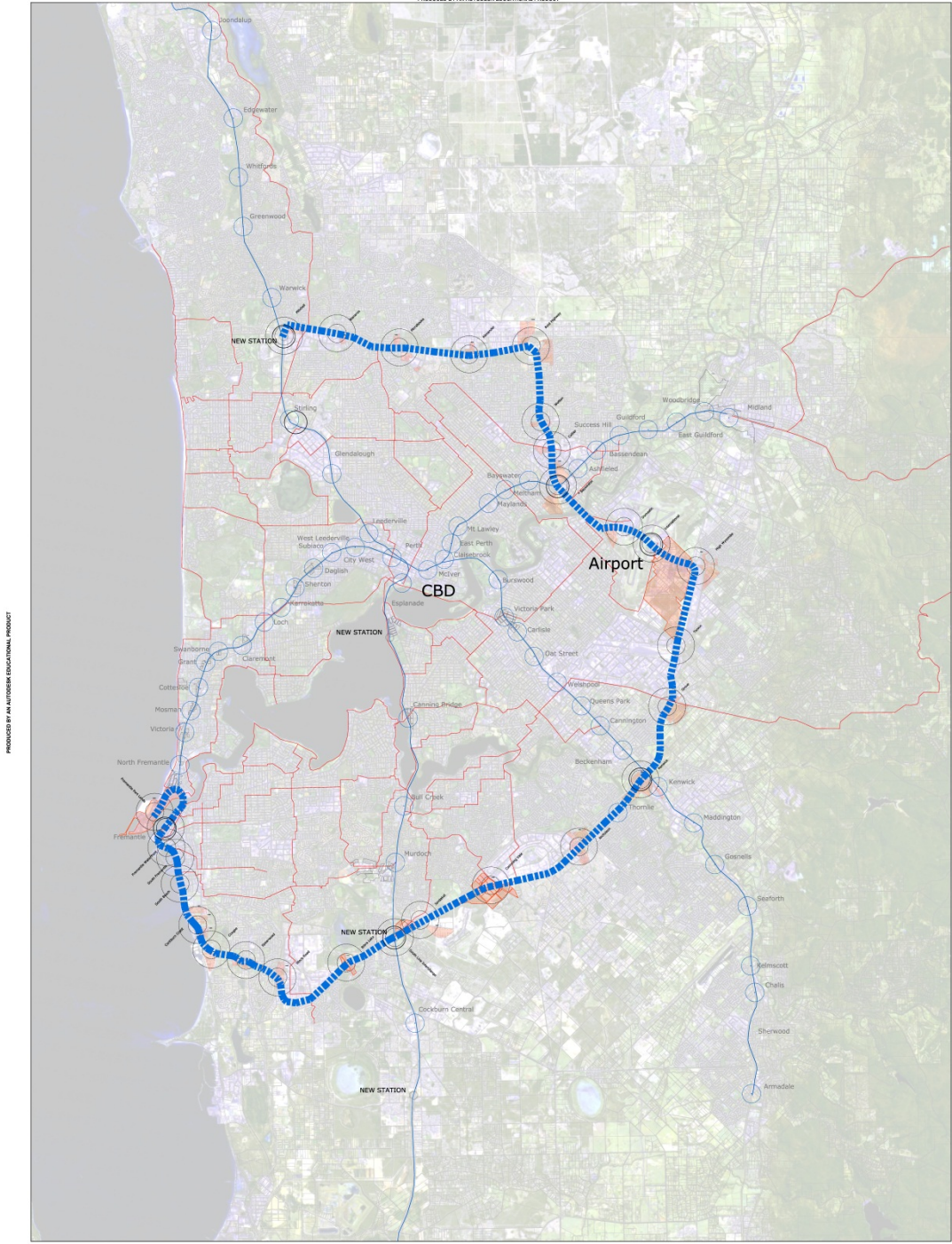
Perth Region 1:50,000   A0 Paper

Figure 84 Perth: Ring Rail and LRT (blue) bus and BRT lines (light green), bus (dark green)

Perth Region 1:50,000

A0 Paper

▬▬▬	LRT Lines Stage 1
▬▬▬	LRT Lines Stage 2
▬▬▬	BRT Lines
▬▬▬	Bus Feeder Lines
▬▬▬	Cycling Route Realignment
▰▰▰	Northern and Southern Ring Rail
▬▬▬	Current Heavy Rail Line

Rail Transit Station with Redevelopment Potential

BRT Station with Redevelopment Potential
Major New Network Connection

NEW STATION ON CURRENT LINE

Current Line Station

Figure 85 Perth: Ring Rail (Blue) and priority Cycle Routes (Red)

As a diagram, the plan is more simply rendered below:
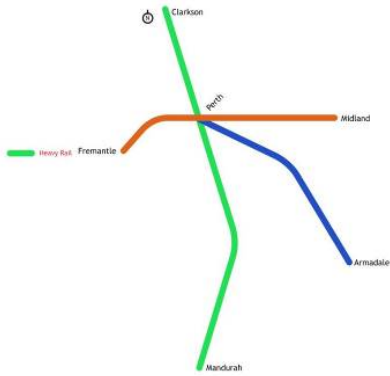
Figure 86 Current Rail Lines
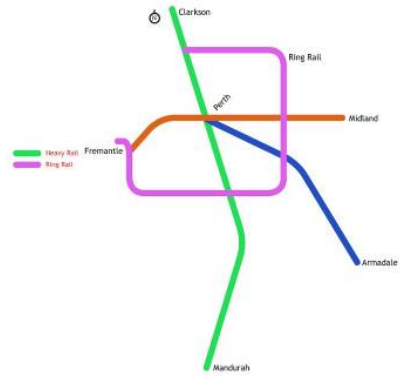
Figure 87 With Ring Rail
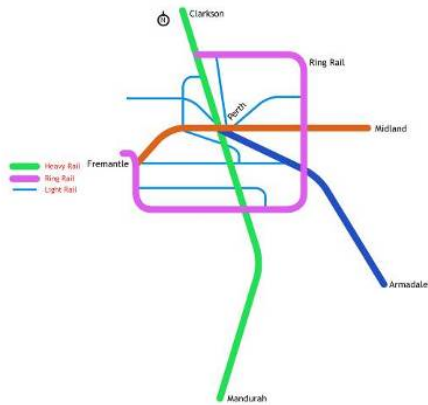
Figure 88 With LRT Lines
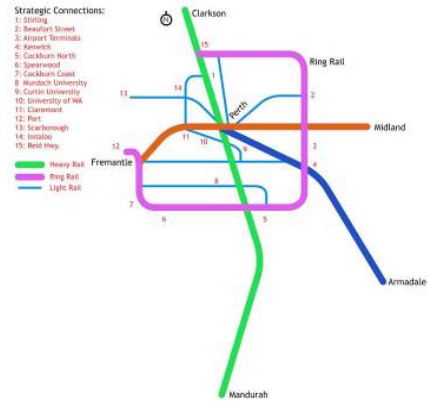
Figure 89 Major Land Use Connections

Strategic Connections:
1: Stirling
2: Beaufort Street
3: Airport Terminals
4: Kenwick
5: Cockburn North
6: Spearwood
7: Cockburn Coast
8 Murdoch University
9: Curtin University
10: University of WA
11: Claremont
12: Port
13: Scarborough
14: Innaloo
15: Reid Hwy.

— Heavy Rail
— Ring Rail
— Light Rail
● ToD Large
· ToD Small
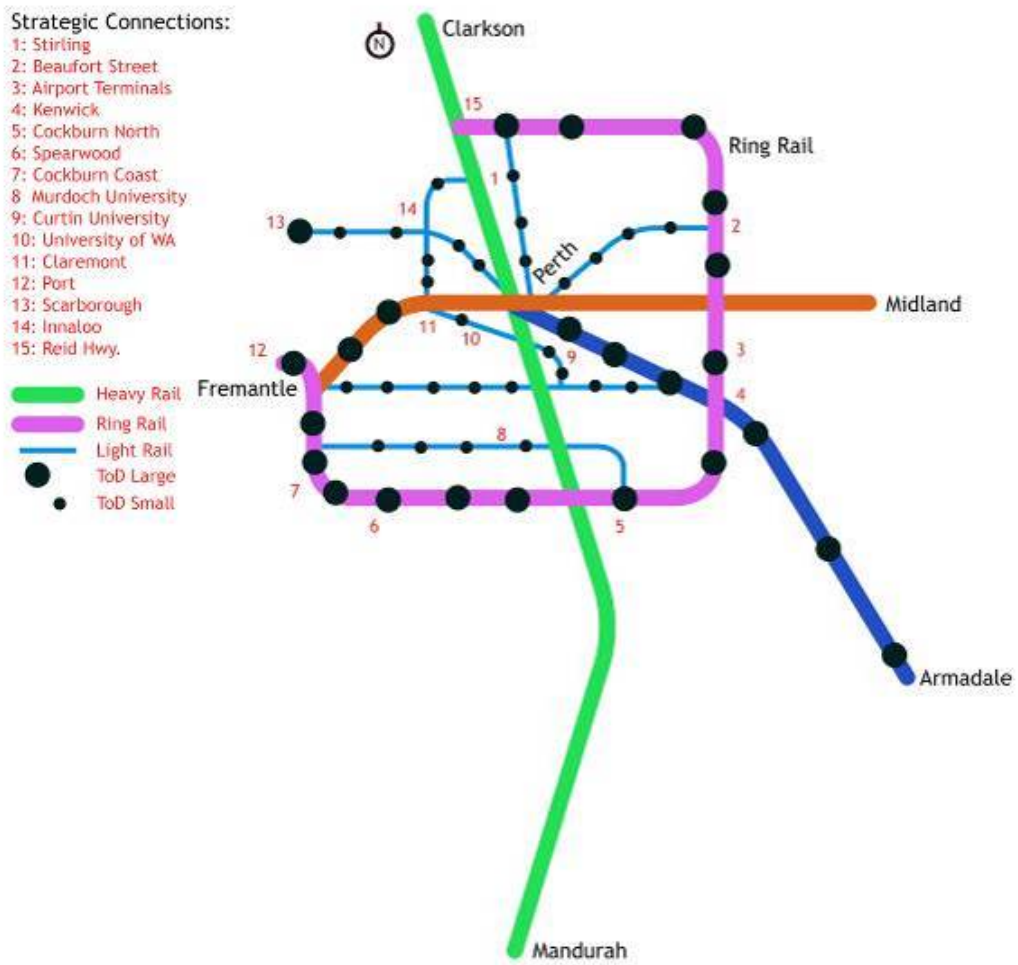
Figure 90 Range of TOD locations

4.2.7 VISUALISATIONS

To make the impact on the ground more apparent, two visualisations were prepared and are presented below:

Figure 91 Fremantle's East End, before and after

Figure 92 Scarborough Beach Road, before and after

SOURCE FOR ABOVE IMAGES: AUTHOR, 2013

4.3 RESULTS: THE LOCAL SCALE - VICTORIA PARK **MODEL 3.1**

An automobile-dependent city can be restructured around a series of transit cities of 20 to 30 kilometres in diameter, with a Town Centre as its focus and Local Centres linked along the transit services feeding the Town Centre. Although linked across the city for many functions, these transit cities with their centres can provide a level of self-sufficiency that can form the basis for a far less car-oriented city (Newman & Kenworthy, 2006).
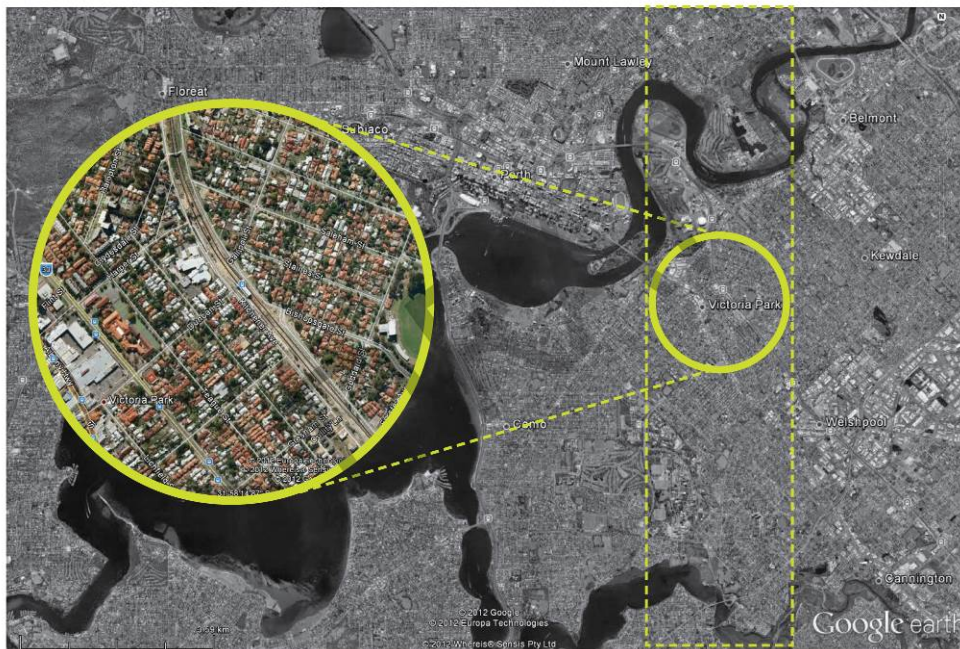
Figure 93 Victoria Park Location

This model, Model 3.1, is extracted from Model 2, having been a fundamental part of calculations as one of over one hundred sites in the Perth region found suitable for re-urbanisation. The site was a part of the model; we now look closer at the opportunities and impacts of up-zoning and transit service increases.

Hyperlink to Local Scale Model – Victoria Park
https://www.dropbox.com/s/qblkbe6vmku4vsx/GLUTIE_Victoria%20Park.xlsx?dl=0

Figure 94 Victoria Park: Train

4.3.1 BACKGROUND OF LOCAL SCALE: MODEL 3.1

The Victoria Park train station is well suited to an expanded role in a network of transit-oriented precincts, and could serve as a town centre within the Western Australia State Planning Policy 4.2 (Western Australia Department of Planning, 2012a). To achieve this a comprehensive and clear vision for the area is required and Victoria Park needs to identify trends to be built on. This visual analysis will first describe two sites within what is known as Victoria Park, how they are different and the opportunities and constraints inherent in this separation of services.

4.3.1.1 VICTORIA PARK OBSERVATIONS

While the two sites of the 'centre' and the 'station' are relatively close and linked by 540 metres of Duncan Street, they are separated by a second highway, Shepperton Road. This 'road' acts more as a highway arterial than does the parallel Albany Highway which, despite the name, is more a shopping main street. Furthermorethe station and centre are

beyond eye-shot of each other making the walking trip to the high-order Public Transit service unpleasant and uncertain (see Figure 97).

C E N T R E

The centre of Victoria Park is situated along the Albany Highway, historically the principal link between Perth to Albany in the far south of the state. It has a pleasantly traditional two storey built urban environment with a highly walkable street fabric of safe and plentiful intersections (Figure 94 & Figure 96). The buildings mostly offer multiple 'openings' (windows and doors) along with many types and scales of 'destinations' (shops, stores, services, amenities) which are well shaded by canopies, verandas and street trees. Much of its building facade has heritage value and provides evidence of an attempt to create safe pedestrian crossings at significant points. However, further to the north and south of this 'centre', the Albany Highway lives up to its name and serves as a high capacity collector or minor arterial road with the concomitant 'strip'- like feel of car lots, pawn shops, take away food stuffs, forgotten parks, and little consideration for pedestrians in an automobile-oriented highway location (see Figure 95 & Figure 99). The 'centre' has an appropriate mix of services and amenities, and anecdotal evidence suggests it does seem to be growing in importance due to its proximity to both Curtin University and the Central Business District of Perth. This will be an important consideration in the future as these two centres continue to grow in their own right, with Victoria Park's 'centre' equidistant between the two growing nodes of business, medicine and education. Victoria Park may be linked with these regional anchors more firmly with the long awaited 'Knowledge Arc' Light Rail Transit provision (Newman & Scheurer, 2010; ACNU & Jones, 2012; Emerson, 2012) . While improvements are needed along some or most of Albany Highway, at the 'centre' of Victoria Park Albany Highway supports the good 'bones'. The good bones, or inherent structuring elements conducive to positive growth, are evident along this multiple block long stretch ending at the intersection of Duncan Street to the station.

S T A T I O N

At the station there are no retail or commercial services, nor does there appear to be zoning in place to provide these amenities. There is an institution, the Association for the

Blind of Western Australia, Guide Dogs WA[36], which may certainly be retained and incorporated in a land intensification program.

Figure 95 Albany Highway - Victoria Park's shopping street

Figure 96 Albany Highway - Perth's used car lot zone

STATION PRECINCT RETAIL AND COMMERCIAL

There are, significantly, several small scale 'family run' shops, the corner stores of another era, relatively close to the station. One is in Duncan Street at Sunbury Street, another in Gallipoli and Howick Streets and yet another in Lathlain Place (Figure 98). While they may provide only a small measure of the overall retail trade of Victoria Park and perhaps only a fraction of most families weekly shopping the fact these still exist in a contemporary retail environment speaks to the quality of this neighbourhood to support such enterprises. It is not hard to imagine that the immediate surrounds of the station could offer retail and perhaps some commercial floor-plate opportunities, currently or

[36]http://www.guidedogswa.com.au/

within a framework of significantly up-zoned land in the station precinct. If such retail can survive now it will thrive under a more intensive land use policy.

Figure 97 Albany Highway - Pedestrian Crossings and Historic Post Office

Figure 98 Victoria Park: Station

SOURCE: AUTHOR. TO THE LEFT OF THE IMAGE IS EVIDENCE OF THE SINGLE STOREY RESIDENTIAL STOCK IN THE STATION PRECINCT.

Figure 99 Victoria Park: Small scale family operated businesses

Figure 100 Victoria Park: Large scale national chain shops reliant on free parking

S C H O O L S

There are at least two schools in the station precinct. While the student population is not known, nor the quality of the schools, it is important that there is already educational infrastructure in place and likely open to receive an increased student population. This is important because the expense of providing for schools is often a major concern in the development of green-field areas.

P A R K S

There would appear to be sufficient park capacity for the population especially if one includes Eftel Oval (a.k.a. Browns Stadium) (Figure 100) and the Swan River foreshore, including Heirisson Island (Matagarup). Any developer choosing Victoria Park as a location for residential investment might consider contributing to a fund for overall public realm amelioration, but there would not need to be hand-over of lands to parks provisions.

Figure 101 Victoria Park: Browns Stadium

Victoria Park has many amenities, services and aspects which could easily be built upon in the creation of a higher-order activity centre. These include the survival of small scale shops, parks, historic buildings, tree-lined streets and the train station itself. All of these give Victoria Park an advantage over many other places equally served by high-order transit. An examination of the station and the transit service contribution to a upgrading of the area to a higher order residential and services node follows.

PTA AND TRANSPERTH

With the frequency of the train and the recent investment in the station, the Public Transport Authority (PTA) has provided well above the minimum required to meet the needs of the residents and make taking the train as safe, clean and clear as possible. Recent investments evident are a new station building (see Figure 97) which includes improved street crossings at the station, extensive access ramps, moderate parking provisions on one quarter of the station site, upgraded lighting, escalators and elevators to reach the platforms, new benches within the station, an arrival time board, public art and even significant planting of trees and vegetation in the immediate surrounds. This is a very well-coordinated series of spaces and the quality of design and construction, while not world class, is well above the minimum provided in more recent iterations of transit stations in Perth. One advantage this station has compared to others, such as Bull Creek, is that is sits within its own right-of-way (Figure 93), not sharing the RoW with automobiles in a grade-separated situation. The flow-on from this is of great importance to its current and future functioning as a Transit-Oriented Precinct of higher order activity. Patrons and residents will not have to contend with high vehicle numbers as they would on a highway arterial.

Except for the need for higher frequency of trains and improved feeder bus services linking the centre of Victoria Park, on Albany Highway, or Lathlain to the station, there should be no reason any person will find fault with the provision of transport via train to and from Victoria Park Station. The only other areas for improvement of the transit service might be legibility and way-finding to the station from the centre of Victoria Park.

RESIDENTIAL STOCK

The housing observed in Victoria Park is significantly low rise single family with a small measure of historically interesting stock. However there are several apartment buildings which, in their orientation and vast car parking plots, do not respect the street or the neighbourhood and are examples of badly executed increased density. While they undoubtedly provide patrons on the Transperth network, they are not examples of what is needed within the Station precinct.[37]

Figure 102 Victoria Park: example of housing stock

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[37]In Perth there is a genuine distaste for high-rise, which is beyond the scope of this research to discuss, which needs to be countered with well-located, amenity delivering, of varying heights and design (well 'massed'), street front retail and/or street fronting townhouses with an excellent regard for the public realm on the front and back.

Figure 103 Victoria Park: Tower in the Park

THIS IS BUT ONE MORE EXAMPLE OF AN ISOLATED RESIDENTIAL TOWER WHICH DOES NOT TRY TO FIT INTO ITS SETTING, IS SURROUNDED BY A VERY LARGE PARKING AREA, HAS POOR CONNECTION TO TRAIN STATION, HAS NO SHOPS AND NO JOBS CONNECTED TO IT.

THE STREET GRID

Though skewed and split in half by the train RoW, the street grid does offer a great opportunity to infill and redevelop parcels with a strategy of amalgamated lots for larger floor plates which are typically what even 'medium' density (5-10 floors) developers will require before considering a project to be feasible. To be clear, it is much harder to create a floor plan for a building of higher density living, let alone manage increased pedestrian and vehicle traffic, from within a dendritic street pattern. Victoria Park and Lathlain have a great grid network; using it to its best advantage will provide dividends when potential foot traffic increases result from higher activity intensity.

Aside from this visual analysis, other points of departure for understanding Victoria Park within a broader regional context will be presented below.

4.3.1.2 BROADER CONTEXT

AUSTRALIAN BUREAU OF STATISTICS

According to the ABS, Victoria Park and Lathlain have these characteristics compared to Australia and Western Australia:

- its residents are younger than the Australian and Western Australian average with fewer persons married and fewer ever having been married;
- residents are better educated at a tertiary level, 27.8% to 14.3% in Australia;

- there is a significant Asian population with double the average Australian Chinese ethnicity along with a far larger proportion of Mandarin, Indonesian and Korean spoken at home than the Australian average;

- 55.9% of respondents had both parents born overseas while the Australian average is 34.3%;

- personal and household median weekly incomes are higher than the Australian and West Australian average;

- there are more couples without children, but also fewer one parent families;

- 47.7% of dwellings were separate houses, 21.4% were semi-detached, row or terrace houses, townhouses etc., 30.6% were flats, units or apartments compared with the Australian averages of 75.6%, 9.9%, 13.6% respectively;

- there are more two bedroom and far fewer four bedroom dwellings;

- there is a slight increase in households reporting 'no car' with 10.1% to 8.6% for Australia and 6.1% for Western Australia.

All of this is available through the Australian Bureau of Statistics (ABS, 2011) webpage.

What this means for the opportunities and constraints of this station precinct, within a Western Australian and Australian context, is difficult to say without falling into presumptive fallacy. However, that concern aside, we can formulate an image of a younger than average, upwardly mobile with extra wealth, well-educated to the tertiary level, new Asian immigrant society which lives in smaller homes and owns fewer personal vehicles. This does promise well for increased activity in this location as many of these characteristics are ideal for transit-oriented developments, or re-developments, to succeed: young, wealthy, educated, denser, new to country and open to change, aware of new opportunities and willing to live in a more compact way so long as the amenity is high.

LOCAL STRUCTURE PLANS AND R-CODES
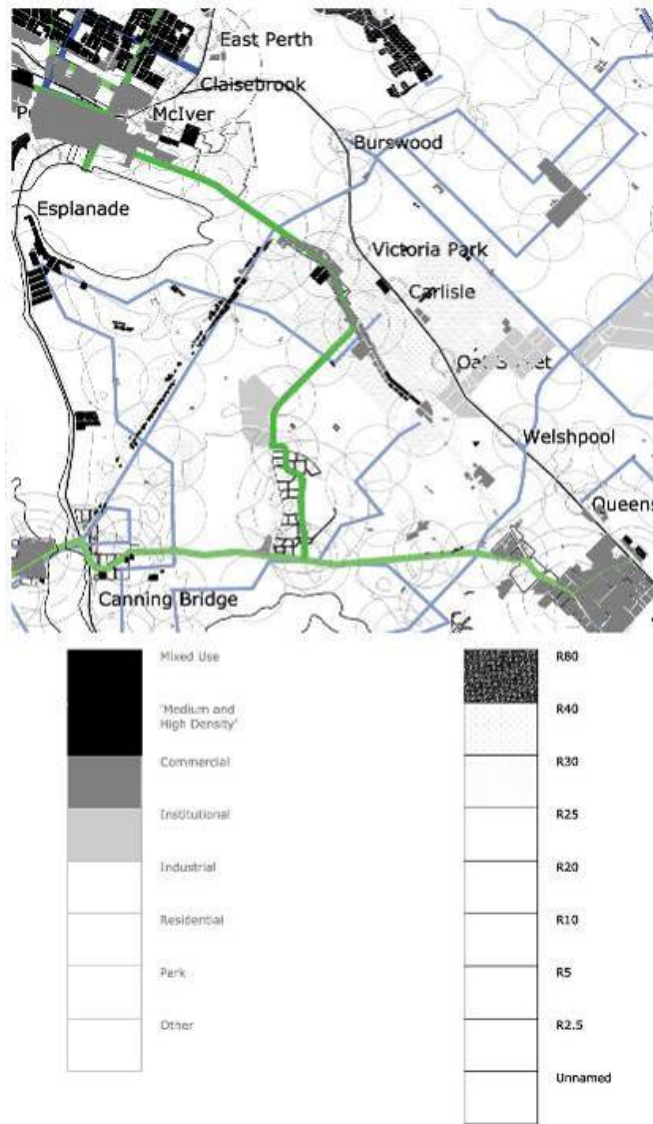
Figure 104 LSP and R-Codes Overlay

Though possibly not apparent in this image, the Local Structure Plans (LSP) and Residential Codes[38] (R-Codes), would be allowed to have an increase in residential population to 40 persons per hectare with only a slight increase in the 'centre' to 80. There

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[38]The Local Structure Plans (LSP) and Residential Codes, or R-Codes, digital files for the whole of the metropolitan region were originally given to the author by the Western Australia Department of Planning, and they are thanked for their willingness to cooperate on this project.

are several other areas either zoned for increased activity in the general area or coded for increased density, but a very limited number near the Victoria Park station precinct.

It is worth mentioning that R-80 can easily be a modest set of townhouses and R-40 a series of shared wall terrace houses. Were the entire precinct rezoned to R-80, at a 62.8 hectares there would only be a net growth of 5,024 persons, far below the circa 20,000 projected to achieve even a small slice of the required infill redevelopment as promoted in Directions 2031.

While it is beneficial to have up-zoned and increased R-Code areas adjacent to transit stations and along corridors of high amenity, and even small increases are beneficial to the whole, it is important to consider the scale of the task ahead of Perth. If Perth is to move towards greater infill and less greenfield development, it will be necessary to consider a vast increase in all these factors from what is currently planned. Victoria Park has the bones and ability to grow much more than is currently anticipated.

The WAPC's 2004 Residential Density and Housing Examples (WAPC, 2004b) intended to show R-80 and other examples of achieved density in Perth while the R-Codes (WAPC, 2010) lists the statutory requirements.

DIRECTIONS 2031

Directions 2031 brings many disparate ideals regarding urban future together into one document describing itself as a 'high level spatial framework and strategic plan that establishes a vision for future growth of the metropolitan Perth ... region; and it provides a framework to guide the detailed planning and delivery of housing, infrastructure and services necessary to accommodate a range of growth scenarios' (Western Australia Department of Planning, 2011).

> Infill and greenfield -housing targets: On current trends it is estimated that the amount of infill residential development achieved as a proportion of total development between now and 2031 will be between 30 and 35 per cent. The connected city scenario seeks a 50 per cent improvement on current trends and has set a target of 47 per cent or 154,000 of the required 328,000 dwellings as infill development. ...The Department of Planning will continue to work with local

governments and service delivery agencies to further develop the housing targets program and move to start realising infill development opportunities.

The connected city model is preferred because: We must prioritise land that is already zoned: we already have a significant supply of land that has been deemed suitable or potentially suitable for new urban development, and has been zoned accordingly under the metropolitan and Peel region schemes. This land will be the first priority for new development (Western Australia Department of Planning, 2011).

The first problem this document encounters is that, despite statements regarding how it will establish a 'vision' for a 'range of growth scenarios' it is very difficult to discern where and how this growth will be actually manifested.[39] While 'high level' reports are not the place for detailed working through all the possible physical layouts of sites, this document too easily places a red or blue/green dot on a map to represent 'activity centres' without paying attention to the character or capacity of these sites. What a study of character and capacity reveals is the actual size of the precinct, whether there are extensive brown-fields or decayed housing stock, what properties are re-developable, why someone would want to develop or indeed live there, what is already present to help or hinder higher intensity urban forms, and evidence that these sites will be able to bring a marked increase towards the 47% urban infill. Directions 2031, while aspirational, underestimates the difficult realities of urban redevelopment for a region long associated with a low-density automobile-oriented lifestyle. This may be so that no overly optimistic 'signals' are sent to developers or community activist groups resistant to higher density.

No matter the signals, Victoria Park is designated to be a Secondary Centre in the hierarchy so thatapplications for higher order redevelopment are more readily received by local governments and the splanning authorities. In the other direction, if the City of Victoria Park applies to State or Federal agencies, such as Infrastructure Australia, for funding to upgrade services, having a 'town centre' designation should make funded improvements increasingly possible. The City of Victoria Park must first understand what

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[39] 713, 000 to 2026 from ABS, say 750,000 to 2031, and 47 % of this is 352,500 persons placed into 154,000 homes equalling 2.3 persons per house, which is close to the national average; but nowhere is mentioned what size these homes will be or how much space is allotted per person.

great opportunities it has and embrace them by preparing the statutory plans and upgrading services necessary to take advantage of these opportunities.

As outlined in the State Planning Policy 4.2 Activity Centres for Perth and Peel (Western Australia Department of Planning, 2012a) the state of Western Australia seeks to leverage its transit infrastructure to:

- reduce the overall need to travel;
- support the use of public transport, cycling and walking to access services, facilities and employment; and
- promote a more energy efficient urban form.

The purpose of the policy is to coordinate land use and efficient infrastructure delivery, with matching benefits of 'business clusters, lower transport energy use and associated carbon emissions', while also defining the role of Activity Centres.

Activity centres are community focal points. They include activities such as commercial, retail, higher density housing, entertainment, tourism, civic/community, higher education, and medical services.

Activity centres vary in size and diversity and are designed to be well-serviced by public transport.

5.2.2 Residential density

(1) Commercial and residential growth should be optimised through appropriately-scaled buildings and higher-density development in walkable catchments of centres.

(2) Higher-density housing should be incorporated within and immediately adjacent to activity centres to establish a sense of community and increase activity outside normal business hours.

Having 'higher density ... in walkable catchments' and 'increased activity outside of normal business hours' requires creation of a genuine compact, '24 hour', place rich with opportunities to work and live. That Victoria Park has already a 'catchment' due to its train station, and a host of amenities already operating and seemingly with good retail turnover,

suggests that it is a suitable candidate for consideration as a site for investment in activity intensification. Intensification in residential units is advisable but also in retail and possibly commercial development Again, if the Town of Victoria Park sees the opportunities resulting from having a designated 'Activity Centre', it could become a more walkable and compact, amenity-rich area collecting higher than average rates per hectare to pay for improvements made to the urban fabric.

VAMPIRE

A few things are apparent when looking at the VAMPIRE (Vulnerability Assessment for Mortgage, Petroleum, and Inflation Risks and Expenditure) map drawn by Dodson and Sipe (2008). The observation most pertinent to this study is that the areas immediately adjacent to the Victoria Park Station are shaded orange to even a shade of redin Lathlain to the east of the train station proper. This shading, representing degrees of vulnerability, is likely accounted for by the high stress level experienced by mortgage holders due to a lower than average household income.

> ... households in inner suburban locations typically experience the advantages, from an oil vulnerability perspective, of higher incomes and lower reliance on automobiles for transport than those in outer suburban zones. These patterns are not transitory but a durable structural feature of the Australian metropolis. Urban structure and the local conditions of resilience and adaptability that urban structure engenders will be a critical factor that shapes household socio-economic circumstances under conditions of higher petroleum prices or mortgage interest rates (Dodson & Sipe, 2008).

If the above statement is true, transit-oriented redevelopment near the Victoria Park Station would seem able to leverage the 'higher incomes and lower...automobile' factors to benefit the entire region with a purpose-built, market-driven, planned Activity Centre as outlined in State Planning Policy 4.2, section 5.2.2 Residential Density, and at least one of the hierarchies outlined in Directions 2031. As a means by which to evaluate the land

surrounding the train station as an ideal site for transit-orientedredevelopment[40] the VAMPIRE map shows the likely 'flexibility' of a neighbourhood to lot amalgamation.

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40 With concomitant community consultation, investments in underground service upgrades, rezoning and likely density bonuses to attract risk-adverse multi-family developers.

Vulnerability Assessment for Mortgage, Petrol and Inflation Risks and Expenditure
2006 Census Data Analysis of Perth

Perth VAMPIRE
- 0 - 9 (Minimal Vulnerability)
- 10 - 14 (Low Vulnerability)
- 15 - 16 (Moderate Vulnerability)
- 17 - 18 (High Vulnerability)
- 19 - 30 (Very High Vulnerability)
- No Data
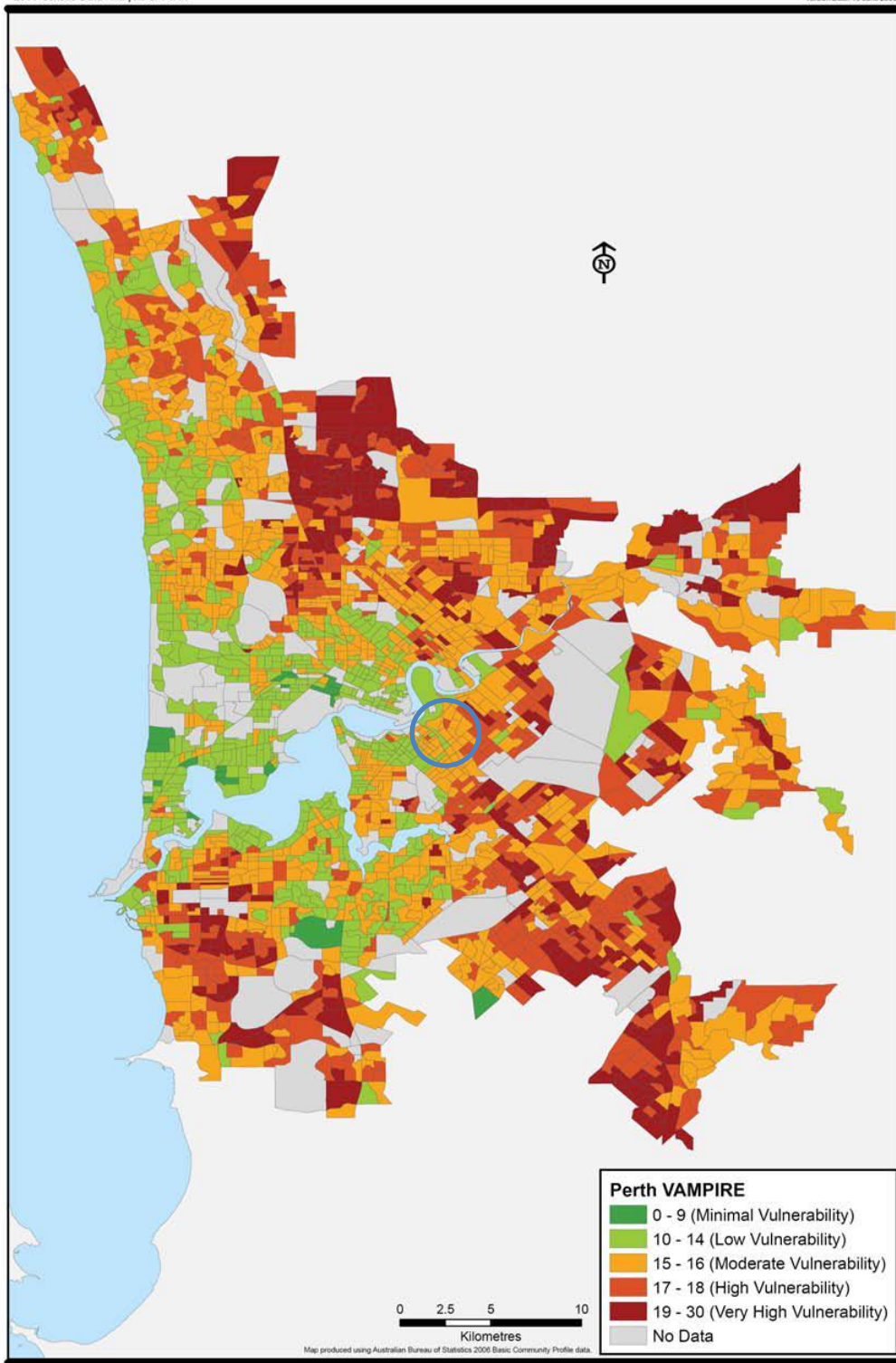
Figure 105 VAMPIRE Analysis

As a word of note, this degree of vulnerability (as in the V of VAMPIRE) seems odd given the desirable amenities in place: waterfront and parks, jobs in the CBD, shops along Albany Highway, and high quality public transport. This can be explained within the methodology by, for example, Mosman Park which has a higher rate of low-income households yet has excellent and easily accessed high quality public transit. Most other areas of similar geographical location, close to the river, on the train line and proximate to a major centre are of the two shades of green, signifying low vulnerability to changes in oil price fluctuations and mortgage rate increases. It appears that the VAMPIRE maps demonstrate where wealth is significantly distributed more than the accessibility to services and amenities by foot, cycle or public transit.[41]

The usefulness of the VAMPIRE is therefore mitigated when discussing transport issues as it seems not to pick up accessibility as an indicator. To discuss accessible mobility we had best turn towards SNAMUTS to tell us how a neighbourhood is performing.

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41 Again, this shows 'flexibility' of lot amalgamation as, frankly, wealthy areas of cities rarely accept significant higher density redevelopments.

SNAMUTS or 'Spatial Network Analysis of Multimodal Urban Transport Systems' (Scheurer, 2012), designed by Dr Jan Scheurer, is intended to:

> ... identify and visualise strengths and weaknesses of geographical coverage, network connectivity, competitive speed and service levels in a coherent mapping exercise. The tool is designed to aid discussion and to lend weight to decision making within the fields of land use planning and transport planning, particularly where outcomes leading to more sustainable transport options are needed (Scheurer & Curtis, 2008).

It is clear from the SNAMUTS polygons that the area of Victoria Park, again, has very mixed results for an established inner-city neighbourhood with a train station at its core. Here Lathlain receives a better score than Victoria Park proper and one can only surmise that this is due to a lack of feeder buses linking Victoria Park, East Victoria Park, Tech Park and Curtin University to the higher speed train network. A critical factor in SNAMUTS is that higher speed lowers the overall 'contour' of distance to be travelled at a particular threshold. Effectively, the slower the transit on a long route, the less 'accessible' is the census tract. Were a bus to have a direct route to a train station and feed directly into this speedy service which took the passenger quickly to many possible destinations, the accessibility ranking would be higher. Given that it is unlikely that most patrons from the broader Victoria Park region will prefer to split a Public transit trip into several modes it is advisable that an increase in frequent buses and trains and/or a new mix of mode such as a LRT be added. This is of course, in addition to improved pedestrian realm, cycling infrastructure, and higher intensification of uses through proactive zoning to encourage higher residential density and privately operated amenities such as grocery stores. Such amenities will only come with more residential population, and more population can only be accommodated if there is a higher order of multi-modal transport options. Again, growth here would be advisable due to the adjacent work areas, park spaces, amenity-rich Albany Highway (see Walk Score below) and existing train station.
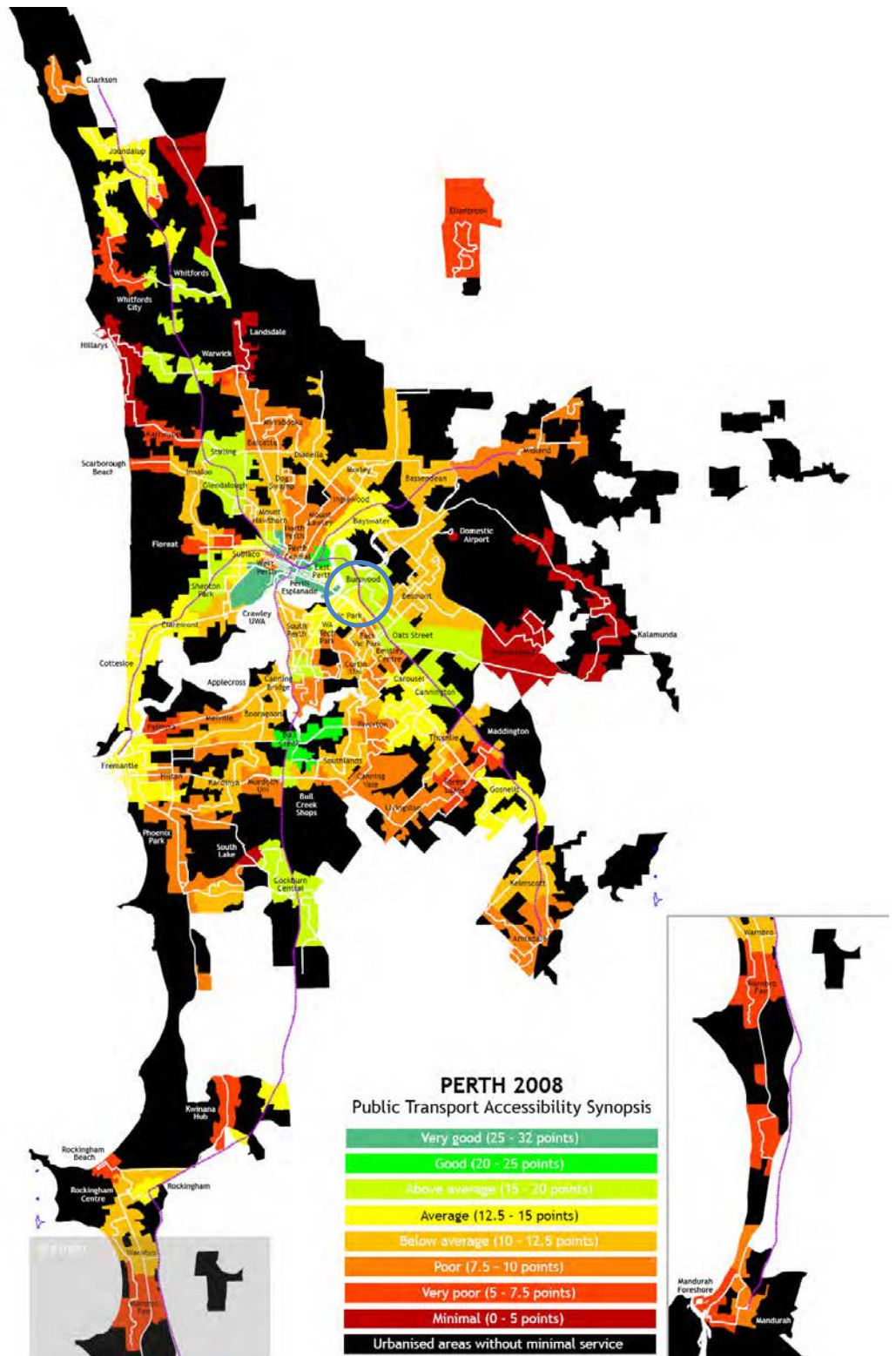
Figure 106 SNAMUTS report on Perth

SOURCE: (SCHEURER, 2012)

SNAMUTS shows how a city or region is performing and can evaluate projections; however it is perhaps best used to show where transit services are lacking. Which service is chosen to fill those 'gaps', SNAMUTS does not say but it does suggest that higher capacity and speed are preferred. What it doesn't show is the quality of the places the transit serves, and so we need to turn to a series of metrics composed by Walk Score.

WALK SCORE

Walk Score has proven to be a very evocative means of estimating the 'walkability' of a given neighbourhood. Walkability refers to the ability to walk to services and amenity destinations from an exact address and is based on 'data sources including Google, Education.com, Open Street Map, and Localeze' (Walkscore, 2013). The Street Smart tool, an extension of Walk Score, accurately shows how much more difficult it is to access local amenities and services in dendritic, cul-de-sac neighbourhoods than those with a high intersection density and block length (Benfield, 2011).

> Street Smart Walk Score calculates a score by mapping out the walking distance to amenities in 9 different amenity categories. In amenity categories where depth of choice is important, we count multiple amenities in a given category. Categories are also weighted according to their importance (details below). The distance to a location, counts, and weights determine a base score of an address, which is then normalized to a score from 0 to 100. After this, an address may receive a penalty for having poor pedestrian friendliness metrics, such as having long blocks or low intersection density. The following categories, counts and weights are used: amenity weights = "grocery": [3],"restaurants": [.75, .45, .25, .25, .225, .225, .225, .225, .2, .2], "shopping": [.5, .45, .4, .35, .3], "coffee": [1.25, .75], "banks": [1], "parks": [1], "schools": [1], "books": [1], "entertainment": [1] (Walkscore, 2012).

However, its limitation as a tool in this exercise is that there doesn't appear to be a weighted value for the quality of Public Transit Service in its algorithms. Further limiting its functionality for Perth is that the Your Commute tab does not appear to register any of this region's bus or rail transit options even when the right-click function selects the Victoria Park station directly.

Walk Score Street Smart results show that Victoria Park Station Precinct **to the west** is very walkable due to the cluster of services along Albany Highway immediately accessed

from Duncan Street. However, once the measure is taken just **to the east** of the station, in what is properly Lathlain, the results become more mixed with a 'somewhat walkable' result. The two obvious factors leading to the decline in Lathlain are a decrease in amenities, noticeably grocery stores, restaurants and shopping, and that the 'long blocks' created with the only two possible options to cross the tracks, being grade separated bridges, prove to be a genuine barrier to the amenity cluster along Albany Highway.

Walk Score®
Drive less. Live more.™

| Cities & Neighborhoods | Apartments & Rentals | Why It Matters |

Like 25k

Get Your Score: 63a kitchener ave victoria park wa australia   Search

Street Smart
78 Out of 100 **Very Walkable**
63A Kitchener Ave Victoria Park

Understanding Your Score

Street Smart Walk Score is calculated using walking distances to the following amenities.

Category	Points	Name	Distance
Groceries	16.9 out of 20	Shortway Store	.7 km
Restaurants and Bars	13.4 out of 20	Himalayan Nepalese Restaurant & Cafe	.7 km
		Seoul Buffet	.7 km
		Chi Restaurant	.8 km
		Makan 2 Cafe	.8 km
		Koto Sushi	.8 km
		Mahsuri Satay Restaurant	.9 km
		Catalano's Cafe	1.1 km
		Brando's Pizzeria Cafe	1.1 km
		The Causeway Bar	1.2 km
		Eve Nightclub (inside Burswood Entertain...	1.8 km
Shopping	10.8 out of 15	Salvos Stores	.7 km
		Windows Boutique	.8 km
		Cinders Boutique	.8 km
		Jacobson's Pharmacy	.8 km
		Adultshop.com	1.1 km
Coffee	11.5 out of 15	Gloria Jean's Coffees	.8 km
		Aroma Cafe - Victoria Park	.8 km
Schools	5.7 out of 6	Ursula Frayne Catholic College Secondary...	.5 km
Parks	4.7 out of 6	G O Edwards Park	1.2 km
Books	6 out of 6	Talking Book Library	.3 km
Entertainment	4.6 out of 6	Patch Theatre	.8 km
Banking	5.7 out of 6	CBA ATM (Centro Victoria Park)	.5 km
Pedestrian Friendliness	-0.8	(see below)	
Total Walk Score	78 out of 100		Agree Disagree

Add a place   Click an amenity on map to remove

Pedestrian Friendliness

Short blocks and lots of intersections are better for walkers.

Average Block Length: 141 meters
Good

Number of Intersections: 143 per sq mi
Fair: –1% penalty

Walkability by Category

Figure 107 Walkscore for Kitchener Ave side of Victoria Park Station

Figure 108 Walkscore for Rutland Ave side of Victoria Park Station

In short, the potential for walking in Victoria Park Station precinct is positive, with a generally good density of intersections and short blocks (except for crossing the grade

separated train tracks) but could improve with more destinations placed closer to the station which may come through up-zoning if any transit-oriented redevelopment project is carefully managed.

The internal report (not publically available) Perth TOD Opportunities Review: Key Findings Report (Arup, 2011) study for the Public Transport Authority states:

> "Victoria Park is the highest performing station across the Development Criteria...The station catchment is relatively free of major road transport impediments; Shepperton road only severs a relatively small proportion of the 800m catchment. There is not a high amount of park and ride patronage associated with the station and the local street network has significant residual capacity. Cycling provisions around the station are reasonable and there are no measured environmental or contamination constraints within the catchment."

The section on Victoria Park's opportunities concludes with a note that the reasons for Victoria Park being a good candidate for TOD-type consideration are due to what it lacks, rather than its strengths. Rather than trying to fit an ill-suited task to a site, such as a new major transit hub, it is preferable to assign a task to a site which will help deliver some of the larger goals of the transport network and State Policies.

> "Overall, the TOD credentials of the station are strengthened by its low performance on the Interchange and Link Criteria."

This is a sound rationale for using the transport (road and rail) infrastructure already in place to its best and optimum purpose.
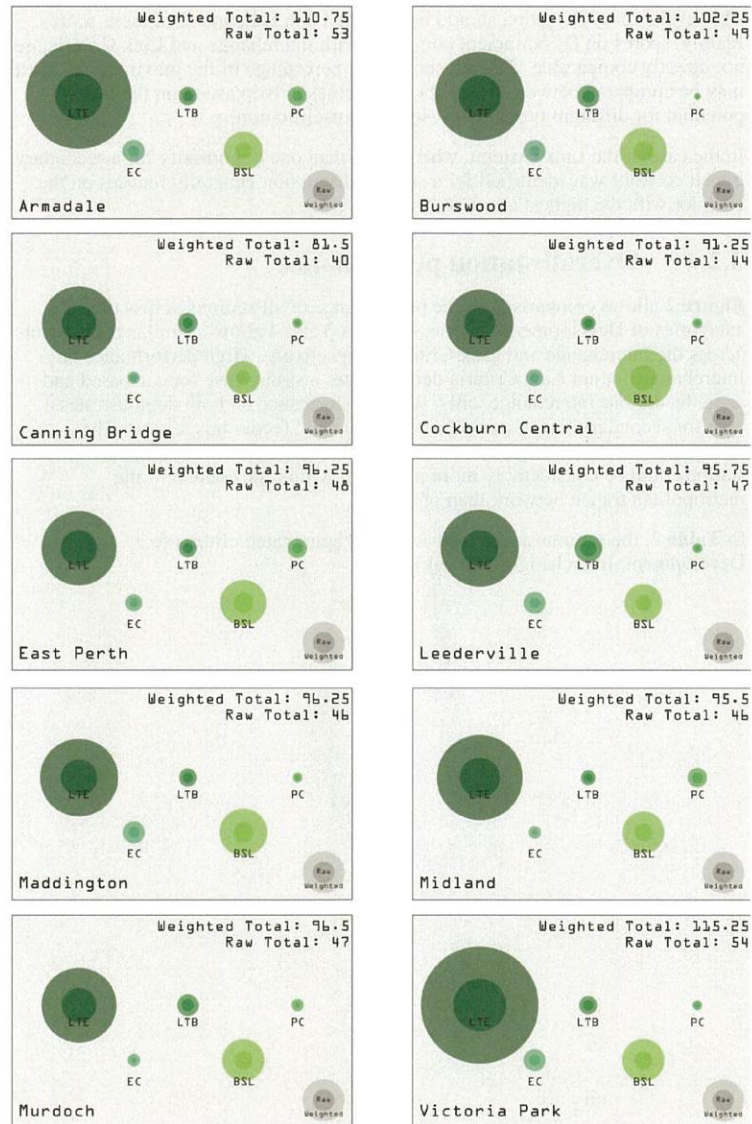
Figure 2 – Comparative performance across sub-categories of Development Criteria

Figure 109 ARUP report 'Comparative performance across sub-categories'

The key to unlocking the TOD advantage at Victoria Park is found on page 113 of the Technical Report of the same study which states 'Given nominal susceptibility to change, TOD could be encouraged over time through strategic property acquisitions and amalgamation and/or greater opportunity for land owners to intensify as of right'. To the author this means two things:

- a systematic land banking by multi-family type developers should not only be allowed but encouraged through direct rezoning and R-Coding (see Local

Structure Plans above) with a setting of minimum density and maximum parking targets; and

- permitting current land owners to build higher and taller multi-family units on their property if they have sufficient space for footings and floor-plates able to accommodate a building of reasonable economic return and of sufficient square metres to warrant redevelopment, and they are able to connect to head works.

On this last note, a word of caution. It is not advisable to allow redevelopment in the area on small lots if it results in larger floor-plate homes for fewer people. An example of this is the West Australian 'battle-axing' of lots which provides meagre gains in population density, with concomitant increase in automobiles, while not attaining enough density to support transit. What is advisable is the amalgamation of lots to create either stacked town-house, larger three storey walk-ups or yet larger floor-plate condominiums. Such multi-family building types in the right locations, with the correct orientation to the street and an appropriate level of district amenities (see Walk Score above), can meet local and regional targets for transit orientation as well as complete, compact and walkable neighbourhoods.

4.3.2   METHOD OF LOCAL SCALE: MODEL 3.1

The methodology used to derive the results was a functional part of the larger model developed for the ring-rail section above. The difference was the analysis of the photographs and first-hand observations and reference to Australian Bureau of Statistics, State planning policies VAMPIRE, SNAMUTS, Walk Score, and consulting reports to reinforce the findings.

4.3.3   MODEL OF LOCAL SCALE: MODEL 3.1

The Local Scale Model, (or Model 3.1) as employed in this study of Victoria Park, Western Australia, is similar to Model 2, The Regional Scale, but with a more detailed background which renders the 'local' much more prominent than the 'regional'. Drawing on visual observations (ocular estimation), ABS statistics, land use zoning and R-Codes, State planning policies, the VAMPIRE and SNAMUTS tools, Walk Score and the PTA report by Arup we hope to identify the options for transit-oriented Development in a place, in this instance Victoria Park.

4.3.3.1 SCENARIO PLAN

Perth is, by all accounts an auto-centric region which aspires to move towards more walkable, compact, transit-oriented living and working. Victoria Park is one of several sites within the region suited to increased intensification of residential living. With a reasonable measure of accuracy, the author has looked at Victoria Park and drawn a polygon to represent the likely bounds of residential land best suited to a coherent 'masterplan' of strategic long-range redevelopment in the Victoria Park Station precinct. The bounds of this polygon can be disputed, but it is intended to be generous enough to reflect the 'spill-over' effect of a concerted redevelopment effort while discreet enough to not affect the entire neighbourhood of leafy tree-lined streets. This polygon, and its hectares, can be discussed for finer refinement but will serve the purposes for this exploration.

From the model's algorithm this area had certain proportions taken out of its total for Public Open Space and for road and other Infrastructure, 10% and 15% respectively. For the remainder one of five 'types' of mixed use was applied, the one best suited to this particular set of circumstances. For Victoria Park this was Residential + Mixed which

devotes 75% to Residential purposes, 15% to Commercial (as a floor-plate, as one might find on a second floor for professional practices) and 10% for Retail (ground-oriented store front shopping or other innovative solutions). While not a complete listing of all the possible needs for a genuine community to flourish, this will provide the basis for a possible scenario.

The number of storeys (floors) permitted for each use on the site is based on the requirement that new residents have sufficient park space, work space and retail space to feel 'complete' in their neighbourhood. <u>For this scenario a maximum of 10 floors was set.</u>[42] The model calculates how many residents, how many shops, how much commercial space there will be in this new mixed-use neighbourhood. It also estimated parking requirements from these land uses if the current policies are followed, and the trip numbers generated by this type of mixed use. The ultimate aim is not to determine what can or can't happen in Victoria Park, or any other site, but to see how this scenario might fulfil the objectives of current planning policy.

Below are several charts to indicate the success of this polygon with a 10 floor maximum.

<div style="border:1px solid #336699; padding:8px;">

4.3.4   RESULTS OF LOCAL SCALE: MODEL 3.1

</div>

The results will follow in graph form with an explanatory caption below each graph.

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42 This is the similar to the height Washington D.C. is currently set at, but not without great deal of recent handwringing. See Kaid Benfield's post on the Natural Resource Defence Council's "Switchboard": http://switchboard.nrdc.org/blogs/kbenfield/why_i_support_the_dc_building.html regarding the debate in Washington D.C.
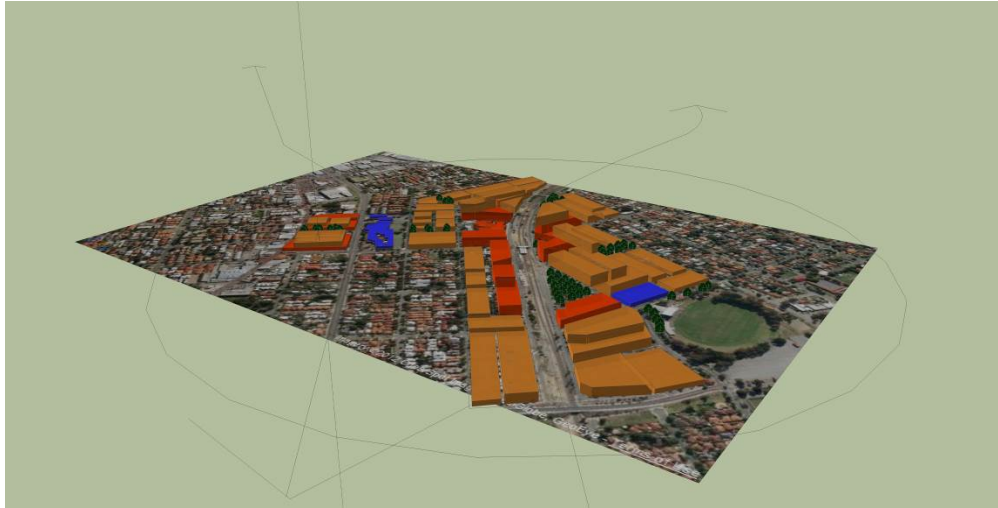
Figure 110 Victoria Park in 3D and in Plan

Victoria Park

	Area M2	Net Total
Victoria Park	629,241.2	471,930.9
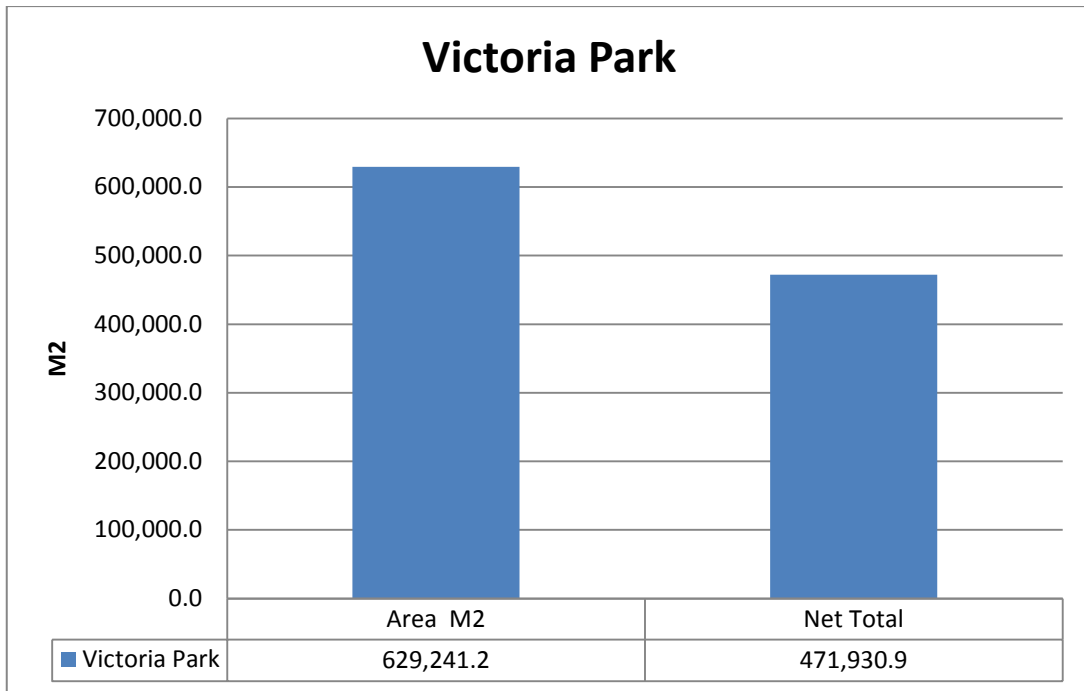
Figure 111 Victoria Park: Area Gross and net

Victoria Park

	Residential M2	Commercial M2	Retail M2	Total Area
Victoria Park	306,755	94,386	70,790	471,931
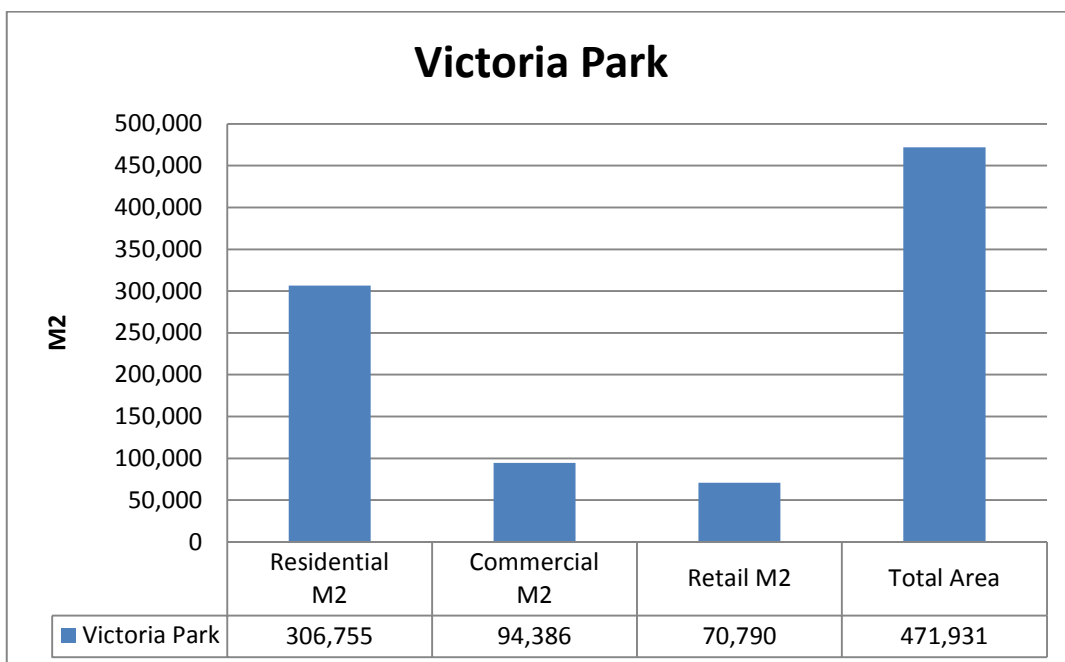
Figure 112 Victoria Park: mix of land use (at ground)

Victoria Park

	Residential M2	Commercial M2	Retail M2	Total of all Redevelopment M2
Victoria Park	1,472,424.5	226,526.8	56,631.7	1,755,583.0
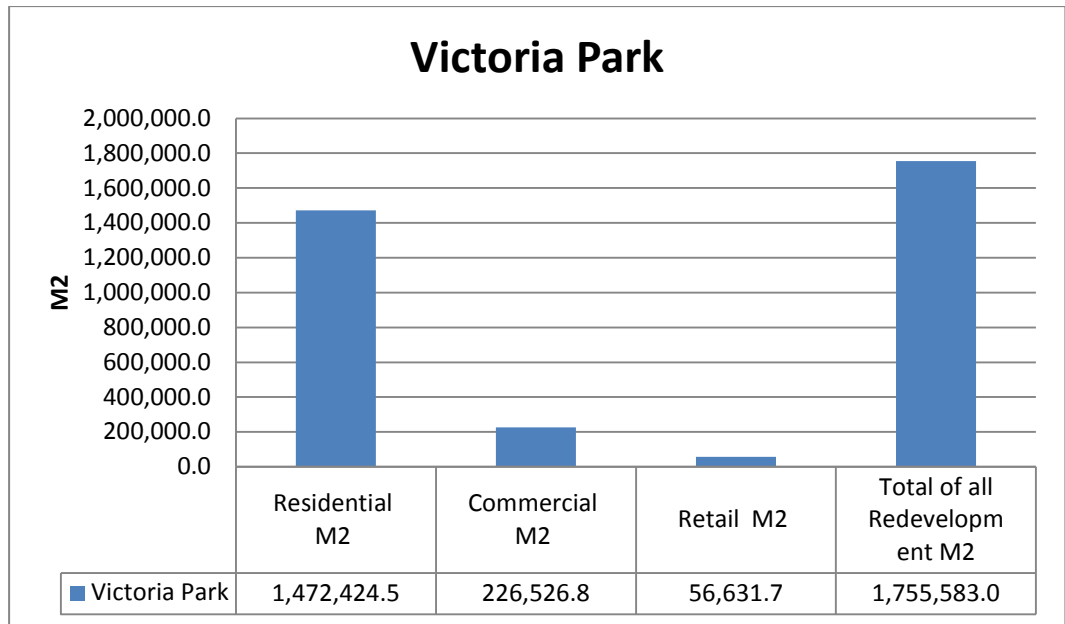
Figure 113 Victoria Park: Volumes of Residential, Commercial and Retail space: 10 storey maximum

Victoria Park

	Total Hectares = Sprawl Reduction	Average Floor Area Ratio (FAR)
Victoria Park	175.6	2.8
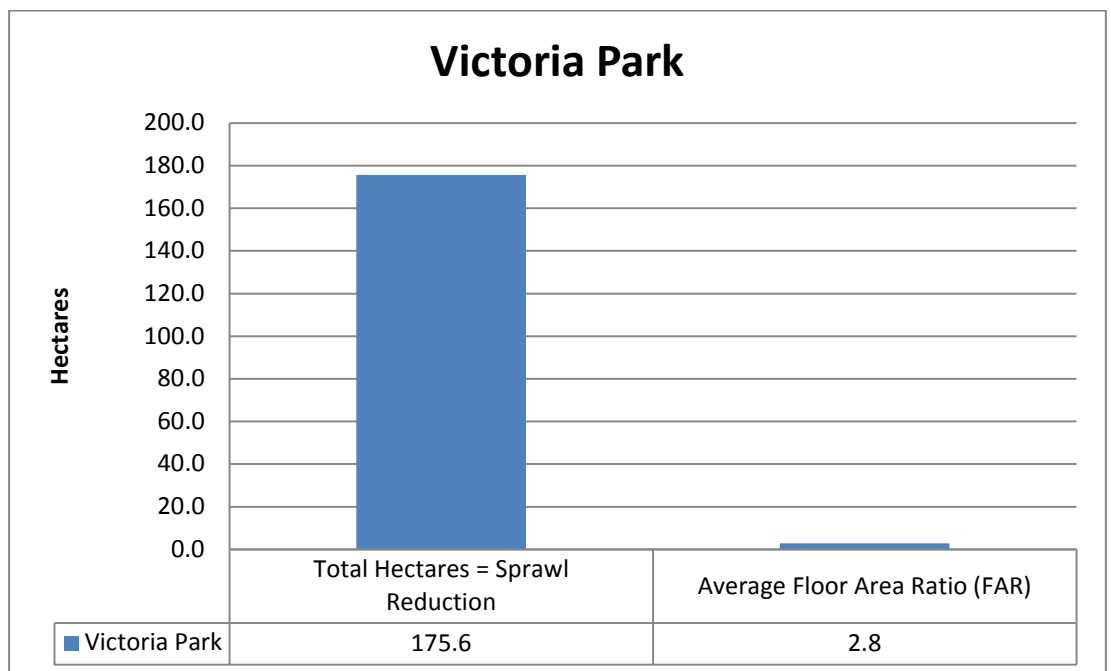
Figure 114 Victoria Park: Sprawl reduction and Floor Area Ratio

Current Victoria Park Station

	Reside ntial 100M 2 /dwell ing (Plan...	Years of housin g suppy (HIFG, 2012)	Reside nts @ 2 perso ns/ 100 M2	% of region al popul ation growt h	R-Code	Comm ercial 100M 2 units	Comm ercial Emplo yees @ 1/20 M2	Retail 100M 2 units	Retail Emplo yees @ 1/25 M2	POS 100 M2 Units	Total Units of 100 M2
■ Various	14,724	0.9	29,448	3.47%	234	2,265.	11,326	566.3	2,265.	629.2	18,185
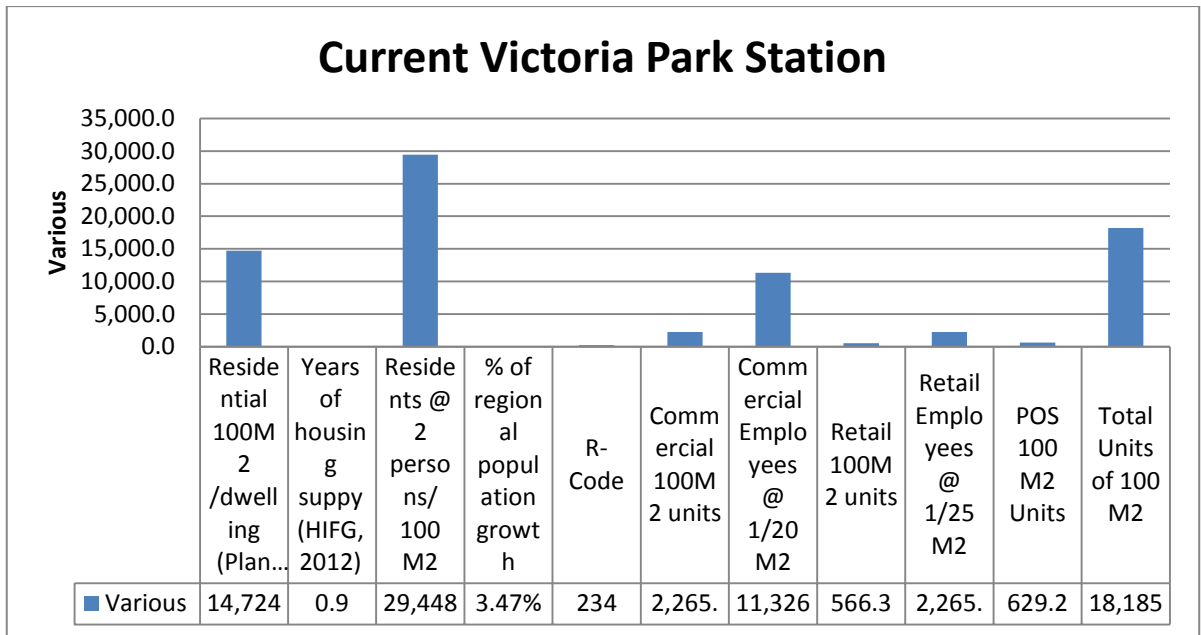
Figure 115 Victoria Park: Compendium of units

THIS CHART INCLUDES RESIDENTIAL UNITS AT 14,724; YEARS OF HOUSING SUPPLY FOR THE REGION

(0.9); AND A PERCENTAGE OF REGIONAL GROWTH ACCOMMODATED (3.47%).

Victoria Park

	Total # Parking Stalls	Total M2 Parking Space	Redevelop ment Total M2	Redevelop ment Total -Parking Space	% Parking Space
■ Victoria Park	24,949	498,988.3	1,755,583.0	1,256,594.7	28.4%
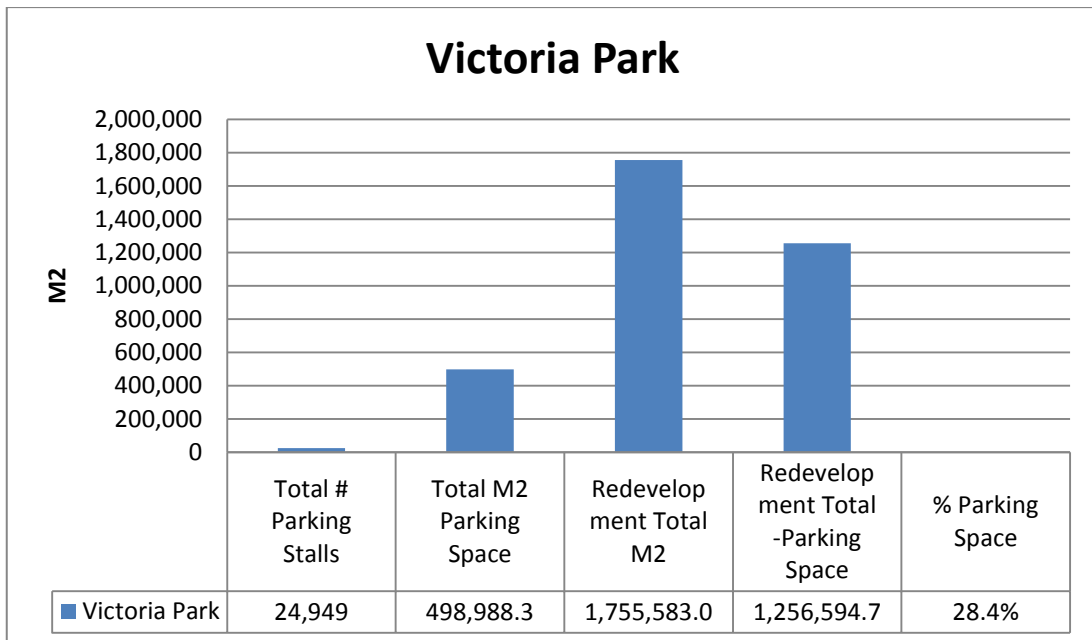
Figure 116 Victoria Park: Parking rates expected based in Road and Transport Authority of New South Wales

Victoria Park

	Residential Trip/ day (RTA) 3.3.2	Commercial Trip/ day/100M2 (RTA) 3.5	Retail Trip/ day/100M2 (RTA) 3.6.1	POS Trip/ day/100M2 (RTA) p.3-23	Total Trip generation
■ Victoria Park	73,621	22,652.7	28,315.9	28,315.9	152,906
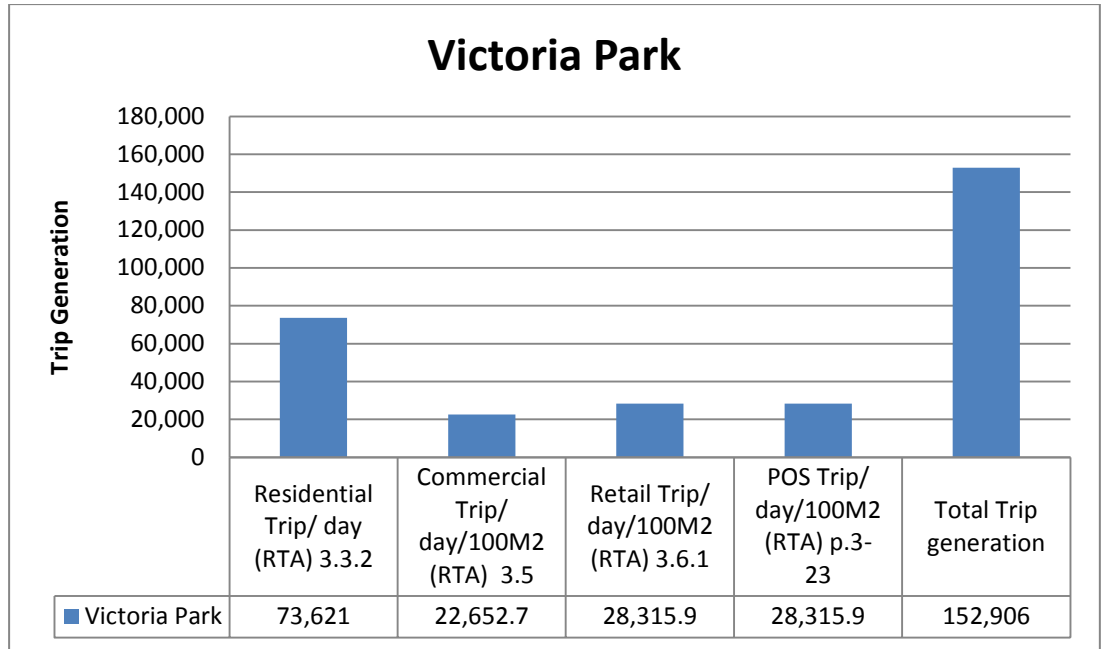
Figure 117 Victoria Park: Trip generation expected based in RTA of NSW

Victoria Park

	Carbon Produced, per person, in Australian BAU (World Bank)	Carbon Produced, per person, in this scenario in Global Best Practice (World Bank)	Total Carbon Saved per person vs. Sprawl in this Scenario
■ Victoria Park	547,741.9	312,154.0	235,587.9
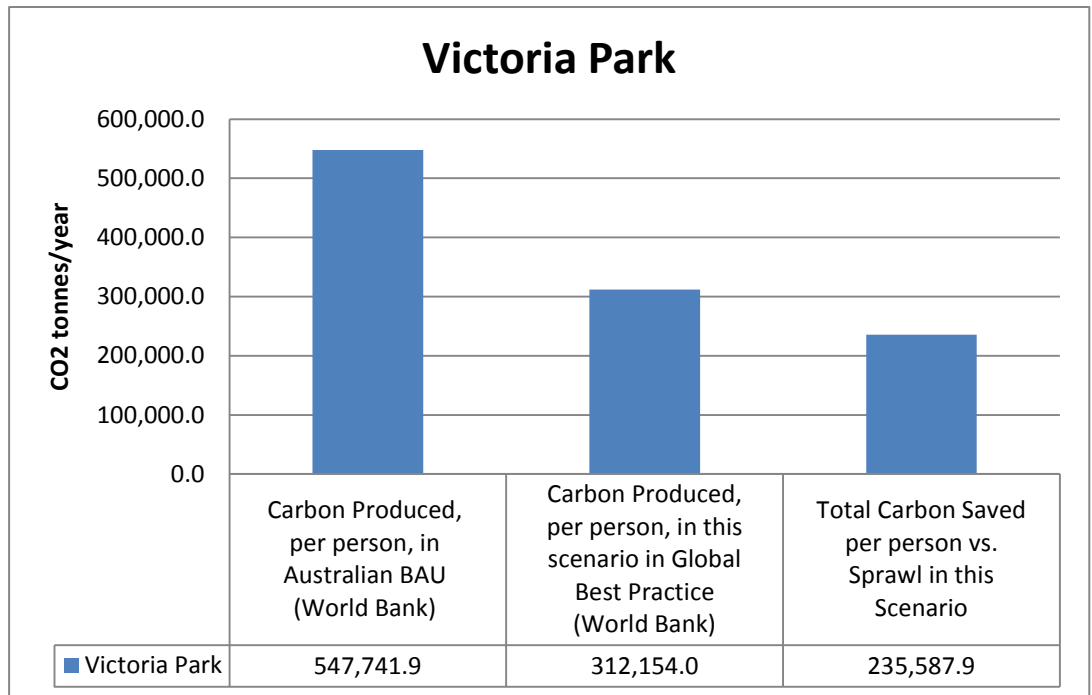
Figure 118 Victoria Park: Carbon improvements per person in Victoria Park
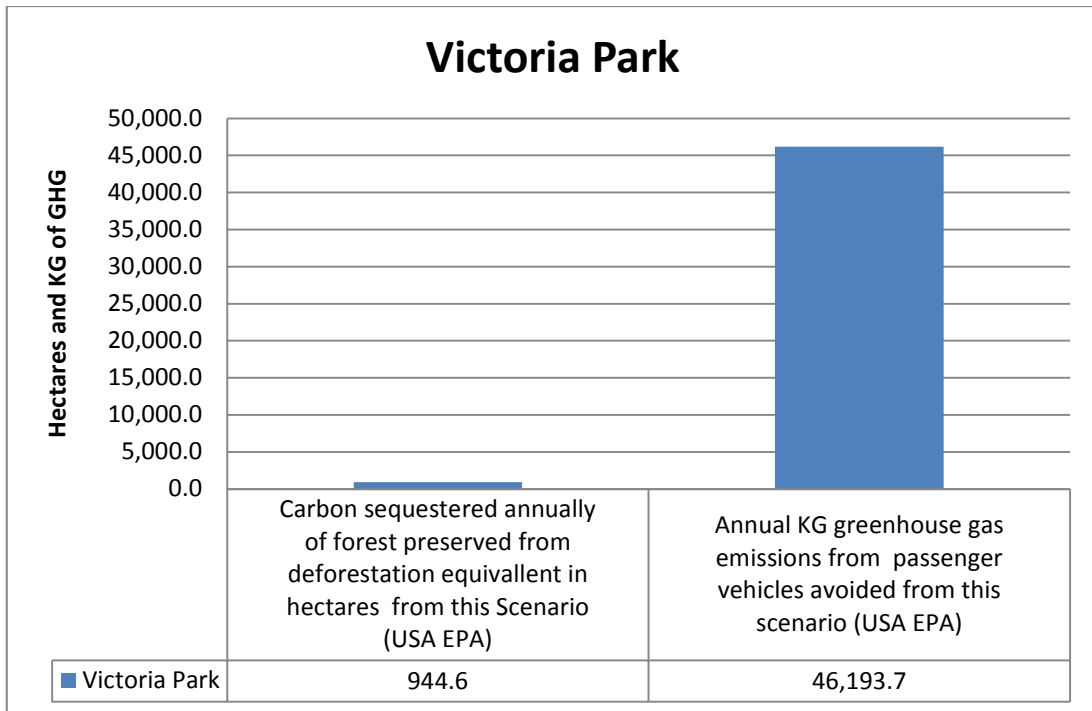
Figure 119 Victoria Park: Carbon and Green House gas benefits from the USA EPA
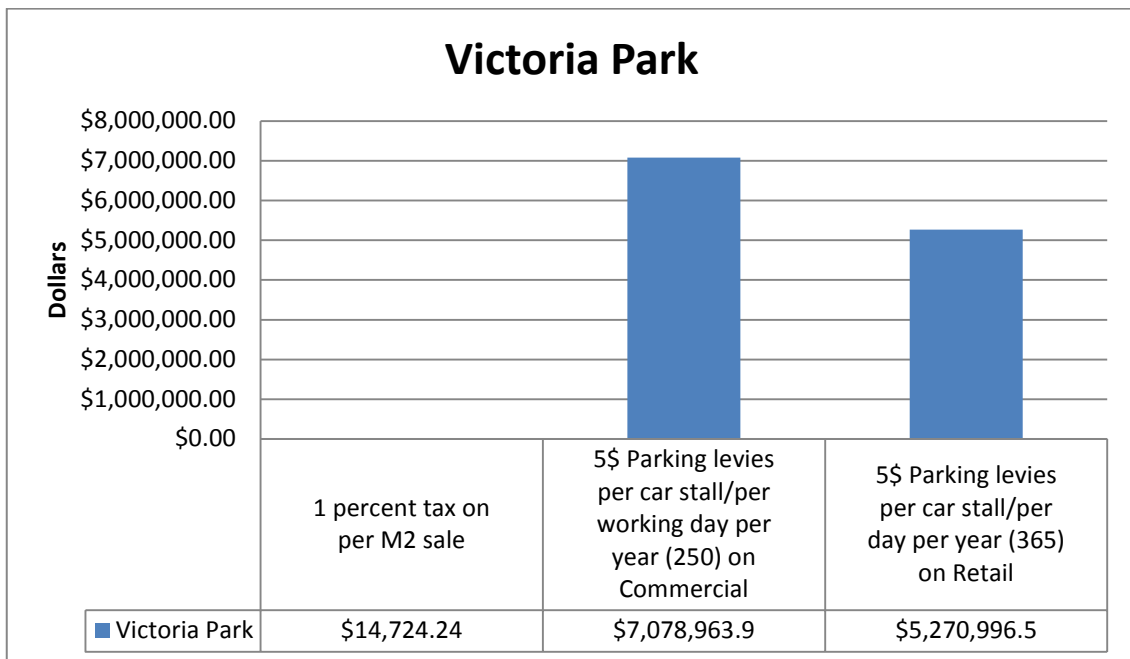
Figure 120 Victoria Park: Indicative Value Capture

Value Capture from a subtle 1% stamp duty tax on residential sales and parking charges on commercial and retail businesses.

Victoria Park

	Total Cost Avoided (Trubka et al) per dwelling/year (over 50 years)
■ Victoria Park	$111,478,141.8

Figure 121 Victoria Park: Total Costs Avoided

Costs Avoided from not needing to construct and maintain electricity, water and sewerage systems and roads infrastructure for infill development in Victoria Park

Victoria Park

	Overall improvement in Walking Rates in HWUE (Trubka et al) km	Dollar Benefit per dwelling per year (Trubka et al) with Healthcare cost only	Dollar Benefit per dwelling per year (Trubka et al) with Healthcare and Productivity
■ Victoria Park	17,227.4	$1,251,560.8	$11,396,565.6
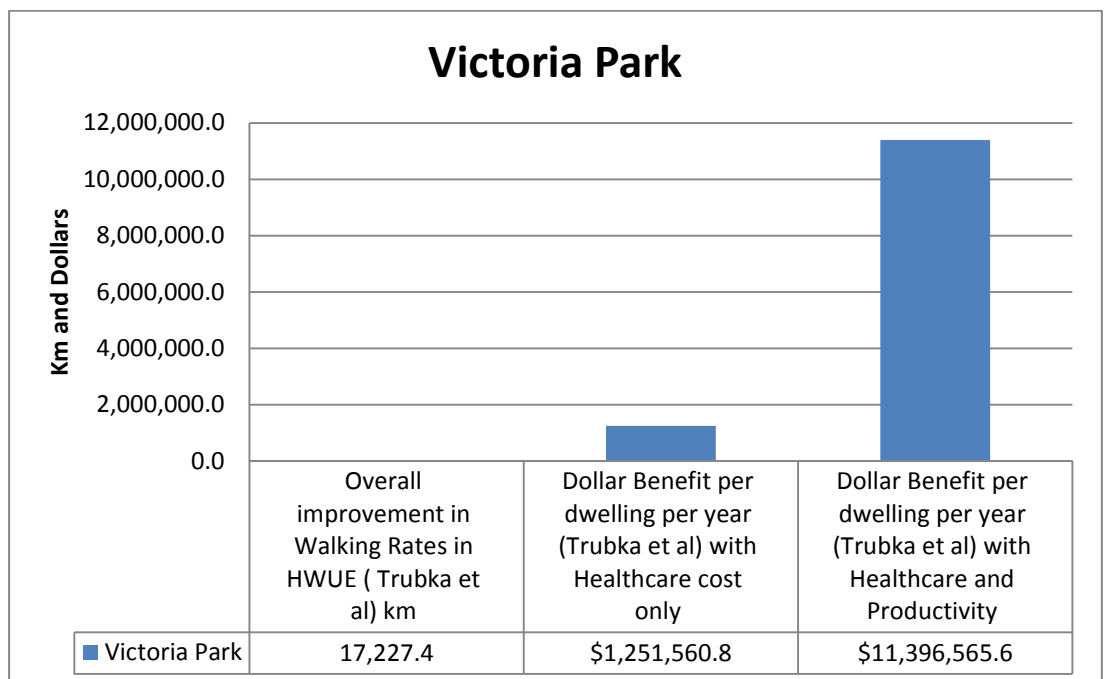
Figure 122 Victoria Park: Walking rate improvement

There are dollar benefits from healthcare improvements and productivity increases due to living in High Walkable Urban Environments (HWUE).

Victoria Park

	Libraries expenses per person/year (ALIA.org.au)	Recreation Area Per person (Cities Institute)	Hospital beds per person (World Bank)	Per capita expenditure on government school's buildings and grounds, WA, 1996–97 ($per student)
Victoria Park	$1,177,939.6	715598.3	111.9	$3,494,554.1
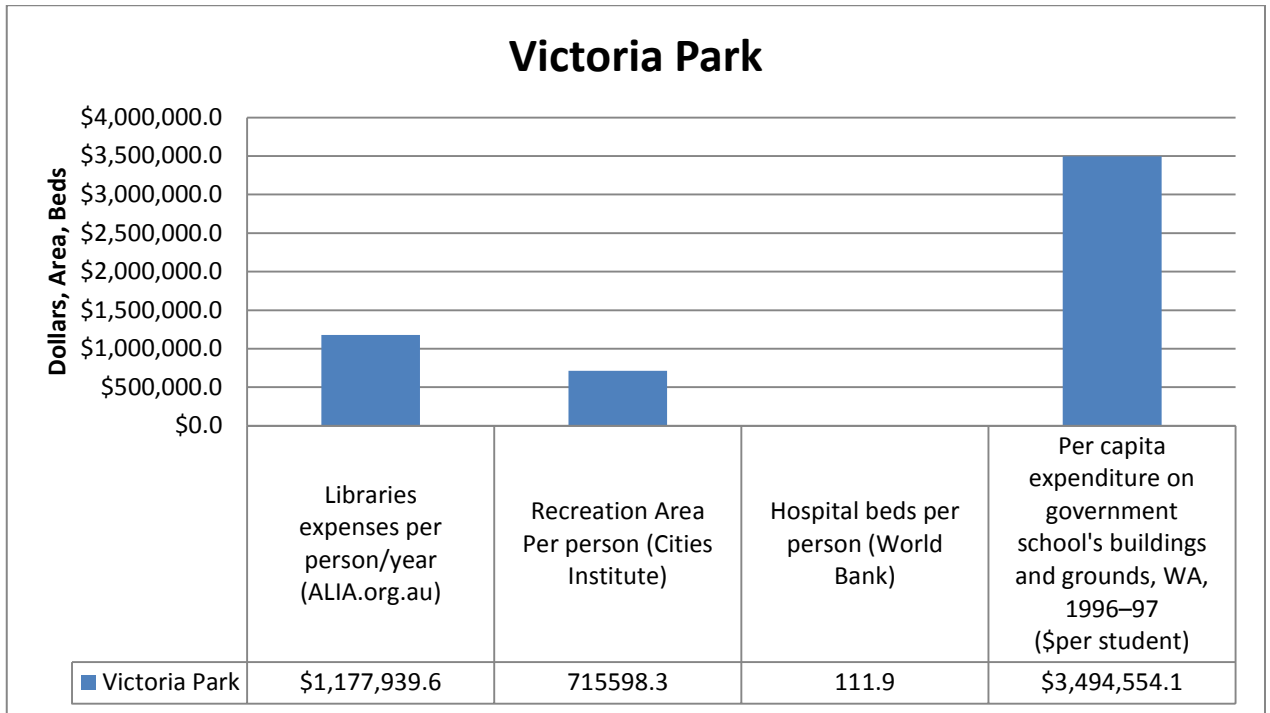
Figure 123 Victoria Park: Public Services

Public services should increase commensurate to population growth.

Victoria Park

	Precinct VKT Change (Trubka)	Transport Time Savings (Trubka et al.)per dwelling per year
Victoria Park	287,122.8	$30,214,151
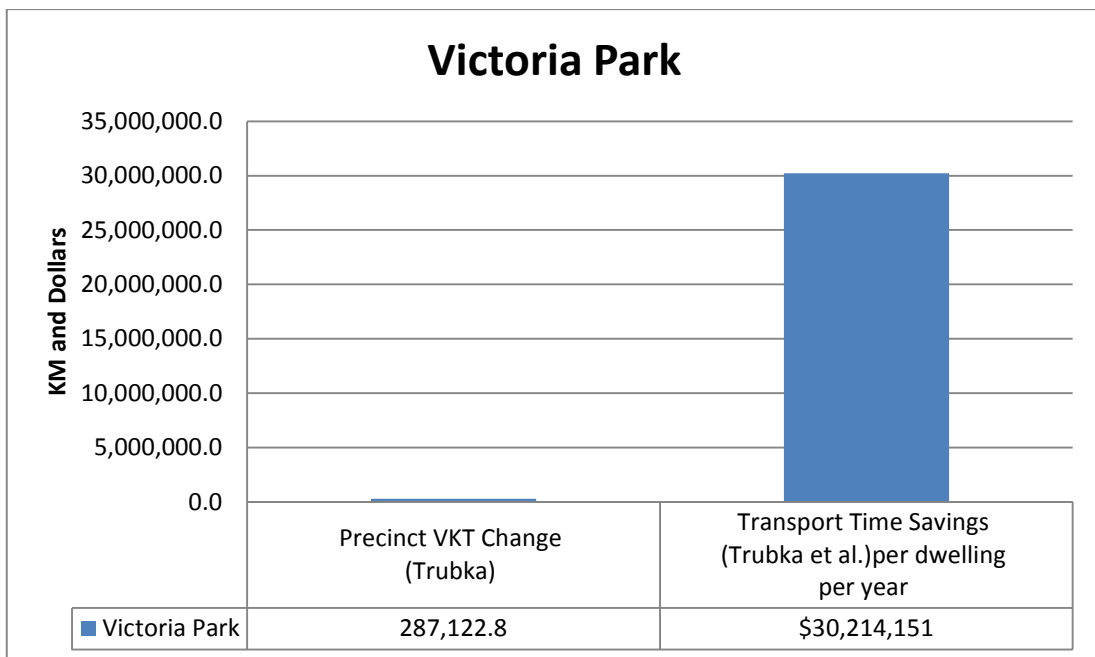
Figure 124 Victoria Park: predicted precinct total Vehicle Kilometre Travelled (VKT).

VKT change and transport time savings per dwelling per year.

4.3.5 CONCLUSION AND SUGGESTIONS FOR MODEL 3.1

Before Victoria Park can achieve any one goal, no matter how moderate or extravagant, there needs to be visioning with local communities, rezoning and infrastructure upgrades. The long-term aim for the area as a part of the much bigger picture of the regional and national growth will have to include a higher degree of mixed uses permitted by zoning, R-code increases to allow increased density as of right, and State direction to make clear the legal status of lot amalgamation strategies. All of these changes will enable land transactions to achieve larger lot parcels. In addition, design guidelines will be required to ensure a minimum of quality and coherent street frontages, underground service upgrades and retention of small scale shops. Future Local Structure Plans, and later visioning masterplan stages, will need to be precise about the end goals so as to reassure the residents and leverage negotiations with potential developers and builders.

The scale of the task of meeting requirements of State Planning Policy 4.2 and projections by the ABS are daunting. There should be no doubt about the need for Victoria Park to share some of the increase in overall metropolitan activity, be it residential solely or as a mixed-use precinct. More importantly Victoria Park should growby exploiting its advantages to become a highly desirable transit-oriented inner city area rich in amenities and services. If an inner city, established locale such as Victoria Park achieves a modest success, surely many other areas of the Perth Metropolitan region will follow suit. The scale of the task to turn Perth from an automobile-oriented way of living to a blended multi-modal city better prepared for the 21st century is large, but can be accomplished precinct by precinct.

It is clear that local and more detailed planning will be necessary to achieve a Transit-Oriented Region: by site, precinct, neighbourhood and council there will be difficulties. This modelling, while speculative and optimistic, demonstrates the levels of benefits and costs, pay-offs and trade-offs, to be aware of when planning for Land Use and Transport Integration in a Transit-Oriented Region.

4.4 RESULTS: THE LOCAL SCALE - STIRLING CITY CENTRE MODEL 3.2

No place is worth visiting that doesn't have a parking problem (Markusoff, 2012).

Model 3.2 remains within the local scale but instead of focussing on calculating what could be achieved by land use planning, it reviews the leading document on planning for the local area under question to uncover the differences in real estate yields with different modes of transportation. The differences are due not to speculation or hype, but to the capacity of a public transport mode to convey passengers per hour and the associated reduction in parking, liberating both surface area and financial capital to build toward maximum allowable heights.

Stirling City Centre, located between Mitchell Freeway and Scarborough Beach Road along the northern commuter rail line, has an ambitious plan to become a second Central Business District. To ascertain what was genuinely attainable as real estate yields, (based in the height, width and mix of use of floor-plates) the researcher prepared a model to demonstrate that: *With each increment of public transit Level of Service, there is a proportional reduction in the need for roads and parking space for cars which adds to the corresponding opportunity to build a denser urban fabric with a higher mix of use and walkability.*

Hyperlink to Local Scale - Stirling
https://www.dropbox.com/sh/rp1f605spi05fsc/AACP55fzUuHQ9K54sBuFTRUua?dl=0

4.4.1 REAL-ESTATE YIELDS

The method employed to determine the optimal 'real-estate yield based in transport provisions' involved a review of all the consultant reports regarding the potential of the site and those prepared by Stirling City and the Stirling City Centre Alliance on a proposal for light rail for the district.

This involved a thorough reading of studies and reports ranging from the initial conceptual ideas for this project to the current understandings of needs and aspirational/potential yields. This was important as, to date, there had been no assessment of different estimates of square metre yields for each of the eight variables considered in this report:

- Residents (dwelling or persons)
- Dwellings per hectare
- M^2 of commercial office space
- M^2 of retail space
- Jobs
- Parking
- Public Open Space (POS)
- Appropriate mode.

While there are more variables to urban development than these eight, these are the primary ones considered in the reports and which are subject to the policy and practice of the Stirling City Council and Stirling Alliance and the Western Australia Planning Commission (WAPC).

The findings were set into a spread sheet with just whole numbers where possible, but often text was the only reference.

Each consultant wrote their study to their own specifications. Some consultants focussed on dwellings, some on persons, some on dwellings or people per hectare; some looked at net or gross floor areas while some wrote only on one topic. Not all reports were pertinent to the whole, but some helped to fill in the gaps based on the lead consultant's opinion and expertise. It should be noted that all the reports either overlapped or used slight variations of the project's impact polygon.

The following figure shows the range of reports presented to the author and reviewed for analysis.

Infrastructure Australia Submission

Program Business Case

Recent Work

Studies not Reviewed

A. A demonstration of collaborative leadership in a city building context, Stirling, Year unknown
B. Business case: Operational and seed funding, Stirling, January 2010
C. Stirling City Centre Structure Plan, October 2010

Studies Reviewed

1. Stirling City Centre Alliance Infrastructure Australia Submission, SCCA, November 2010
2. Program Business Case for the Stirling City Centre Alliance Project, Paxon, June 2012
3. Stirling City Centre Economic & Landuse Mix Assessment, Urbis, March 2012
4. Stirling City Centre Light Rail Feasibility Study - Phase 2, Parsons Brinkerhoff, November 2010
5. Stirling Tram Feasibility Study - Preliminary Patronage Estimates, Parsons Brinkerhoff, February 2010
6. Stirling City Centre Access and Parking Strategy, SKM, August 2010
7. Development Packages, Urbanism, June 2011
8. Herdsman and Glendalough Concept Structure Plan Report, Hassell, January 2011
9. Stirling City Centre Detailed Yields Analysis, Hassell, July 2011
10. Stirling City Centre Urban Typology Framework, CODA & Roberts Day, January 2013

The results of this literature review are summarised in this table:

Table 13 Outcomes of Stirling City Centre Literature

	Residential	Dwell./h	Comm./Office	Retail	Jobs	Parking
High	52,000 people	112	877,000 M^2	461,451M^2	51,500	24,160
Low	1,530 people	30	54,0000 M^2	6,600M^2	7,909	1,692

Though the figures for Floor Space Yields from the study reports for Residential, Commercial and Retail land uses are to be taken as educated estimates, it is important to have a targets for people, cars and transit services which the planning process can achieve. (see Table 10 Outcomes of Stirling City Centre Literature). Success will be measured by uptake of opportunities by developers, residents, and commercial and retail lease holders. It is also important to deal with Traffic Impact Assessments (TIA) on a project by project basis and to plan for the anticipated number of people and their cars so that appropriate levels of service can be built in to the urban fabric. This includes sewerage and water systems, numbers and widths of traffic lanes, kilometres and widths of dedicated cycle lanes, mode and capacity of public transit, provision for schools, public open space and parking. Success will be measured by comfort and liveability.

Understanding the relationship between urban form, transit and parking is crucial.

4.4.2   METHOD TO LOCAL SCALE: MODEL 3.2

Using the land use and density tables provided by the Stirling Alliance a model was developed to understand the interaction between height of buildings, mix of land uses, reservations for Public Open Space and setbacks, and the influence that surface or structured parking might have on the potential for a precinct to be both walkable and

transit serviceable. This algorithm essentially tries to add quantitative rigour to the theory of Land use and Transport Integration (LUTI) through urban design and the development process.

4.4.2.1 LAND USE AND TRANSPORT INTEGRATION INDEX

Three groups of factors are identified from the base information to better understand the relationships between these variables: the Land Efficiency Factor, Transport and Land Use Factor and the Composite Index which unifies the previous two. Together they form the Land Use and Transport Integration Index.
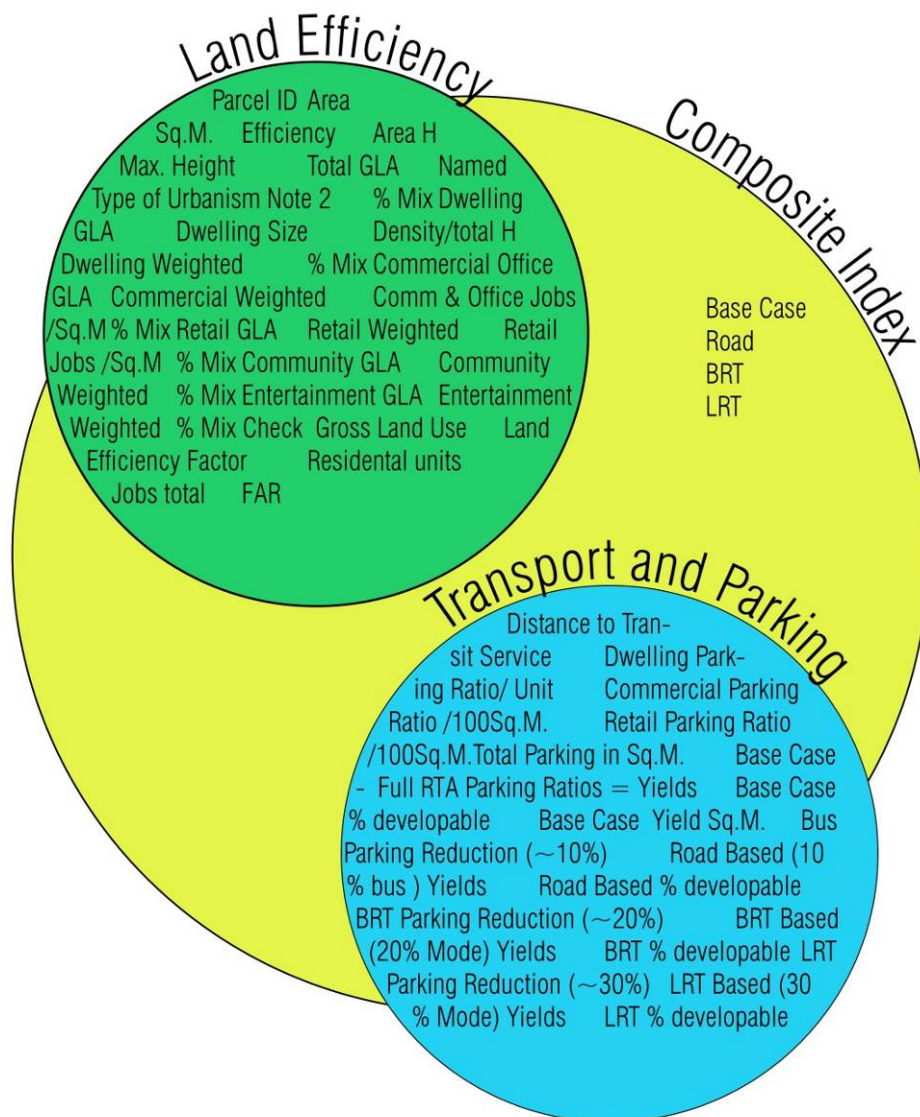
Figure 125 Diagram of the Land Use and Transport Integration Index

LAND EFFICIENCY

Using Excel as a spreadsheet to arrange the model, the basic units of square metres (denoted as m^2 or sq.m.) for residential, retail and commercial office space were multiplied by the percentage of urban form to be devoted to each land use and multiplied again by the number of floors predicted for each precinct of urban fabric. This reveals the *aspirational* Net Lettable Area for each land use type, block by block and precinct by precinct across the whole of the SCC.

TRANSPORT AND PARKING FACTOR

The impact of various transit modes on the capacity of the built form to realise the *aspirations* of Land Efficiency must then be assessed; this is described as the Transport and Parking Factor. The different transport modes are:

- Base Case (no Public Transit, fully reliant on the NSW's GTGD),
- Road (with a regular bus service),
- Bus Rapid Transit (on a separate Right-of-Way or with lane priority), and
- Light Rail Transit (on a separate Right-of-Way or with lane priority).

GUIDE TO TRAFFIC GENERATING DEVELOPMENTS

Table 14 Quick Guide to RTA of NSW Guide to Traffic Generating Developments

Residential Parking	Residential Trip Generation	Commercial Parking	Commercial Trip Generation	Retail Parking	Retail Trip Generation
1 per Apartment Unit	5 per unit	2.50 per 100M^2	10 per 100M^2	5.10 per 100M^2	50 per 100M^2

Main Roads of Western Australia (MRWA) directs us to use the New South Wales Road and Transport Authority's (RTA) Guide as a basis for decisions on traffic generation and parking ratios. The RTA's guide is considered a standard for Australia.

With this established, we are able calculate day time and night time populations as well as predict traffic generation and parking requirements according to the RTA.

Note 1	MODE CAPACITIES FROM PB FEASIBILITY REPORT	Capacity	Hours of transit	Daily Trips	% Capacity	Remainder	Note	
			12	1,145,508			RTA Trips is 5 per residence, 10 per commercial 100 Sq.M. and 50 per retail 100 Sq.M.	Page reference
	Bus	6,600	79,200		0.07	0.9	Bus: peak hour capacity of up to 6,800 passengers per direction. 4000 typical	10
	BRT	20,000	240,000		0.21	0.8	BRT: 4,000–20,000 passenger per hour	19
	LRT	30,000	360,000		0.31	0.7	LRT: 9,000–32,000 per hour typical. LRT systems can achieve a throughput of between 30,000 and 40,000 passengers per hour. However, this requires high levels of vehicles per hour and high priority within the corridor.	4, 24,25

Figure 126 Mode Capacity Chart from the model

The capacity of each mode (see Figure 125 Mode Capacity Chart from the model) to accommodate the aspired to 'daily trips' stemming from the land use was used to reduce the parking ratios required for each lot of land. The parking reduction rate is the inverse of the transit mode's ability to carry 12 hours of heavy transit requirements. This inversing of the numbers maintains a transparent balance.

This reveals the real-estate 'yield' of floor space (see, for example, Figure 131 Transport Scenario Yields) and a percentage of the project area (Figure 132 Total SCC: Percent Developable) which might be 'developable' based on the transit modes planned and provided to the SCC. This, of course, has huge implications for understanding the volume and dimensions of physical services to be provided by the city and state to accommodate these residents and workers. It also is significant for understanding the potential for Value Capture in these areas for investment in public transit.

C O M P O S I T E   I N D E X :

What this model demonstrates is how growth of activity intensity in an area begins to determine the transportation system required to fuel that growth. This is not the 'predict and provide' modelling which has predicted and indeed provided space for automobile-oriented low-slung sprawl over the last 40 years. Rather this is a 'relational model' demonstrating the pay-offs and trade-offs for each decision made on transit provision, parking ratios, density and height, mix-of-use and public open space reserves. Though there are many obstacles to implementation, there are many options for policy makers, planners and designers to help shape the city; this has been known, but the relationship has rarely been demonstrated in a clear and transparent model.

To help understand the influence and the degree to which any one variable affects all the others, a Composite Index was developed to demonstrate the step-changes in the delivery of higher efficiency land and higher service public transport delivery.

The composite index is the percentage developable (as decimal) of each transit mode scenario in the Transport and Parking Factor multiplied by the Land Efficiency Factor divided by the Distance to Transit. The result is a roughly whole number, to two decimal places, which can be graphed, as shown in Figure 133 Total SCC: Composite Index Score.

4.4.3   EQUATION TO LOCAL SCALE: MODEL 3.2

Y^{123}	Yield of Real Estate	LE	Land Efficiency
A	Area	U	Residential Units
E	Efficiency being Area minus POS; setbacks; right-of-ways for utilities, internal roads and surface parking	FAR	Floor Area Ratio
H^{123}	Maximum allowable height on an area due to precinct size (small precincts have lower heights allowed)	Tr	Trips expected from GLA[12345]
M^{123456}	Mix of Dwellings, Commercial, Retail, Community and Entertainment land uses	Di	Distance to Transit Service
GLA	Gross Lettable Area	Pk^{123}	M^3 Parking expected from Units
GLA_w^{12345}	GLA Weighted	Pr^{1234}	Parking Ratio based on Mode Scenarios
S^{123}	Size of residential, Commercial or retail space per person	MY^{1234}	M^3 Yields based on Mode Scenarios
R	Resident	D^{1234}	% Developable based on Mode Scenarios
J	Jobs in Commercial and Retail	$Mode^{1234}$	Mode capacity to move person per hour

Tr	Trips expected from GLA	Mode$_a$^{1234}	Allowed increase in Development due to reduction of parking
		CI	Composite Index

Expressed as an equation, the model may be expressed thus:

$$GLA = E \times H^{123} M^{123456}$$

$$U = \frac{Dwelling\ GLA}{Sd}$$

$$LE = \frac{GLA_{W^{12345}}}{E}$$

$$FAR = \frac{GLA^{12345}}{A}$$

$$Y = Pk^{1232} \times Mode^{1234} \times Mode_a^{1234}$$

$$D^{1234} = \frac{Y}{GLA^{12345}}$$

$$CI = \frac{D^{1234} \times LE}{Di}$$

Model 3 uncovers Yield as the amplification of C (Capacity from Model 2) with modifications for reduced parking due to increased transit provisions multiplied by the increased floor area this creates. It is equal to Parking scenario 1, 2 or 3 multiplied by the public transport Mode (*M*) capacity 1, 2 or 3 which signifies how much the parking may be reduced from the base case. This is multiplied again by the allowable increase in built form due to the decrease in parking.

$$\mathbf{Y = Pk^{1232} \times Mode^{1234} \times Mode_a{}^{1234}}$$

4.4.4   RESULTS OF LOCAL SCALE: MODEL 3.2

The results, below, demonstrate that there is sufficient capacity in the land base and within the suggested urban fabric volume (building floors) illustrated in a report prepared by Hassell, an Australian consulting firm, from 2011. However, what is also demonstrated in the Land Efficiency columns is that with each level of service in Public Transport *and the concomitant reduction in parking ratios* there is an increase in the Transport and Parking Factor. It is notable the area with the greater Floor Area Ratio (FAR) and the greatest mix of residential, office and retail uses is where there are the greatest gains in efficiency if higher order public transit service is inserted as a co-condition of urban consolidation, along with parking ratio reductions.

The Total Southern Precinct and 2G 2H1- 2H4 Block will be used as examples of the model's results for the Stirling City Centre (SCC). It would be pointless to demonstrate, in charts, all the results of all the blocks and precincts. In this first example, the Total SCC, there will be an expanded discussion on the role and function of the model. The following sections will demonstrate the ability of this model reveal the potential of each block of the Precincts, and up to the next scale of the SCC in its entirety, to become a high-capacity transit and high real-estate yield Activity Centre.

Legend

Stirling City Centre

Color	Storeys
15 Storeys	
12 Storeys	
10 Storeys	
8 Storeys	
7 Storeys	
6 Storeys	
5 Storeys	
4 Storeys	
3 Storeys	
2 Storeys	
1 Storey	

Note:
Indicative of maximum height within each streetblock. DAP's will identify specific distribution of building heights.

Revision	Date	Scale	Client	Project Name	Drawing
A/Plot Ratios	28 June 2011	1:12,500@A4	City of Stirling	Stirling City Centre Stirling	SK095A Stirling City Centre Yields
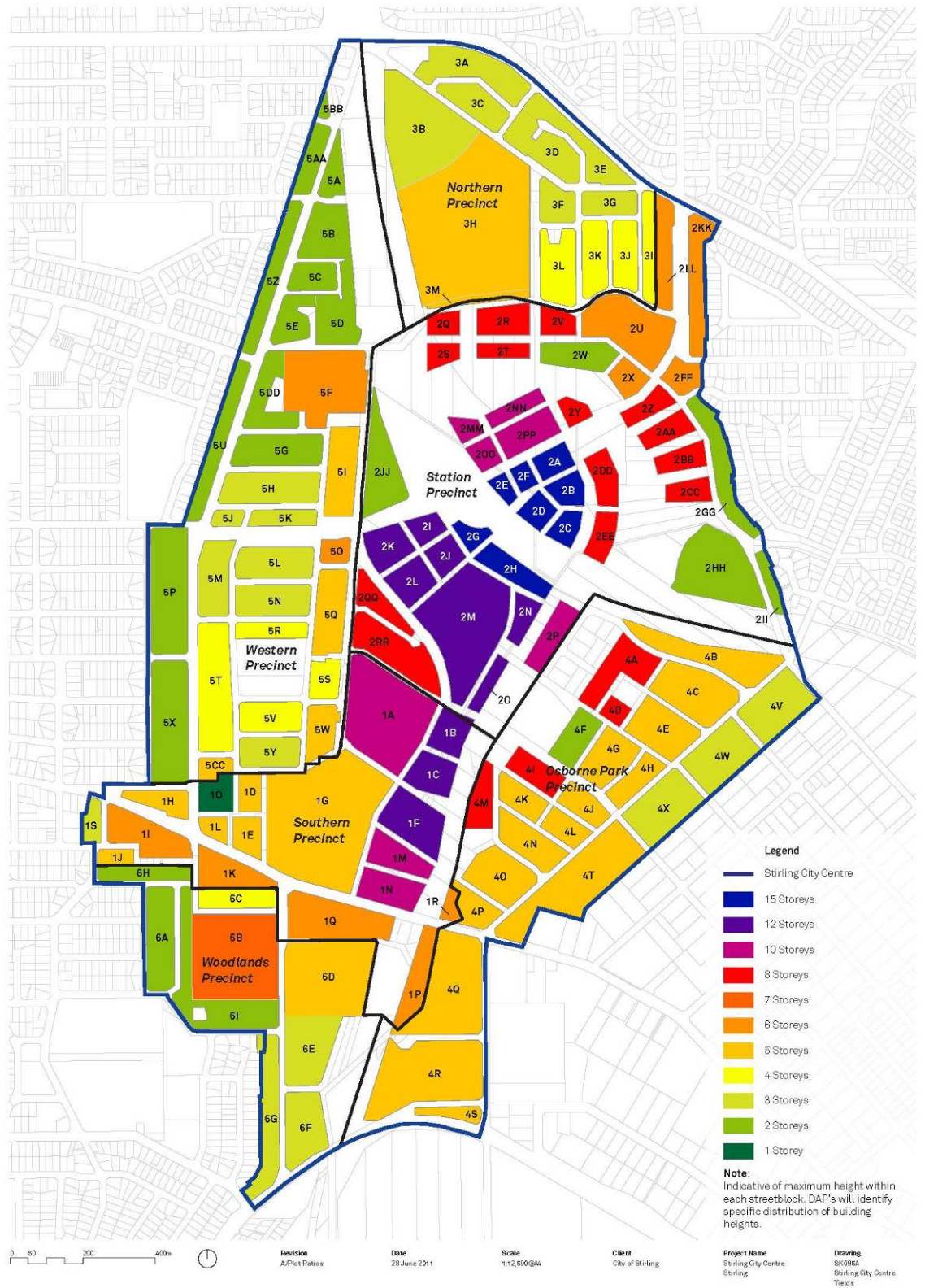
HASSELL

G:\pro\ple\02\PPP0255\17 Drawings\17b_Media\Illustrator\Housing Strategy Study\PPP0255_SK095A_Stirling City Centre Yields_ai

Figure 127 Total SCC area and Precincts

SOURCE: HASSELL CONSULTING

4.4.4.1 TOTAL STIRLING CENTRAL CITY RESULTS

This first charts show the results of the entire project site. Most of these charts are only intended to convey results in the most efficient manner possible.

Total SCC: Area, GLA and FAR

	Area Sq.M.	Efficiency	Max. Height	Total GLA	FAR
TOTAL	2,116,915	1,270,149.00	6.2	7,864,484.22	3.72
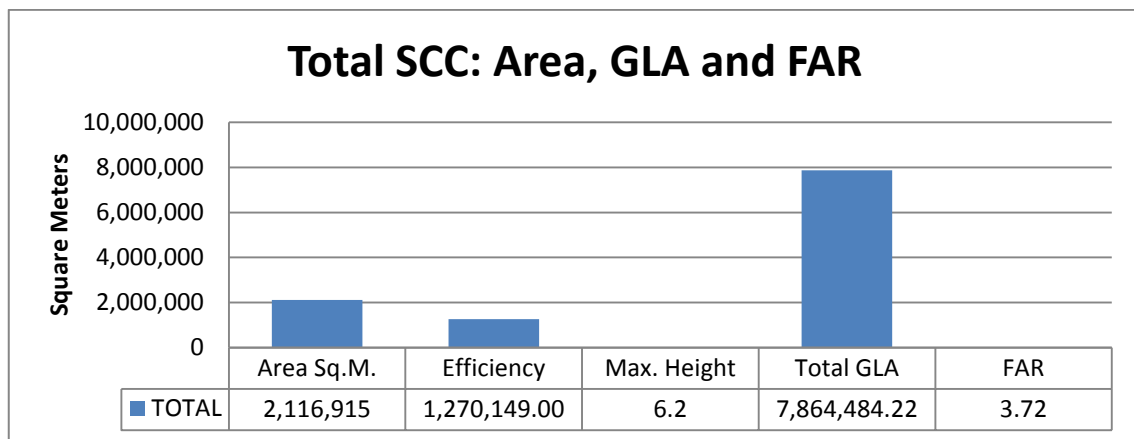
Figure 128 Total Stirling City Centre (SCC): Area, GLA and FAR

This first chart represents the metres squared of the entire project site. This is a compilation of the size of all the blocks in each precinct, lot by lot, expressed as Area. Efficiency, as a term here, is the reduction of land taken from that base area for Public or Private Open Space, internal roads and drives, setbacks, utility reserves and other. Maximum Height is the *average* maximum height across the entire SCC. Total GLA is the Gross Lettable Area once the land area is increased to the allowable maximum. As Gross, not Net, it is effectively the 'envelope' of the building including stairs, corridors, lobbies, walls and other such areas which will eventuate in a reduced Net figure. FAR is the Floor Area Ratio which is the total Gross Lettable Area divided (/) by the Area sq.m. In this instance it is 7.8 million / 2.1 million m^2 which results in a figure of 3.72. In global terms, 3.72 is very modest for an urban area but certainly 'urban' in feel. It represents approximately 3.7 times the lot coverage, or roughly the same as, for example, a 4 floor building with a very modest setback and a minor courtyard. See Table 12 Floor Area Ratio explained (below) for more on this topic.

Floor Area Ratio (FAR)

The floor area ratio is the principal bulk regulation controlling the size of buildings. FAR is the ratio of total building floor area to the area of its zoning lot. Each zoning district has an FAR which, when multiplied by the lot area of the zoning lot, produces the maximum amount of floor area allowable on that zoning lot. For example, on a 10,000 square foot zoning lot in a district with a maximum FAR of 1.0, the floor area on the zoning lot cannot exceed 10,000 square feet.

From: New York City Department of Planning Zoning Glossary

http://www.nyc.gov/html/dcp/html/zone/glossary.shtml#floor
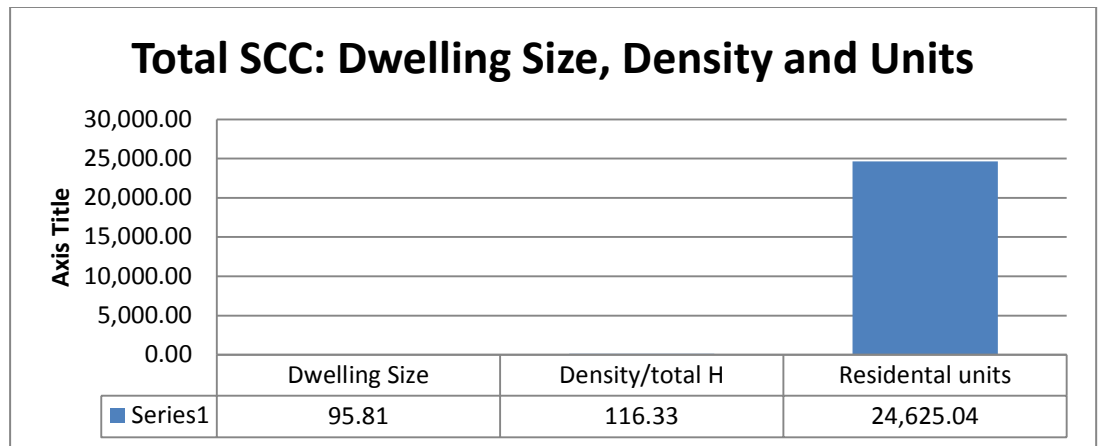
Total SCC: Dwelling Size, Density and Units

	Dwelling Size	Density/total H	Residental units
■ Series1	95.81	116.33	24,625.04

The average dwelling size across the entire SCC is shown to be almost 96 m^2 with an average density of 116 dwellings per hectare equalling 24, 625 dwelling units. This is derived from Residential land use only being given a 30% value of the total m^2 of 'yield'. If this were raised, as it most undoubtedly will be in detailed modelling, there would be a

much higher number of residential units. However, likewise, if the 'land efficiency' were changed or the height limits altered these numbers will rise or fall immediately. At this stage in the modelling these results only represent *aspirational* yields, untempered by transport limitations.
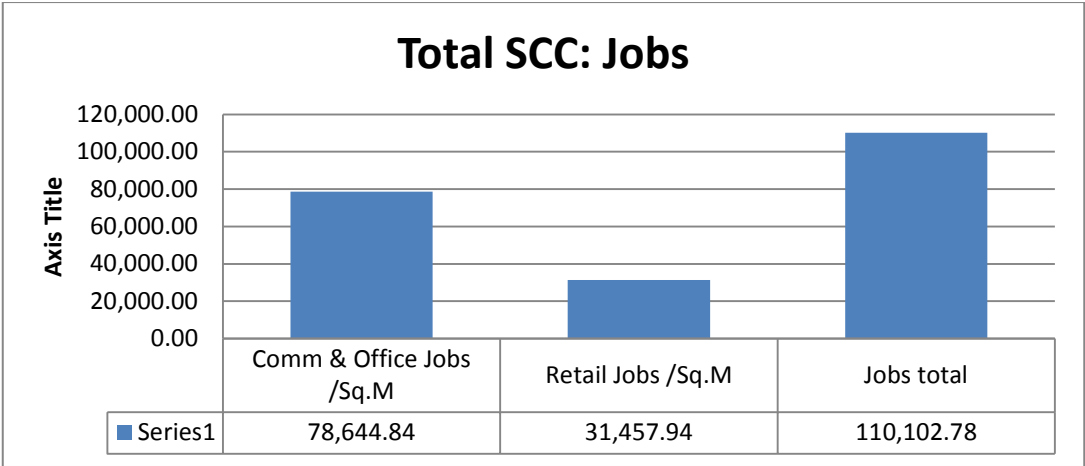
Figure 130 Total SCC: Jobs

Commercial and Office property yields could generate over 78, 600 jobs and Retail could produce 31,400 given a 30% mix and 20% land use mix, respectively. This demonstrates *aspirational* 'yields' in **one** scenario. However, this will be most likely reduced in detailed modelling as in some locations the SCCA will allocate a much higher proportion of land use to both Commercial and or Retail, near transit corridors, while in other residential areas it may not be seen as appropriate to have as high a rate of job creation.

The Land Efficiency Factor of the Total SCC is 1.58. While this is an abstract number, it represents the weighting of value (between .01 and 1.00 with the sum equalling no more or less than 1.00) of the specific mix of land uses on a given block or precinct *divided* by the land available after the initial efficiency is taken into consideration. This number will rise or fall in detailed modelling when the efficiency of land is altered and when the default values are shifted to reflect attitudes about how important certain land uses are to the creation of the Stirling City Centre.

Total SCC: Parking by land uses and in total Meters Squared in Base case

	Dwelling Parking Ratio/ Unit	Commercial Parking Ratio /100Sq.M.	Retail Parking Ratio /100Sq.M.	Total Parking in Sq.M.
■ Series1	24,625.04	58,983.63	80,217.74	3,931,833.91

Figure 131 Total SCC: Parking

This chart shows, in the first three columns, the numbers of parking spaces for each dominant land use according to the NSW RTA's Guide.[43] The column on the far right hand side shows the impact in m^2. It is a dramatic number, at almost 4 million square metres, especially when the total aspired to Gross Lettable Area is only 7.8 million. The effects of this parking ratio application will be shown in the following two charts.

Total SCC: Transport Scenario Yields

	Base Case Yield Sq.M.	Road Based (10 % bus) Yields Note 1	BRT Based (20% Mode) Yields Note 1	LRT Based (30 % Mode) Yields Note 1
■ Series1	3,932,650.31	4,876,355.76	6,763,766.66	8,179,324.84

Figure 132 Transport Scenario Yields

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[43] New South Wales Road and Traffic Authority 'Guide to Traffic Generation'
http://www.rta.nsw.gov.au/roadprojects/community_environment/documents/guide_to_generating_traffic_developments.pdf

If the aspirational 'yields' are combined with the number of daily trips generated[44] with the transit mode capacity (Figure 125 Mode Capacity Chart) there is a sharp diminution of the possible yields due to the reality that if a portion of a building's fabric and/or capital is to go towards parking there is an equal reduction in lettable area, or 'yield'.

Developers will stop projects if there is too much cost (parking) without enough return (yield), and reduce the scope of a project. Ultimately, a parcel of land will trend under these market restricting policies towards what we do find 'predict and provide' transport models produce: low-density car-dominated suburban fabric.

On the positive side, however, we see clearly that Light Rail Transit, or a transit mode of similar hourly capacity, can provide enough non-Single Occupant Vehicle movements to be able to reduce the parking requirements enough to allow the expected aspirational yields.

With a high capacity, high frequency transit service, the yields can be expected to rise as the Transport Impact Assessments can be expected to permit higher density and day-time activity in the precincts.

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[44] New South Wales' Road and Traffic Authority 'Guide to Traffic Generation'
http://www.rta.nsw.gov.au/roadprojects/community_environment/documents/guide_to_generating_traffic_developments.pdf

Total SCC: Percent Developable of GLA

	Base Case % developable	Road Based % developable	BRT % developable	LRT % developable
Series1	0.50	0.62	0.86	1.04

Percent as decimal (y-axis: 0.00 to 1.20)
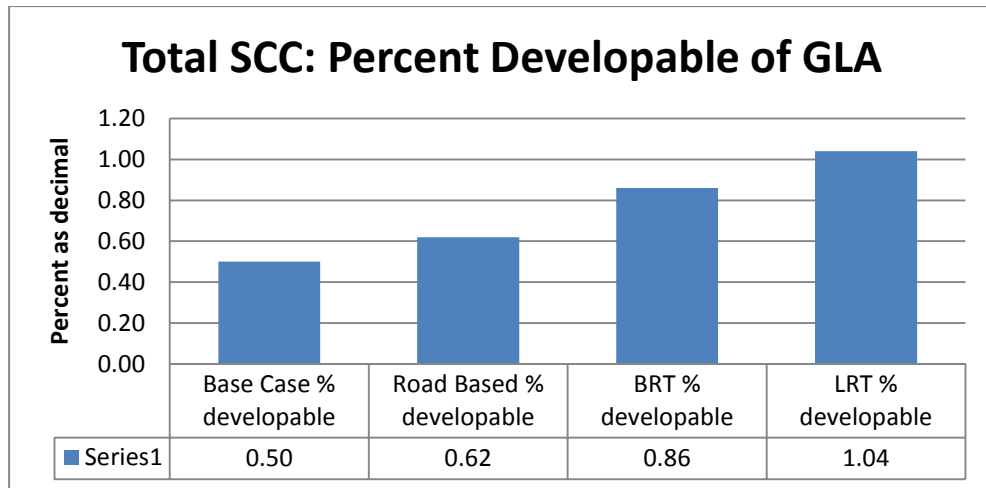
Figure 133 Total SCC: Percent Developable

This chart reflects the percent, as decimals, in development yields the SCCA may expect for the SCC if parking ratios are reduced and transit is provided. A Light Rail Transport service will be able to accommodate the transport needs of 104%, or more than is aspired to, in this scenario.

Total SCC: Composite Index Score

	Base Case	Road	BRT	LRT
Series1	1.85	2.30	3.18	3.85

Composite Index (y-axis: 0.00 to 5.00)
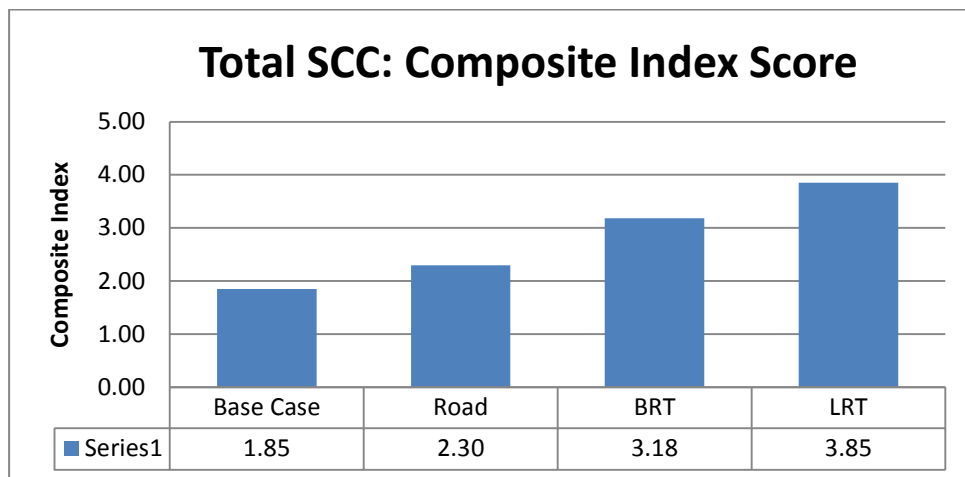
Figure 134 Total SCC: Composite Index Score

The composite index reflects, more abstractly, the relationship between parking, transit, yields, heights, distance to transit, land use mixes and land efficiency. It shows how much more 'integrated' the scenario with high capacity and high frequency transit may be for the SCC. It demonstrates a change in 2 points from the base case (of no transit provision).

The composite index is the percentage developable (as decimals) of each transit mode scenario in the Transport and Parking Factor multiplied by the Land Efficiency Factor and divided by the Distance to Transit.

The Southern Precinct will be used as an example of results for one precinct of the Stirling City Centre (SCC). It would be pointless to demonstrate, in charts, the results for all the blocks and all the precincts. In this section on the Southern Precinct the discussion will be limited to singular outstanding points.
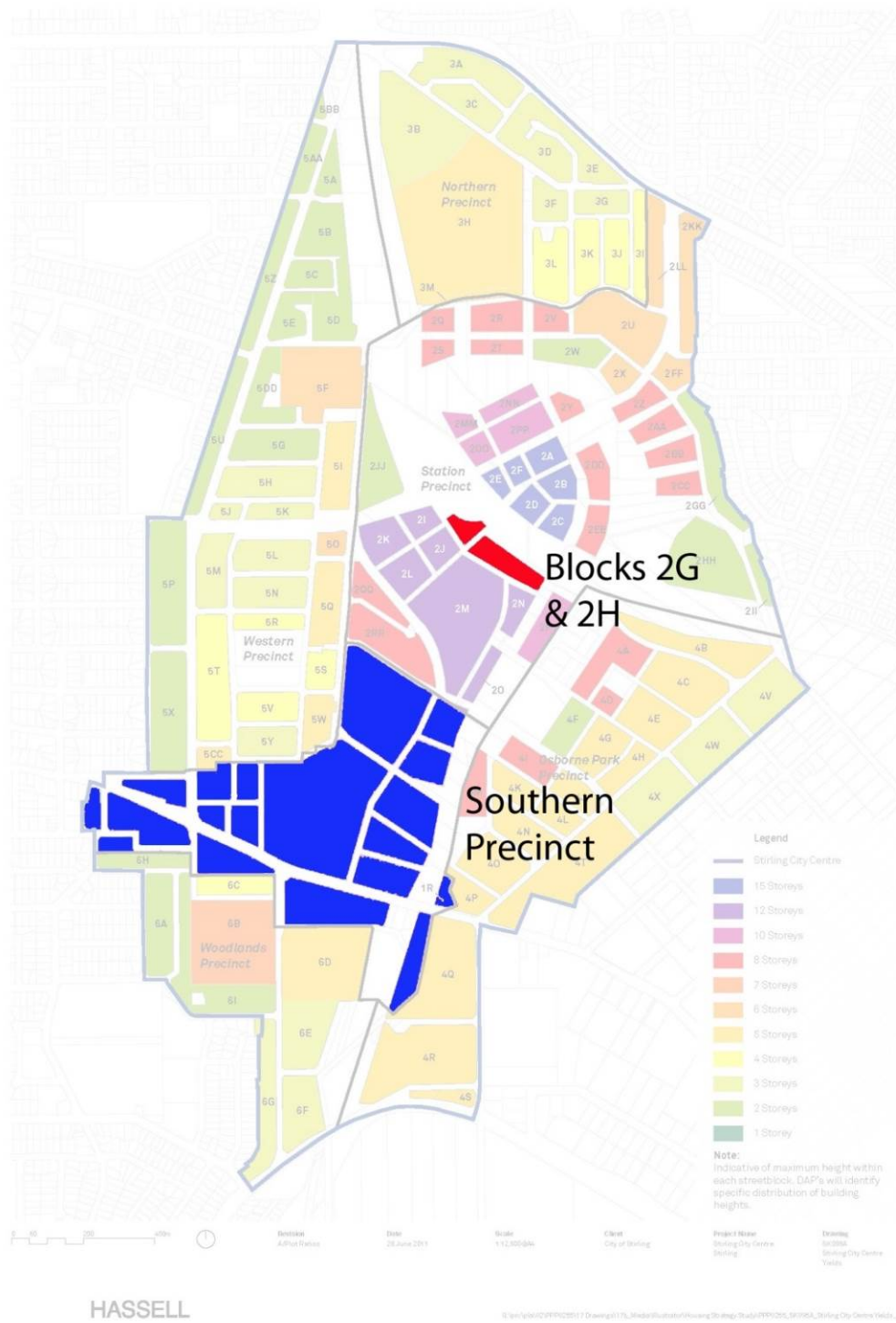
Figure 135 SCC with Southern (Blue) and Blocks 2G & 2H (Red) outlined

Southern: Area, GLA and FAR

	Area Sq.M.	Efficiency	Max. Height	Total GLA	FAR
Southern	287,835	172,701.00	7.4	1,272,870.33	4.42
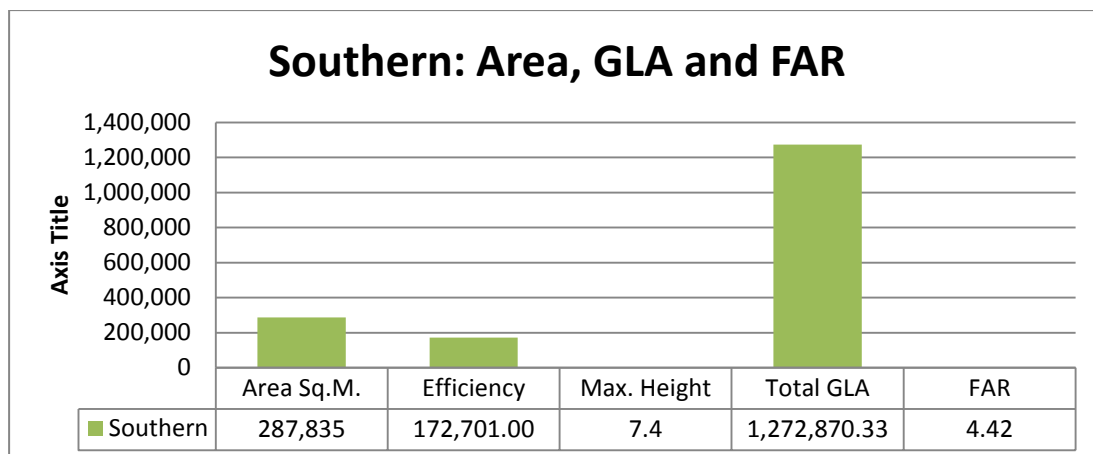
Figure 136 Southern: Area, GLA and FAR

The FAR (see Table 12 Floor Area Ratio explained) in this precinct is 4.42 which gives an indication of the relative 'urban' character. This is somewhat more 'urban' than the average across the SCC, 3.72, though it is not as high as the Station Precinct at 5.45. This FAR number will change in detailed modelling as floor height maximums are altered creating more mass and land efficiencies change and allowing more building bulk over the land.

Southern: Dwelling Size, Density and Units

	Dwelling Size	Density/total H	Residental units
Series1	80	166	4,773
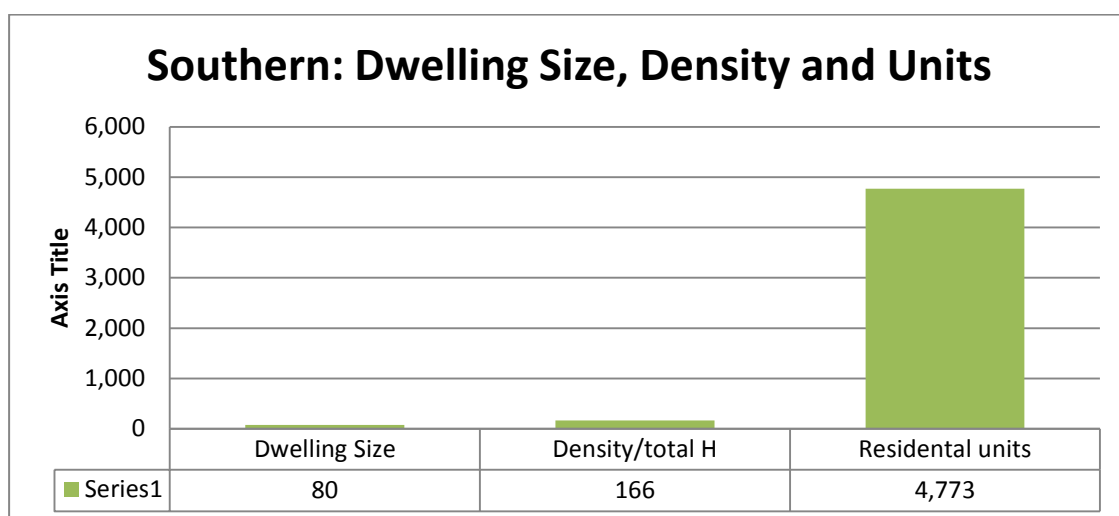
Figure 137 Southern: Dwelling Size, Density and Units

In the Southern Precinct the density will increase noticeably up to 165 dwellings per hectare, based on an average of 80 m^2 for each unit. This is an increase over the 116 dwellings per hectare average across the SCC, but not as high as the 175 dwellings per

hectare which may eventuate at the Station Precinct in the aspirational 15 storey maximum scenario.

Southern: Jobs

	Comm & Office Jobs /Sq.M	Retail Jobs /Sq.M	Jobs total
■ Series1	12,728.70	5,091.48	17,820.18

(Axis Title, y-axis values: 0.00, 5,000.00, 10,000.00, 15,000.00, 20,000.00)
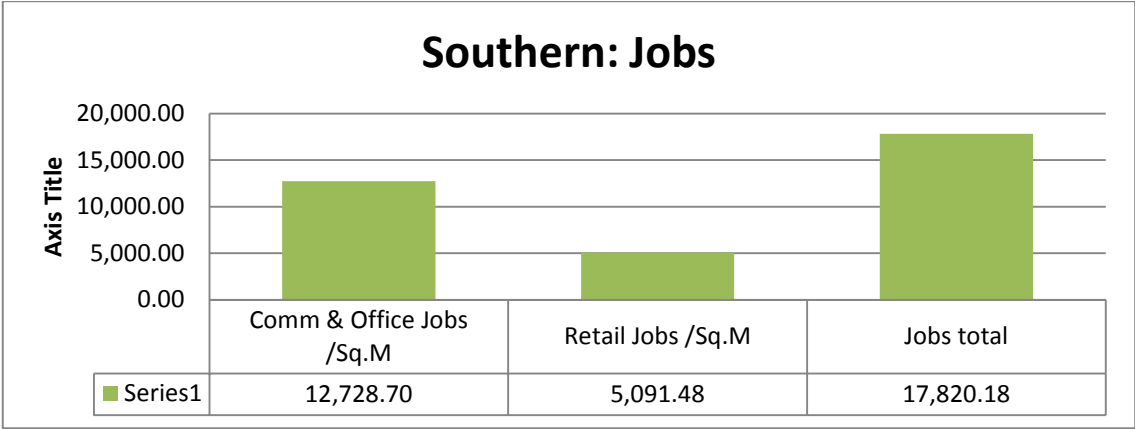
Figure 138 Southern: Jobs

Commercial and Retail jobs in the Southern Precinct, where most jobs currently are located in the malls, large format spaces and street front shops along the Scarborough Beach Road, are set to increase many fold with the envisaged intensity of activity. In this area alone there may be close to 18,000 jobs if the aspirational build-out is approached. The resulting number of morning and evening commutes, not to mention business to business activity and shopping trips, makes a high frequency and high capacity transit mode a fundamentally necessary part of the redevelopment project.

The Land Efficiency Factor of the Southern Precinct is 1.88. This is higher than the overall Total SCC, at 1.58, but would be higher if it were not for a few parcels of land (for example, Western Power's lot) which lower its average. While this is an abstract number, it represents the weighting of value (between 0.01 and 1.00 with the sum equalling no more or less than 1.00) of the specific mix of land uses on a given block or precinct *divided* by the land available after the initial efficiency is taken into consideration. This number will rise or fall in detailed modelling when the efficiency of land is altered and when the default values are shifted to reflect attitudes about how important certain land uses are to the creation of the Stirling City Centre.
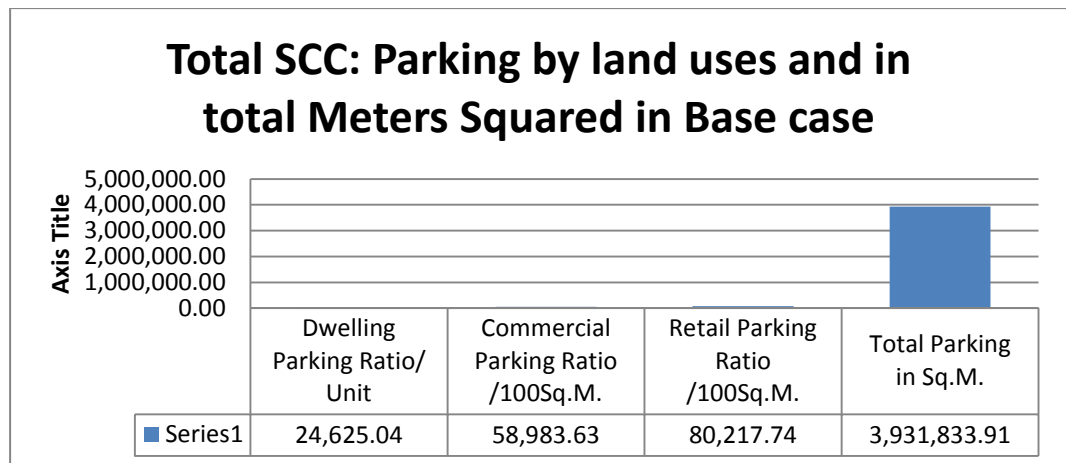
Southern: Parking by land uses and in total Meters Squared in Base case

	Dwelling Parking Ratio/ Unit	Commercial Parking Ratio /100Sq.M.	Retail Parking Ratio /100Sq.M.	Total Parking in Sq.M.
■ Series1	4,773.26	9,546.53	12,983.28	655,273.65

Axis Title
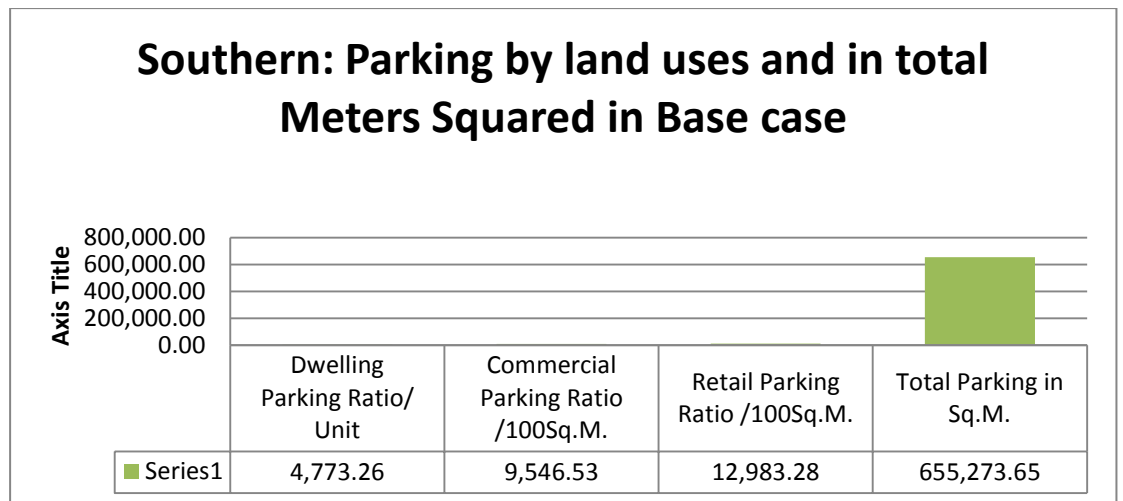
Figure 139 Southern: Parking

However, once parking for such intensity of activity, according to the NSW RTA Guide[45], in the Southern Precinct is factored in we see there will be a high number of spaces and a very large area devoted to the parking of the Single Occupant Vehicles. As the total metres squared of Gross Lettable Area in the Southern Precinct is approximately 1.3 million m^2, this total for parking alone erodes the aspirations of this Precinct unless a real transport alternative to SOV is found with a rise in Public Transit (PT) Service quality and quantity, along with parking ratios being severely altered to reflect the PT alternatives available.
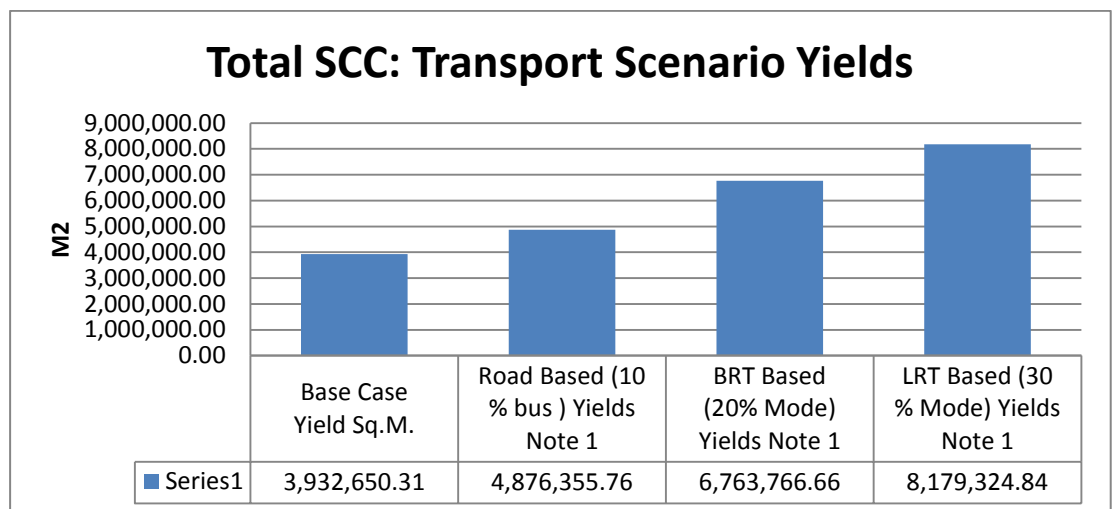
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[45] New South Wales Road and Traffic Authority 'Guide to Traffic Generation'
http://www.rta.nsw.gov.au/roadprojects/community_environment/documents/guide_to_generating_traffic_developments.pdf

Southern: Transport Scenario Yields

	Base Case Yield sq.m.	Road Based Yield sq.m.	BRT Based Yield sq.m.	LRT Based Yield sq.m.
Series1	617,597	764,732	1,060,375	1,205,391
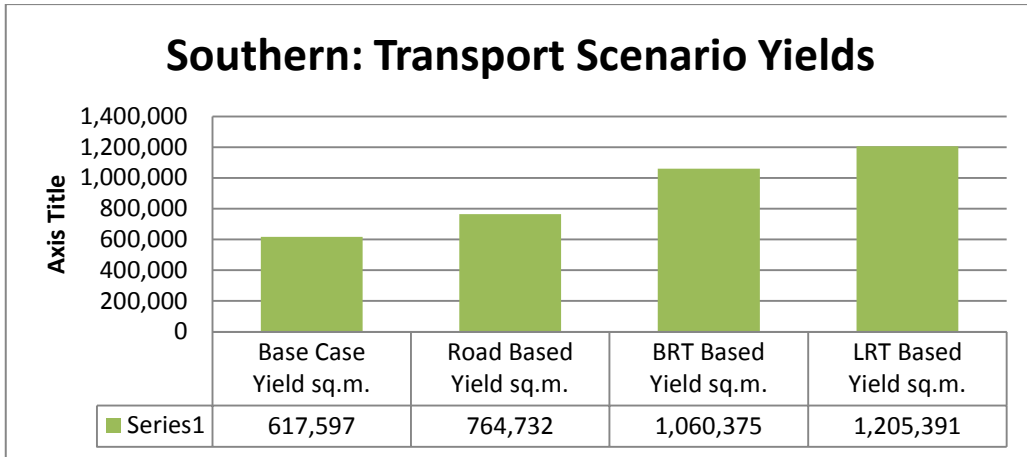
Figure 140 Southern: Yields

In this chart we can see clearly the relationship between the Base Case, with no Public Transport provision, and the Yields outcomes of a Light Rail level of service. With a high capacity, high frequency transit service, the yields can be expected to rise as the Transport Impact Assessments can be expected to permit higher density and day-time activity in the precincts.

Southern: Percent Developable of GLA

	Base Case % developable	Road Based % developable	BRT % developable	LRT % developable
Series1	0.49	0.60	0.83	0.95
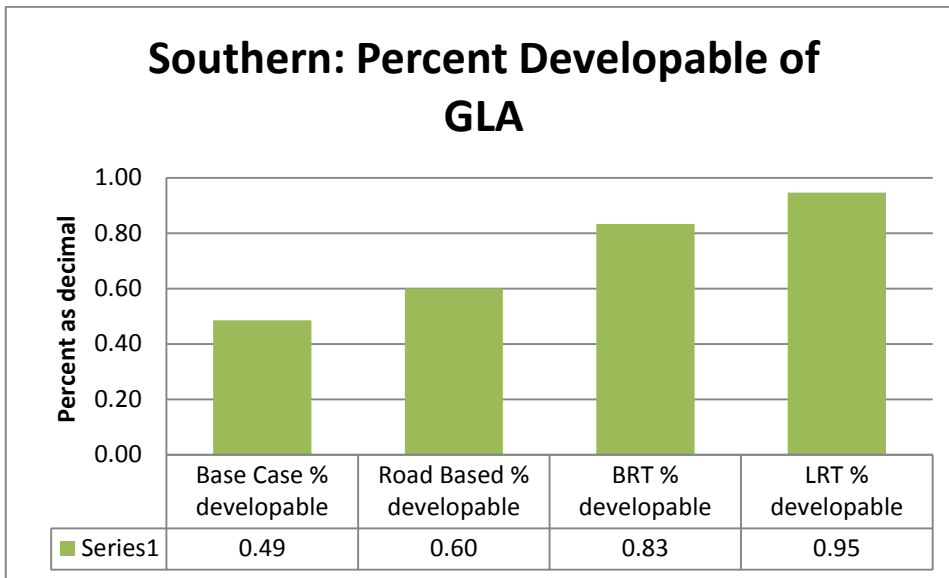
Figure 141 Southern: Percent Developable

A Light Rail Transport service will be able to accommodate the transport needs of .95%, or close to what is aspired to, in this scenario.
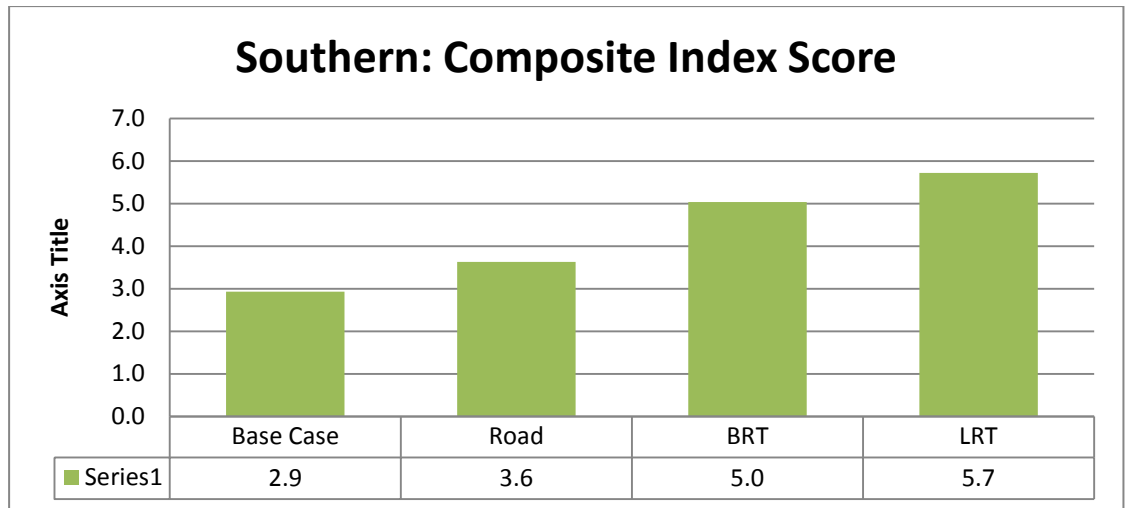
Figure 142 Southern: Composite Index

In the Southern Precinct we can see that, unlike in Figure 133 Total SCC: Composite Index Score where the change in the Composite Index is 2 whole points, there will be 3.3 point spread. This shows that with each increase in some factors, such as density or day-time activity or consistent proximity to transit, there are gains to be made. While these gains may not necessarily be evident to the occasional viewer, with an indicator such as this Composite Index comparisons between similar areas of redevelopment can be made.

This block, a government-owned block in the Station Precinct, will be used as an example of results for one block of land in the Stirling City Centre (SCC). It would be pointless to demonstrate, in charts, all the results for all the blocks and precincts. In this section on Block 2G 2H1- 2H4, the discussion will be limited to singular outstanding points as most have been discussed above. This section will show how the model can reveal the potential of each block of the Precincts, up to the next scale of the SCC in its entirety, to become a high-capacity transit and high real-estate yield Activity Centre.

This section will be shortened for a succinct report.

2G 2H1-2H4: Area, GLA, FAR

	Area Sq.M.	Efficiency	Max. Height	Total GLA	FAR
2G 2H1-2H4	11,990	7,194.00	15.0	107,910.00	9.00
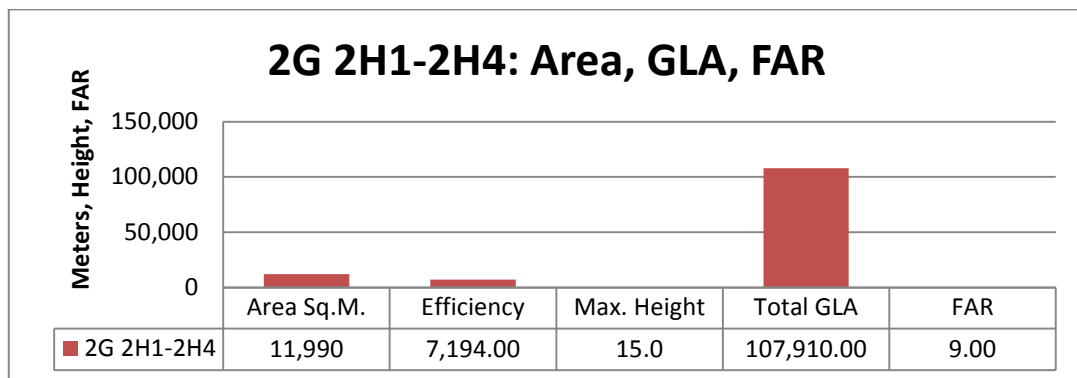
Figure 143 2G 2H: Area, GLA, FAR

In this area, the Floor Area Ratio (FAR) is quite high at 9.00. This equates to quite high density, but given that there is a 60% efficiency (adjustable in detailed modelling) in the land use of the base Area, meaning that there will be significant set-backs and public open space, any over-build of building mass will be mitigated.

2G 2H1-2H4: Dwelling Size, Density and Units

2G 2H1-2H4	Dwelling Size	Density/total H	Residental units
	80.00	337.50	404.66
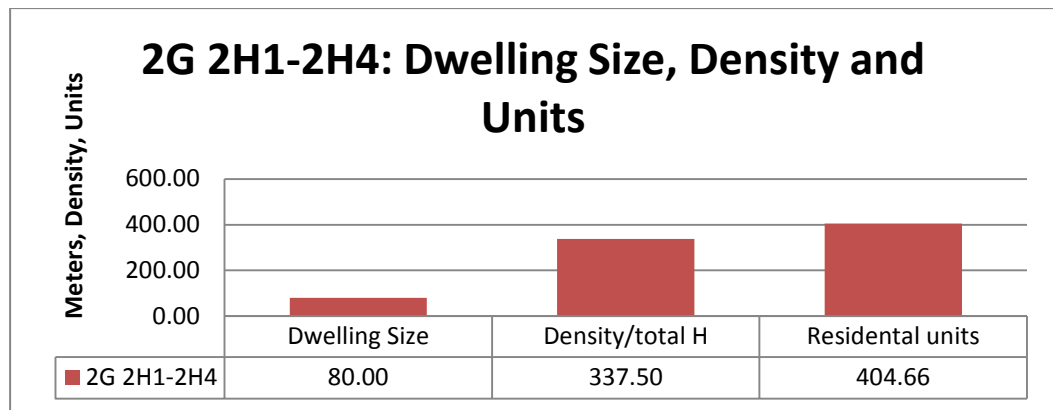
Figure 144 2G 2H: Dwelling Size, Density, Units

With the average dwelling size being 80 m^2 the resultant density of this block, beside the current Stirling train station, may reach 337 dwellings per hectare with 404 total residential units.

The Land Efficiency Factor of the Blocks 2G & 2H is 3.83. This is significantly higher than the 1.58 for the Total SCC or the Southern precinct. This demonstrates the ability of this model to track the changes in land use from a low intensity to a higher intensity outcome with one metric. While this is an abstract number, it represents the weighting of value (between 0.01 and 1.00 with the sum equalling no more or less than 1.00) of the specific mix of land uses on a given block or precinct, *divided* by the land available after the initial efficiency is taken into consideration. This number will rise or fall in detailed modelling when the efficiency of land is altered and when the default values are changed to reflect attitudes about how important certain land uses are to the creation of the Stirling City Centre.

2G 2H1-2H4: Transport Scenario Yields

	Base Case Yield Sq.M.	Road Based (10 % bus) Yields Note 1	BRT Based (20% Mode) Yields Note 1	LRT Based (30 % Mode) Yields Note 1
2G 2H1-2H4	52,357.93	65,434.90	91,588.83	111,204.28
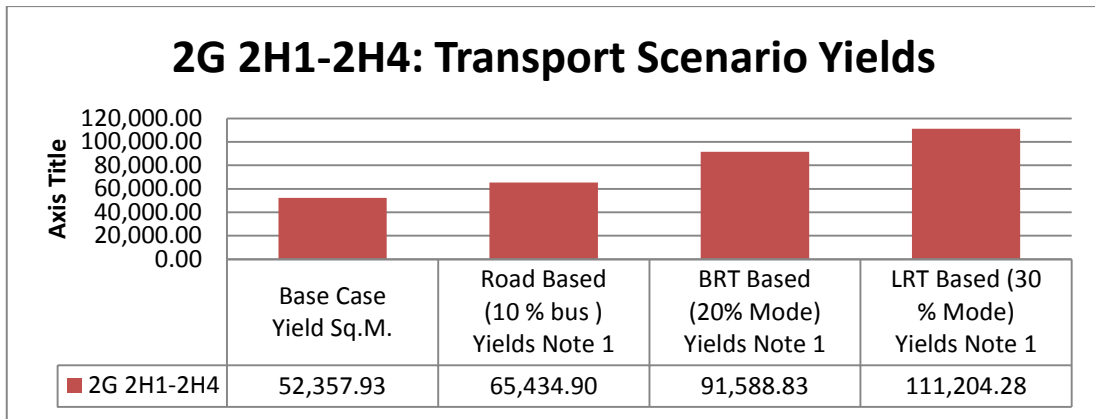
Figure 145 2G 2H: Yields

Under this scenario, the government-owned block beside the train station may increase from the base case by a factor of 100% *if* high quality and capacity to transit is included as a factor in reducing parking ratios. That there is already a high quality, high capacity transit service at this particular block does confound the results, but it underlines the fact that if any transit-oriented, or even transit-associated developments, are to succeed there must be a consistent application of Traffic Demand Management strategies, such as parking ratios, to have a shift in mode choice. Encouraging people to take transit services will only be achieved if 'carrots', such as better transit, and 'sticks', such as no rewards for driving (such as plentiful and free parking) are used to move forward from ideals to policy, implementation, and daily practice.

2G 2H1-2H4: Composite Index Score

	Base Case	Road	BRT	LRT
2G 2H1-2H4	18.56	23.19	32.46	39.42
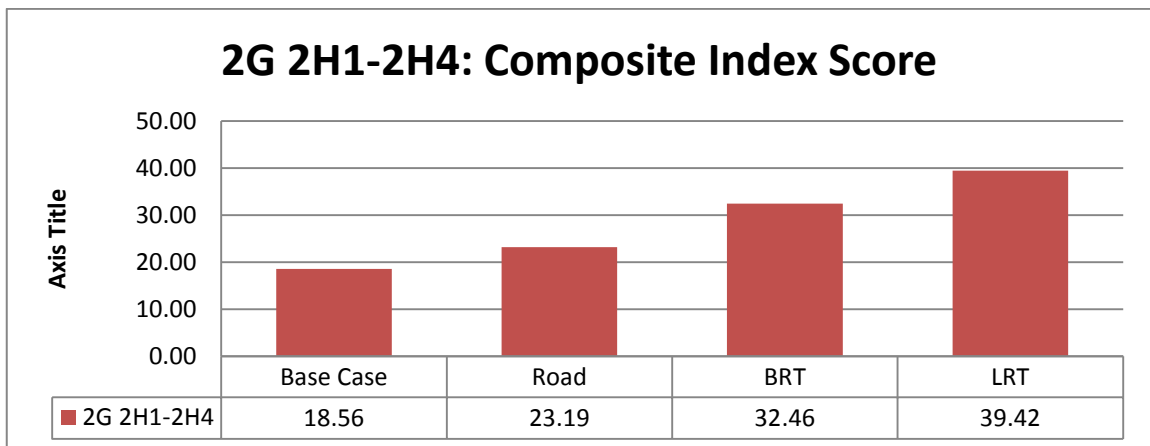
Figure 146 2G 2H: Composite Index Score

The Composite Index in this block clearly shows the ability of this model to track step changes in policy and design practice. Whereas in Figure 133 Total SCC: Composite Index Score we see a change of 2 full points, and in Figure 141 Southern: Composite Index we see a change of 3.3 points from base case to LRT scenarios, in Figure 145 2G 2H: Composite Index Score we see a spread of 20.86 points.

The Composite Index is the percentage developable (as decimal) of each transit mode scenario in the Transport and Parking Factor multiplied by the Land Efficiency Factor and divided by the Distance to Transit. It is intended to demonstrate the step changes possible in outcomes if density, transit access, parking ratios, and mix of use are all considered together as forming the basis of a high-order urban redevelopment.

4.4.5   CONCLUSION AND SUGGESTIONS TO THE LOCAL SCALE: MODEL 3.2

In conclusion, the model elaborated here demonstrates the step changes possible in outcomes if density, transit access, parking ratios, and mix of use are all considered together as forming the basis of high-order urban redevelopments such as the Stirling City Centre (SCC).

The aspirational development, as outlined by the Hassell Report of July 2011 (Stirling City Centre Detailed Yield Analysis), was taken to be one scenario. It remains to be seen, through detailed modelling, what are the possible refined results. The detailed modelling results will be different from those presented in this report as these are *only intended to demonstrate the ability of the model.*

This report shows the strong relationship between built form and transit provisions, demonstrated by the model. If Single Occupancy Vehicles are planned for, development will tqke the form of the low-slung, large format shopping complexes which already dominate the SCC area. If, on the other hand, a high intensity activity centre is planned for, decisions must be made on detailed and specific policy settings and design issues to achieve the aspirations of the redevelopment project.

Ultimately, this model demonstrates how increased activity intensity in an area begins to determine the transportation system required to fuel that growth. This is not 'predict and provide' modelling which has deliberately predicted and indeed provided space for automobile-oriented low-slung sprawl over the last 40 years. Rather this is a 'relational model' demonstrating the pay-offs and trade-offs for each decision made on transit provision, parking ratios, density and height, mix-of-use and public open space reserves. Though there are many obstacles to implementation, there are many options for policy makers, planners and designers to help shape the city; this much has been known, but the relationship has rarely been understood in a clear and transparent model.

Understandably, in private practice and public service it is often difficult to deal with more than one issue at a time. It will be difficult to keep account of every decision as one

step towards a consistent physical outcome, but this model can facilitate a balance of decisions to begin to unfold the ability of the land available to create the urbanism desired.

In closing, a direct quote from page 2 of the Volume 2, 2013 Urbecon newsletter's article titled Expanding land supply" through transport improvements' which underlines the case this model illustrates.

> Significant improvements in public transport…can be seen to be 'creating residential land', that is, adding scope to accommodate housing demand within the existing urban footprint (SGS Planning and Economics, 2013).

Essentially, with public transport and the amenities in a transit-served walkable community we can expect to create more space equivalent to, but higher in order than, greenfield expansion territory. It will be very useful, looking forward, to realise these effects – the land use effects – of public transit as well as the effect efficient land use has on *creating the need* for excellent public transit. The tools outlined here enable us to pursue these relationships in public planning discussions.

4.5 CONCLUSION TO RESULT OF THE MODELS

This chapter has considered: **What are the policy levers available to planners and politicians and how do we measure their impact in a meaningful way?** Following the conclusions of the Literature Review, Chapter 2, that there was a great lack of detail and precision in most of the literature regarding dollars, persons, outcomes of planning and designing for set targets, Chapter 3 set out to develop a methodology which would add precision to the discussion of urban futures and urban systems. Chapter 4 prepared models with methods which are replicable, flexible and transparent to use the most often applicable policy levers for professionals, and the lay public who have an interest, to make meaningful decisions so that their urban systems may have the best of long-range futures with lowered Vehicle Kilometres Travelled, less Greenhouse Gas emitted and with a high provision of excellent public open space and transit services.

The results of these models are presented as a potentially nested series of outcomes. Model 1, the Global Scale, reveals which general direction a city or a neighbourhood may want to pursue vis-à-vis automobile dependence and what levers need to be pulled to achieve the goals. Model 2, the Regional Scale, looked to measuring the space, dollars, benefits and costs of pursuing a strategic plan for a metropolitan area. Models 3.1 and 3.2, the Local Scale, looked in greater detail at local areas to see the benefits of re-urbanising the latent land capacity but with an eye to the associated trade-offs and pay-offs for the future, local residents and workers.

These models produce interesting and shocking results, reflecting the scale of the opportunity but also the immense scale of the challenges to transform a region block by block, neighbourhood by neighbourhood, to achieve stated sustainability goals. What this really means for cities will be explored in the following chapter Analysis and Discussion.

5 - ANALYSIS AND DISCUSSION

The alternative to sprawl is quite simple and timely: neighbourhoods of housing, parks, and schools placed within walking distance of shops, civic services, jobs, and transit - a modern version of the traditional town. The convenience of cars and the opportunity to walk or use transit can be blended into an environment with local access for all the daily needs of a diverse community. It is a strategy which could preserve open space, support transit, reduce auto traffic, and create affordable housing (Calthorpe, 1993 p.16).

… the key to sustainability is to generate these Local Centers and Town Centers as genuinely viable places in each of the transit city sections of the city-region (Newman & Kenworthy, 2006).

THESIS QUESTION: Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?

This chapter aims to resolve: **How best may we analyse the outcomes of the methods within academic and professional practice in the expanding field of Urbanism?** The research has presented a method, or series of interlinked models, to prepare three-dimensional and mathematical models of physical planning options and outcomes. This has approached the literature on sustainable cities and begins to translate them into dimensional volumes of space. However, there are several unresolved questions:

- Where do we build these dense communities? How dense? How tall?
- With what percentage of mixed land-use?
- With what means of transport? Car, bus, BRT, LRT Metro or Commuter rail?

While we search for a progressive direction in city building, we often avoid these questions. To this end this research aims to develop a method to illustrate the pay-offs and trade-offs of following policy settings to realise walkable, transit-oriented, activity-centred and compact-city aspirations. The implications are globally significant, demonstrating the

scale of the operation to change our automobile-dependent cities towards a new urban fabric supporting walking and public transport.

However, despite optimism the results may not be accurate in the long run and despite the precision, the accuracy is entirely subservient to the methodology. The outcomes will be discussed in three parts.

First will be an exploration of what the results mean for Perth and other global cities given the findings. This section will describe the implications and what would be required for Perth, Australia, to become a Transit-Oriented Region.

Secondly the constituent parts of a Polycentric urban form, as a precursor to the Transit Oriented-Region, will be explored including a discussion on Green Land Use and Transport Integration, Landscape of Opportunity, and the twenty minute neighbourhood.

Thirdly there will be discussion of a tiered Hierarchy of Urban Needs. Borrowing the concept from Maslow, the hierarchy will demonstrate how, without basic, secondary and tertiary needs met, a city or conurbation may never achieve the set goals satisfactorily.

5.1 THE PERTH REGION TO GLOBAL CITIES

The Perth Region was used as an experiment site, a petri dish, to examine the potential for overcoming automobile dependence, current or projected, in global cities. Almost all cities are approaching limitations on their capacity to deal with transport networks failing the daily commuters, population growth and distribution across the broader region, ongoing costs to maintain old infrastructure, funding to construct new capital projects, tax-base moving to the suburbs and others.

The methodology used to study Perth focussed on gathering specific data from high-level (national or state) sources. This was so the method would not be hampered in replicating the model elsewhere due to lack of resolution at the local scale. Likewise, many other global cities may not collect relevant data as this is not their core business; other cities will certainly collect data differently or possibly not at all; local or global cities may not be willing to share data for security, privacy or for financial reasons; and lastly a necessary awareness of the data processing time in cleaning and preparation.

To aggregate all the data will be an enormous task and perhaps other researchers may undertake this. However, we must be using skills in planning and design to reach for more 'rational goals' Vuchic spoke for (Vuchic, 2005 p.476). Therefore, most of the data used in this research could be gathered first hand by anyone with patience and aided by Google Earth, Street View, Walk Score and others which in 2014 are online and free to use. Perth was an experimental site for collecting data from documents, agencies, organisations, as well as employing Ocular Estimation and Heuristics in first-hand observations.

The results may not achieve statistical accuracy but they do represent what is possible, and they measure the impact and scale of the operation to be undertaken to achieve even the first tranche of goals. The goals set for this study were to find housing and jobs for just half of the expected population growth of this one automobile-oriented urban region which is opposed to tall buildings. However, the methodology and the resultant models are intrinsically useful to all cities as the data can be applied in a useful and progressive way to other sites.

5.1.1 DELIVERING PERTH AS A FOURTH STAGE URBAN ENVIRONMENT

5.1.1.1 COSTS

The construction costs of capital projects are hard to forecast. Even under the best of circumstances there may be costly delays in delivery of materials, materials which do not meet specifications, political pressures which alter the scope and re-open contracts, weather events and others which are unforeseeable. The best one can do is to put in place contingency funds and extra days on any project. Local contractors may be otherwise occupied, creating a temporary labour shortage or, more critically, there may be a structural lack in local skills training in the workforce. Consequently, estimates of costs can vary widely (ARA, 2013). A few recent documents illustrate the cost of building public transport infrastructure. One is a compilation from the non-government organisation devoted to encouraging transit supply in 'Reconnecting America'. The second source provides estimates of the costs of building rail transport in Australia, undertaken by Scott Martin of Melbourne.

US PUBLIC TRANSPORT CAPITAL COSTS

The United States has been undergoing a significant but not widely known, change in its funding of transport over the last decade. Though still highly automobile dependent, it provides an opportunity now for a reduction in VKT. The physical public transport armature has been building in places as diverse as Salt Lake City, Houston, Phoenix and Los Angeles over the last decade. The projects include bus, Bus Rapid Transit, Light Rail Transit, and metro services.

Hyperlink to US Costs:
https://www.dropbox.com/s/pnyv759psqab8iv/NEW%20TRANSIT%20COSTS%20IN%20US.xlsx?dl=0

Charts prepared by the author showing the costs of constructing each mode to the passenger kilometre are presented in the Appendices, page 455 U.S. Costs per yearly Passenger Kilometre Compared. One hundred and thirty two (132) projects were selected

asr being in the Engineering or Construction phase and therefore having the highest likelihood of accurate costing. A few of the results are presented below:

Capital Cost & Capital Cost to Passenger Km

	BRT	Commuter Rail	Heavy Rail	LRT	Rapid Bus	Streetcar
■ Capital Cost Per Kilometer	$11.1	$20.2	$412.7	$110.5	$2.3	$29.1
■ Capital Cost to Passenger KM ($ Millions)	$19.6	$1.3	$3.6	$7.9	$16.4	$15.4

Million Dollars
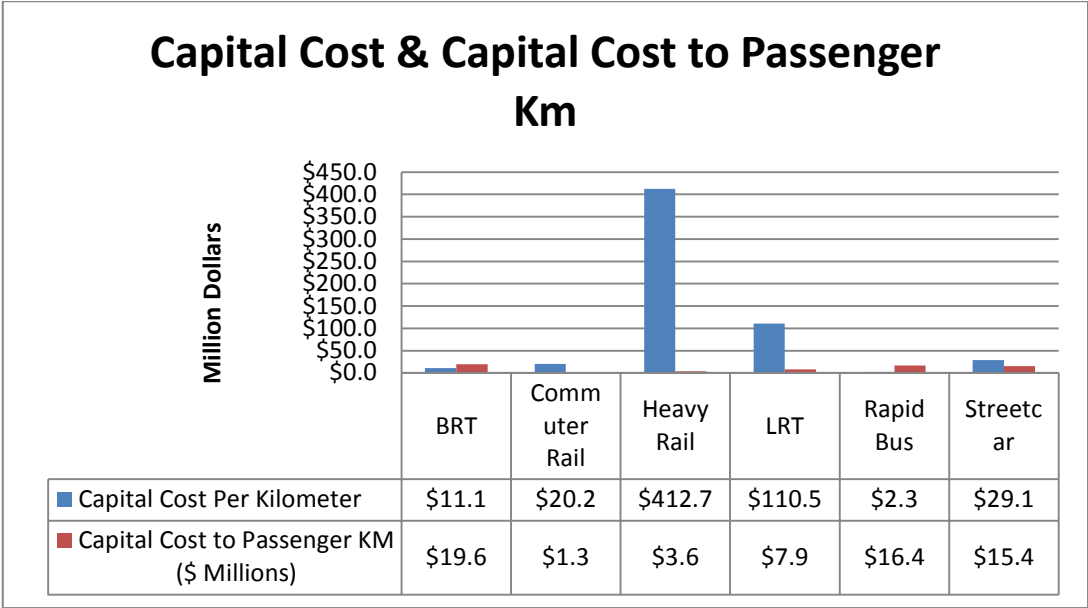
Figure 147 Capital Cost to Passenger Km in United States 2013

Showing the Passenger KM costs alone:

Capital Cost to Passenger KM ($ Millions)

Millions US $

	BRT	Commuter Rail	Heavy Rail	LRT	Rapid Bus	Streetcar
■ Capital Cost to Passenger KM ($ Millions)	$19.6	$1.3	$3.6	$7.9	$16.4	$15.4
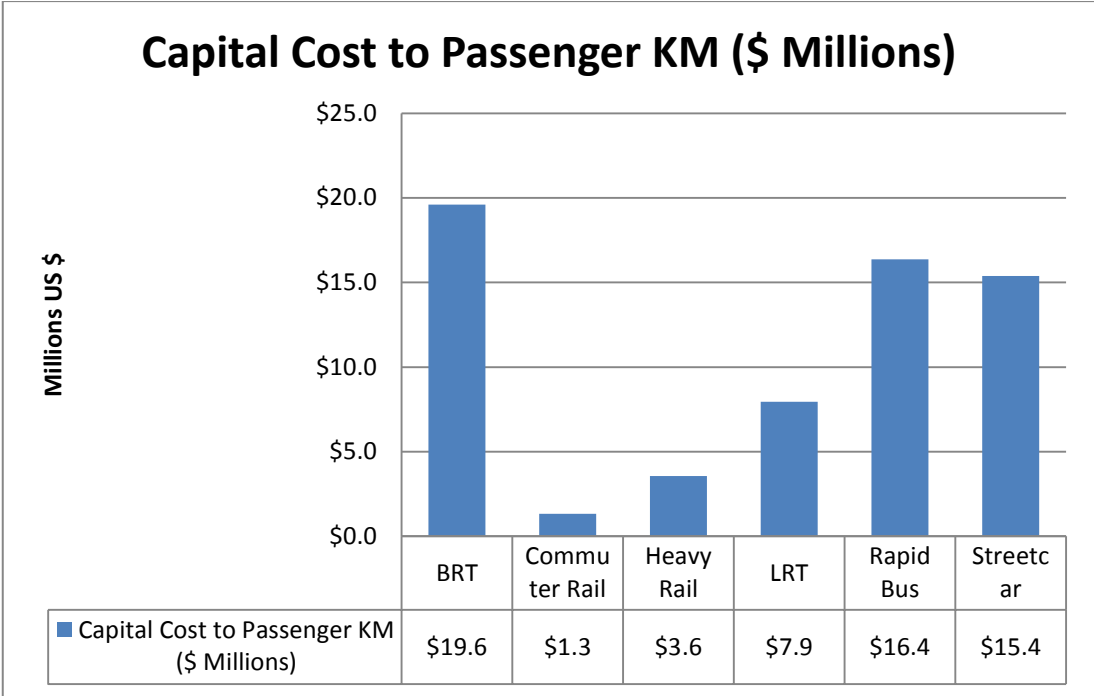
Figure 148 Passenger KM capital costs

It is important to note that the average cost per kilometre by mode is very high for Heavy Rail as this includes the very costly tunnelling subway projects in New York City, and quite high for Light Rail as well, largely due to right-of-way acquisition and underground utility realignments. However, taking account of how many people are served by these kilometres of construction as in Figure 147, we can see that LRT comes down to half of BRT's cost to passenger km. Heavy rail has an even sharper decline to one fifth the cost of BRT to passenger km. Commuter rail likewise comes out lower due in part to an initial low cost stemming from using existing electrified rail exclusive right-of-ways and being able to carry and service many more people over the course of their run. Rail transport, with its ability to access large 'commuter-sheds' of people, to draw them to its service and carry large numbers of people quickly, pays for itself sooner than other modes of Public Transport.

AUSTRALIAN PUBLIC TRANSPORT CAPITAL COSTS

Scott Martin in 2011 reviewed the preceding decade's costs of construction of public transport projects, finding high variability in the numbers. It was demonstrated that tunnelling adds significant costs to any mode's construction bill and that LRT comes out lowest, at an average of twelve (12) million dollars per km, due to the accommodating environment (existing ROW, low incidence of underground utilities and so forth) in which they were constructed over this period.
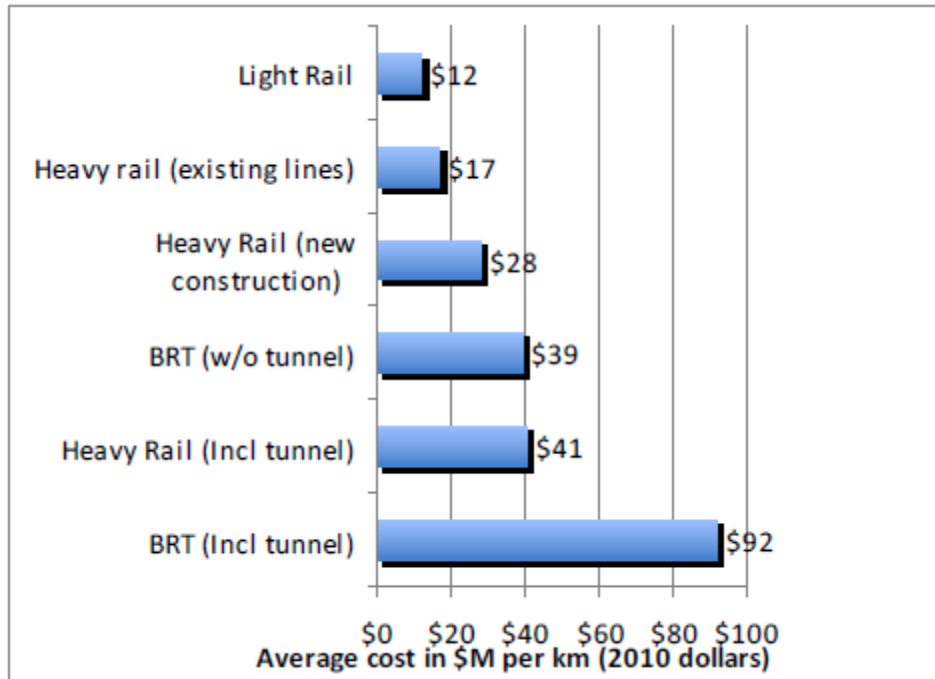
Figure 149 Indicative average per-km construction costs in Australia, 2000-2009

Source: (Martin, 2011)

Without high-capacity transport it is unlikely that any of the activity centres will be more than a one to two storey shopping mall surrounded with extensive free or cheap automobile parking, precisely what exists in much of the automobile-dependent landscape currently. If what is aspired to is more than shopping malls, right-sizing the transit service will be of increasing significance so it is important to know the cost of constructing heavy commuter or Light Rail.

The approximate cost, using the above two cost compilations, is as follows:

The planned sixty-seven (67.2) km of Heavy Rail, or Commuter rail, at grade may cost close to 1.8 billion dollars. This includes all the works from the current Fremantle harbour to the airport along the existing rail right-of way, crossing the Mandurah and Armadale lines, under the airport, crossing the Midland line, along Tonkin and Reid Highways (just as the north-south line does currently in Perth) to meet with the north running Joondalup line. However, with some necessary tunnelling under the airport, a viaduct over the Swan River at Ascot and a signal prioritisation at the Esplanade in Fremantle this number may rise to 2 billion.

Cost to Construct the Rail Network

	KM	$/KM	Total
Heavy Rail	67.2	$28,000,000	$1,881,600,000
Light Rail	105.6	$24,000,000	$2,534,400,000
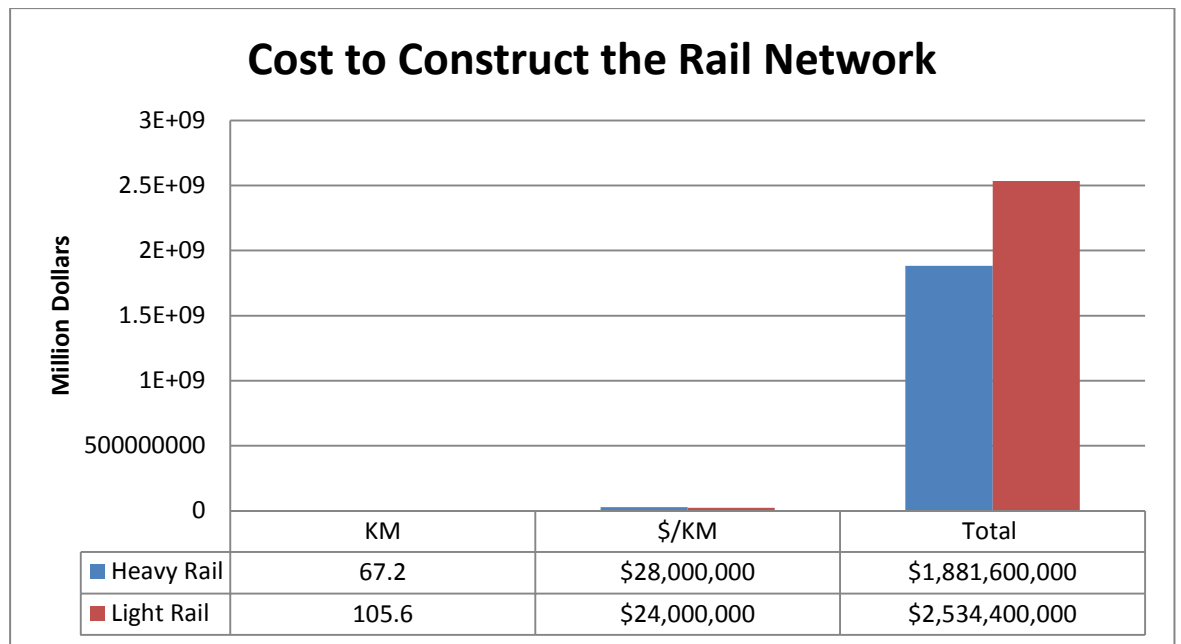
Figure 150 Cost to construct Perth's hypothetical rail network

The Light rail network, functioning to feed the heavy rail Ring Rail while also triggering land supply increase (SGS Planning and Economics, 2013), will cost an average of twenty four (24) million dollars per kilometre to construct along these corridors. These corridors were especially chosen for being wide enough to accommodate the LRT – see Figure 48 Right of Way Dimensions and the LRT in the street – as well to reach parcels of land with high redevelopment potential and current and projected traffic generation. The costs to construct the 105.6 km of rail will be in excess of 2.5 billion, given a highly conservative cost estimate based in Martin's reading of Australian costs but much lower than the current cost estimates in the United States. The discrepancies are often attributed to cost of land acquisition adjacent to the right-of–way and utility realignments, as well as the scale of LRT station design (whistle–stop or Grand Central) and other expensive factors such as surveillance cameras and on-time data screens. It is also important to note that the cost for infrastructure building have been attracting special attention from several bodies concerned with the cost rise of recent years (ARA, 2013 p.11).

PARKING

Parking is another transport cost which must be accounted for. A short list of parking issues related to urban form is presented below.

Table 16 Parking issues and urban form

Parking Issues

- Parking issues in general: availability of generous parking encourages driving and results in an overall automobile-oriented lifestyle

- Surface parking: creates gaps in the fabric of street walls and compromises the ability of a street to be great for walking; causes extensive storm-water runoff which moves surface pollution into the watercourse and causes higher rates of erosion in stream beds; add to the heat island effect greatly; occupies land area of potentially much higher value if changed to residential or commercial uses especially if near transit stations

- Parking structures: hard to make appealing and hard to make work as a part of urban fabric, however they can be done successfully; will invariably be paid-parking run by private or public entities

- Underground parking: the expense to build is offset by higher rates collected from 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 set rates appropriately to make persons consider using other modes of transport; use money raised to offset costs of improving local transit, pedestrian footpaths and cycle routes.

How much do we value the asphalted areas devoted to the automobile? That, of course, depends on the market's willingness to pay for the right to use the space. BBC online world news reported that in 2013 a Bostonian reportedly paid $560,000 for the privilege to own two car parking spaces in Boston's Back Bay Fens (BBC, 2013). While this may be an extreme case, it certainly reflects the elasticity of the demand. Donald Shoup has calculated the high dollar cost of our addiction to the car (Shoup, 1999, 2011).

From Model 2 we can see that across the metro region of Perth, were standard parking ratios applied, there would be an enormous new volume of parking constructed. Though some or most of this could impose a daily fee to be devoted to a public transport fund, it is assumed that this much parking would not be built for the reasons given in the

table above. Likewise, as we can see in the results of Model 3.2 regarding the Stirling City Centre, SCC, trying to achieve compact city goals without the transit is going to be very difficult as the parking requirements consume physical space and capital dollars to construct.

Parking and re-urbanisation

Area	Total M2 Parking Space	Redevelopment Total M2	Redevelopment Total -Parking Space
	19,959,030.1	71,956,883.6	51,997,853.5

Meters Sqaured (y-axis: 0.0 to 80,000,000.0)
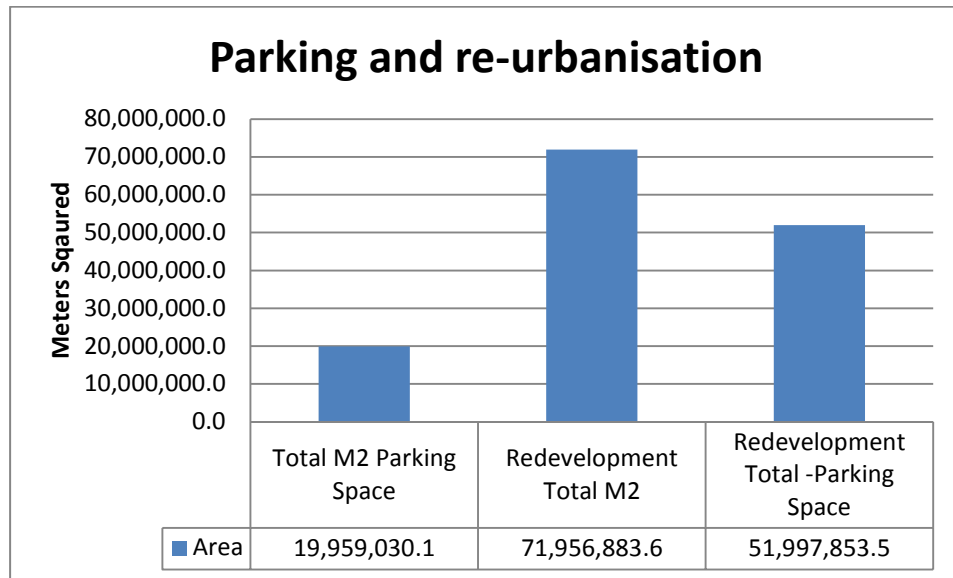
Figure 151 Total land area devoted to parking from Model 2

From Model 3.2 we can see the impacts parking might have on the urban fabric's yield potential as being in the order of between 50% and 30 % of overall redevelopment potential.

Total SCC: Transport Scenario Yields

	Base Case Yield sq.m.	Road Based Yield sq.m.	BRT Based Yield sq.m.	LRT Based Yield sq.m.
■ Scenario	3,932,650	4,833,655	6,643,901	7,527,657

square meters of real-estate
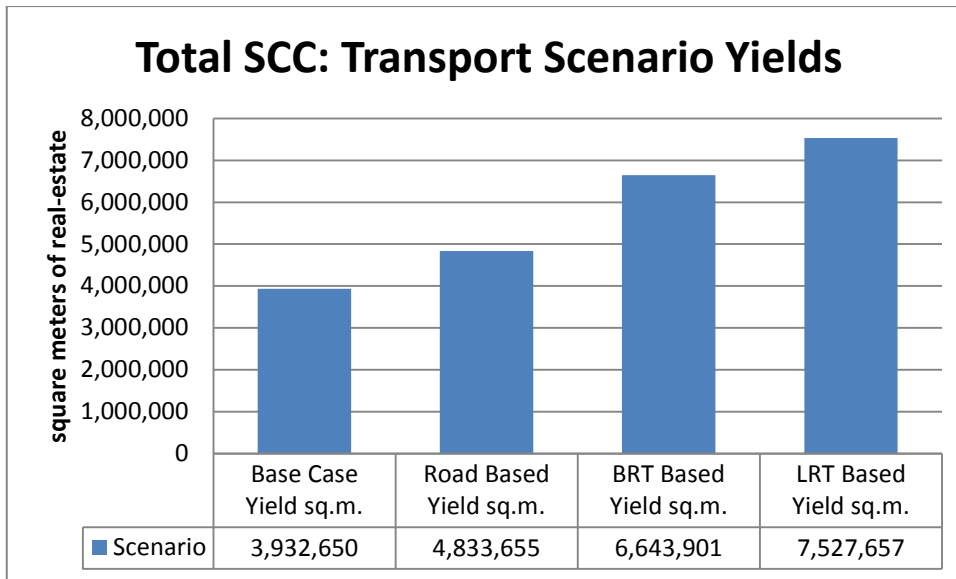
Figure 152 Real Estate Yields based in transport modes capacity

Total SCC: Percent Developable of GLA

	Base Case % developable	Road Based % developable	BRT % developable	LRT % developable
■ % Developable	0.50	0.61	0.84	0.96

Percent as decimal
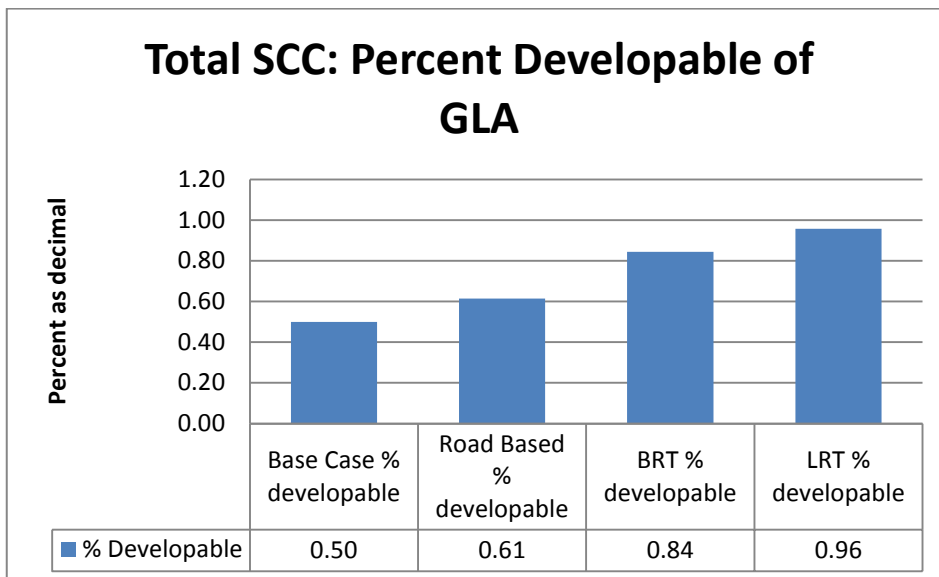
Figure 153 Per cent developable of the aspired density due to transport provision

The results show that without controlling the parking ratios, there will be few inducements to use the public transport provided, causing further congestion on the highways. Parking restrictions serve to increase the potential to profitably build new dense precincts, they create the ability to use Value Capture as a mechanism to pay for increased public transport as the real estate is many times more valuable than the parking, and they improve both the public realm and physical environment with the reduction in stormwater run-off and heat island effects.

Or, in a very pragmatic manner, the points made here regarding sustainable urbanism require:

- 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 (Jacobs, 1961); and

- maximum parking ratios (Shoup, 1999).

COST AVOIDED

The costs that are avoided by planning for a Transit-Oriented Region are related to a wide array of spaces, places and objects. First, by delivering a more compact, walkable, transit-rich series of environments, at different scales and with different tasks, there will be an immediate reduction in greenfield land use. The Ecosystems preserved on farms and in forests have an important role in filtering air and water while providing fauna habitat and human recreation spaces. Thought outside the scope of this study, the economic cost of otherwise having to provide these services (fresh water), and suffering the ill-consequences of air pollution or loss of the wellness benefits of proximity to nature would be very high.

Secondly, there are costs avoided by not having to build the entire social infrastructure in greenfield sites on the outskirts of the urban area. Rather than optimising the existing infrastructure of schools, parks, fire and police stations, health centres and the like, new ones are constructed at great expense while the old ones languish in disrepair and underuse. Some of these factors are listed as costs in studies such as those done by Trubka (Trubka et al.).

Third, the very high costs of underground utilities and roads may be avoided. These numbers are known as the typical part of costing exercises for new greenfield developments. Charles Mahron has written extensively about the high costs to current and future taxpayers of urban sprawl (Marohn, 2012). Roman Trubka has calculated the cost over fifty years, taking account of transport, GHG, health costs and the productivity of sprawl, and found a difference of $378,553 per household, or at an occupancy of 2.4 per house $157,730.00 per person (Trubka et al., 2009).

Measuring these, perforce, means we might be able to rationally manage these costs. With a plan to achieve goals such as government revenue being placed where it may generate long-term benefit over long-term detriment, we may begin to limit the outgoing costs by avoiding low-density automobile dependence.

FUNDING

Worthy of an entire thesis and outside of the scope of this project is funding for rail infrastructure. However, perhaps the best source as a compendium is the Australasian

Railway Association's (ARA, 2014) position paper on the matter listing property-based options including developer contributions and value capture, road user charges including tolls and petrol tax, superannuation (pension) funds, public-private partnerships and tax-Increment financing. More detail is provided by McIntosh et al. (2014) for the Perth region.

There are a host of other subtle funding and financing mechanisms which may be activated by different tiers of government as listed in *Local Funding Options for Public Transportation* (Litman, 2013), being fare increases, discounted bulk transit passes, property taxes, regional sales taxes, fuel taxes, vehicle levy, utility levy, employee levy, road tolls, vehicle-Km tax, parking sales taxes, parking levy, expanded parking pricing, development cost charges or transportation impact fees, land value capture, station rents, station air rights, and advertising. In conclusion Litman notes there may not be any one source which is optimal, but many which may contribute to the task of funding public transport improvements.

> This research discovered no new funding options that are particularly cost effective and easy to implement. Each funding option has disadvantages and constraints. As a result, this study's overall conclusion is that a variety of funding options should be used to help finance the local share of public transit improvements to ensure stability … and distribute costs broadly (Litman, 2013 p.34).

There are opportunities, it should be stressed, to ask developers to contribute towards the impacts that their for-profit projects will have on the immediate, and further, urban environment. However, there are limits to the project's profitability which are illustrated in Appendix A, page 444.

Litman's conclusion in the preceding paper continues:

> Public transit improvements often provide widely dispersed benefits that can justify widely dispersed funding sources. Even people who do not currently use public transit benefit from reduced congestion, increased public safety and health, improved mobility option for non-drivers, regional economic development, and improved environmental quality (Litman, 2013 p.34).

The ARA's list of benefits from high-capacity public transport repeats a few of these in its summation:

- Reduce traffic congestion
- Improve urban amenity
- Help communities achieve their environmental goals
- Promote public health
- Reduce social isolation (ARA, 2013 p.3)

The benefits listed in the Results will be examined with reference to the three pillars of sustainability (Brundtland, 1987; Keiner), Social, Environmental and Economic.

SOCIAL

The social aspects are first accounted for in the model by reserving immediately 10% of all *developable* land for Public Open Space, or POS. Having the means to dedicate land reserves for the use and enjoyment of inter-generation multi-cultural high-density living has enormous benefits (Thompson, 2002; Giles-Corti et al., 2005; McConnell & Walls, 2005). It may be in the form of grassed lawn, street verges for street trees, parks, playgrounds, sports fields, a bench with a shade tree, a wide open plaza or any space the public may access any time of the day throughout the year to be alone or with others. This area is separate from land already deemed *undevelopable* due to it being an existing ecological reserve, which will be touched on in the following section.

The total of all land reserved for POS is:

Hectares of POS

	10% POS
■ Hectares	3,204.4
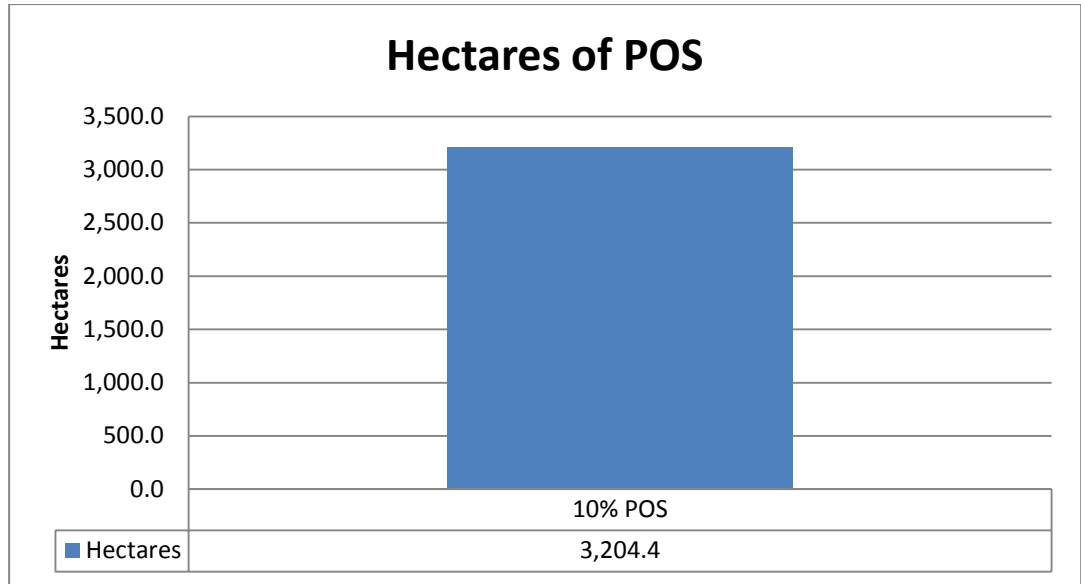
Figure 154 Hectares of POS in the Perth Region, expected

The total enumerated for hospital beds, expected library expenses, schools expenses are:

Select Public Service Provision

	Libraries expenses per person/year (ALIA.org.au)	Per capita expenditure on government school's buildings and grounds, WA, 1996–97 ($per student)
■ Dollars	$43,355,599.2	$128,621,610.9
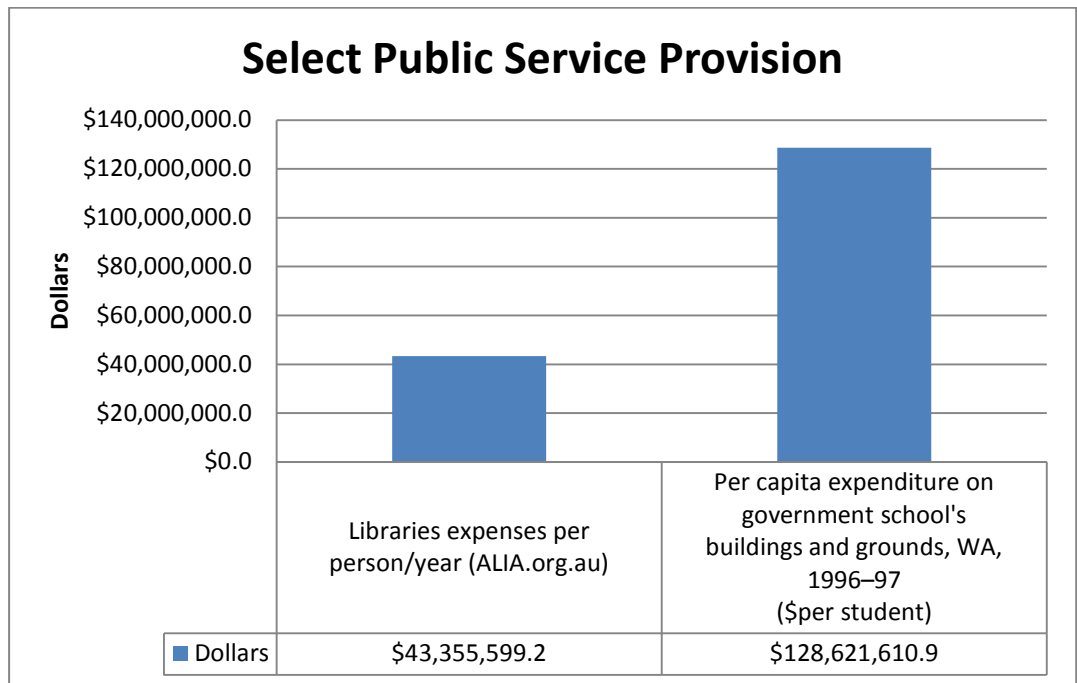
Figure 155 Select Public Services in the Perth region, expected

Select Public Service Provision

Numbers	Recreation Area in Hectares (Cities Institute)	Hospital beds (World Bank)
Numbers	2,633.9	4,119
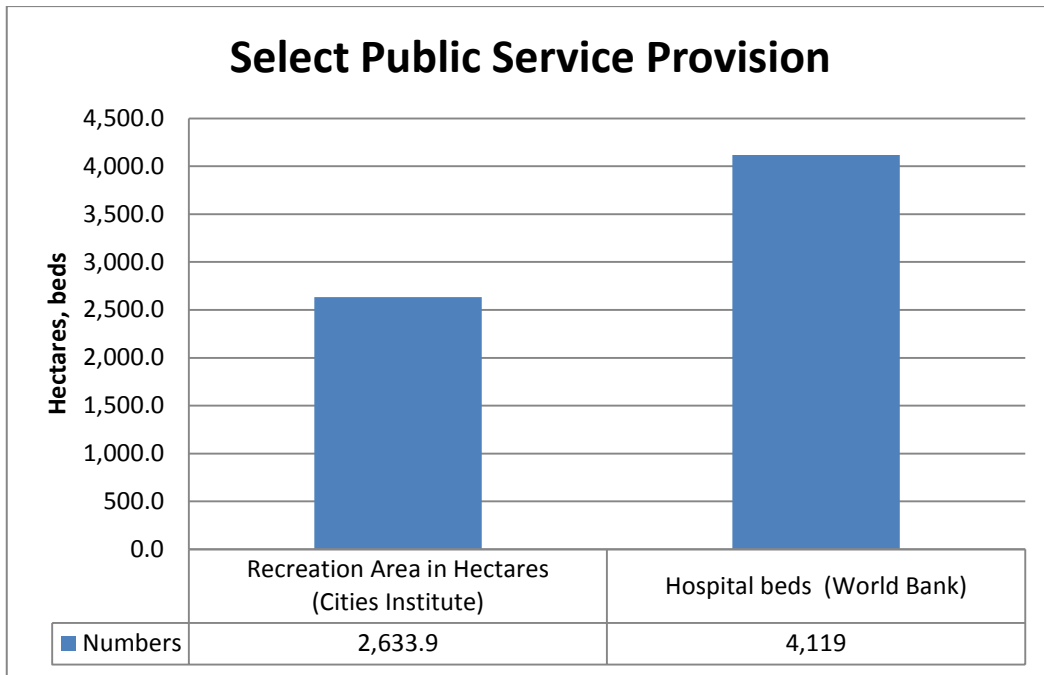
Figure 156 Select Public Services in the Perth region, expected

ENVIRONMENTAL

Undevelopable land includes large swaths of urbanised (i.e. surrounded by urban fabric) ecological reserves in the form of shorelines, lakes, wetlands, remnant forest, hilltops, drainage swales, creeks, rivers and others which must be preserved to be 'designing with nature' (McHarg, 1995) rather than against it. The benefits of preserving these urbanised fragments are the same as for preserving the larger tracts of greenfield farm and forest on the edge of the metropolitan region: ecosystem services filter air and water, give succour to the harried urbanite and provide refuge to the flora and fauna.

The number of hectares of sprawl reduction:

Rail based land redevelopment Sprawl Reduction

	Total Hectares of floor space = Sprawl Reduction
■ All Rail	7,195.7
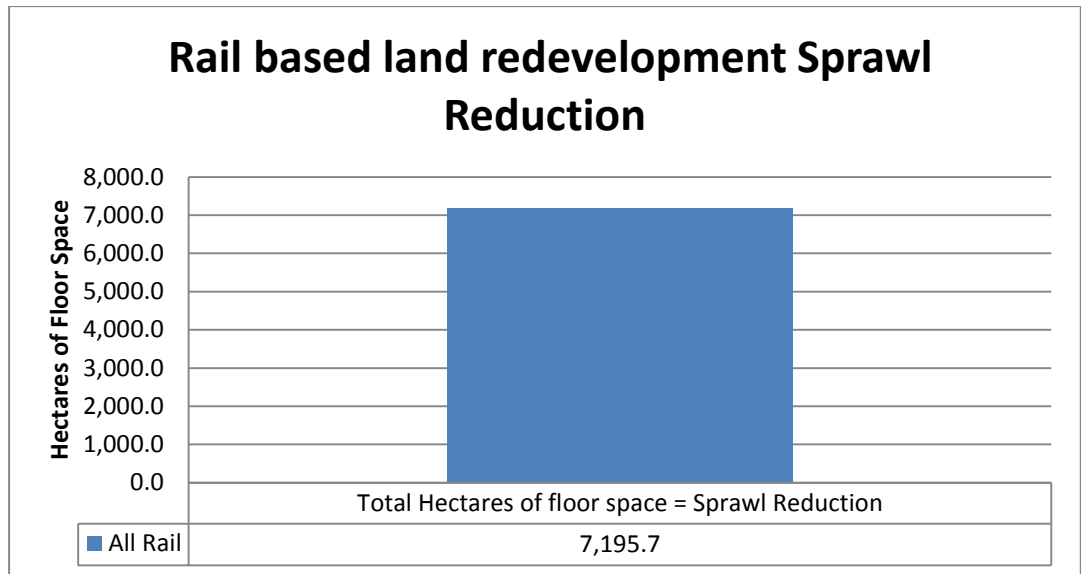
Figure 157 Sprawl Reduction in the Perth region, expected

The Green House gases abated was found to be:

GHG saved in High Walkable versus Low Walkable Urban Environments

GhG Saved though this scenario in KG/day

■ KG
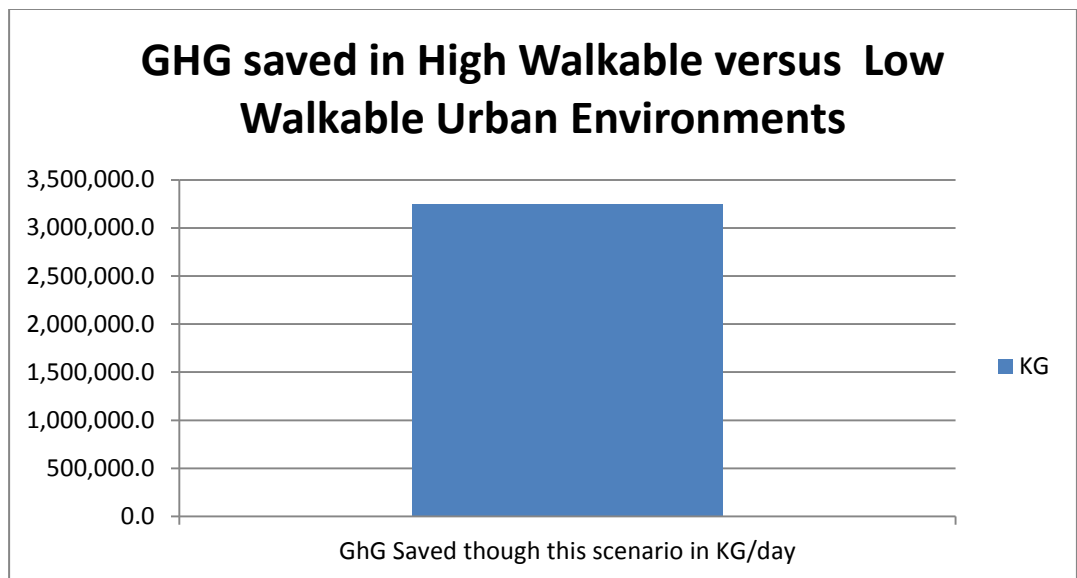
Figure 158 Green House Gas emissions changes in the Perth region, expected

The GHG saved is in the order of 3,000,000 KG/day at build out.

GHG sequestered equivalent is approximately 35,000 hectares of forest according to the USA's EPA (EPA, 2014b).

GHG Sequestered equivalent

	Carbon sequestered annually of forest preserved from deforestation equivallent in hectares from this Scenario (USA EPA)
■ Hectares	34,766.9
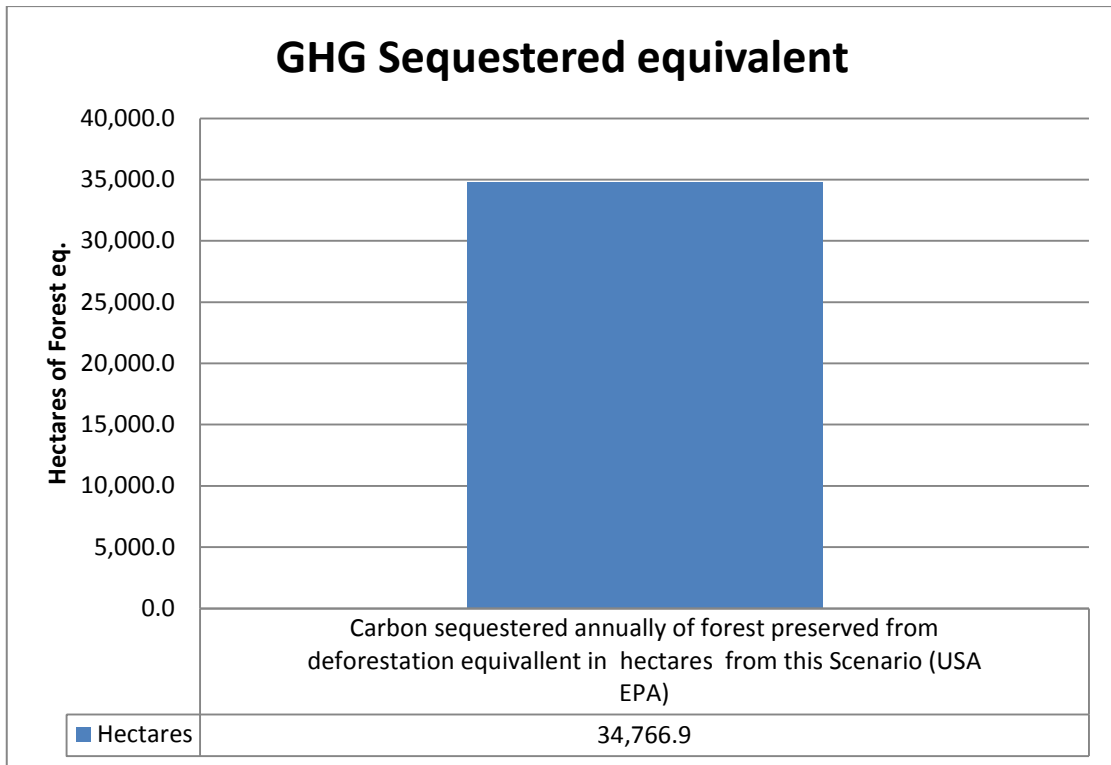
Figure 159 Green House Gas Sequestered Equivalent in the Perth region, expected

ECONOMIC

Cost avoided calculations, based on modelling undertaken recently by Dr Roman Trubka, show that in this scenario the cost savings from building infill versus sprawl in Perth over the next 50 years will be in the order of twenty (20) billion dollars. Furthermore, multiplying the costs avoided by the new infill residences in transit-oriented, walkable, mixed-use precincts optimising existing social and utility infrastructure – if they were to be all present at the same time – would add almost four (4) billion per year. The cost savings are enormous if looked at in this perspective.

Cost avoided: One time and over 50 years

Dollars	Infrastructure Upgrades - Electricity Water Sewer and Roads Costs Difference (Trubka) per Dwelling	Total Cost Avoided (Trubka) per dwelling/year (per year over 50 years)
Dollars	$20,884,392,129.9	$4,103,098,035.1
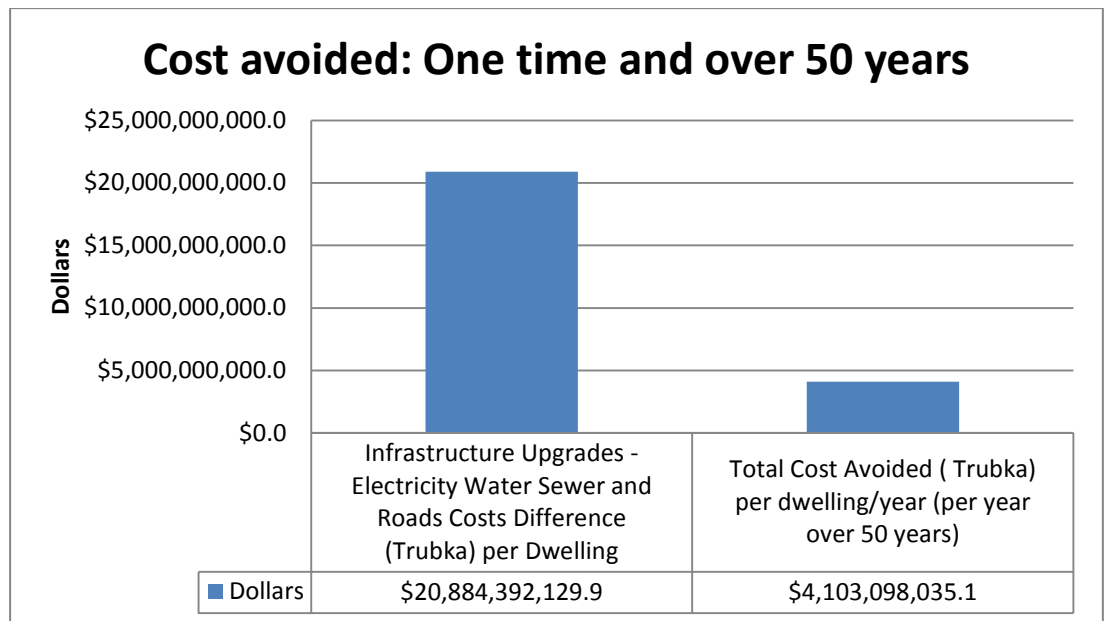
Figure 160 Costs Avoided in the Perth region, expected

Value capture, as mentioned above in the Funding section, has multiple forms. A transparent 1% sales tax, as a stamp duty or a capital gains levy, applied on the value of land or on the built real estate in these new transit-oriented precincts alone could raise significant revenue. This model shows that sixty-one (61) million dollars could be raised on raw land selling at an average of $200 per metre. Two and a half (2.5) billion could be raised from residential properties which average, currently, five hundred thousand dollars in value according to Realestate.com.au.[46] These are estimates, but they do give a scale to the opportunity to raise funds dedicated to paying down debts accrued to build the public transportation which make the very real-estate feasible and valuable.

Likewise a five dollar ($5) per day levy on the new parking places would raise well over $600,000 per year. However, it is hoped that this quantity of parking will *not* be built

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[46] Real Estate page: http://www.rs.realestate.com.au/cgi-bin/rsearch?a=sp&s=wa&u=perth

or the actual densities – with jobs and residences – will not be able to be achieved, see Model 3.2.

Value Capture Funds Compared

	1 % tax on per M2 land sale, if sold at $200/M2	1% of expected rise in residential property values, $500,000...	1% of expected rise in commercial property values, 300/M2^	5$ Parking levies per car stall/per working day per year...	5$ Parking levies per car stall/per day per year (365) on Retail
■ Dollars	$63,715,310	$2,709,724,	$45,840,323	$477,503,37	$231,037,90
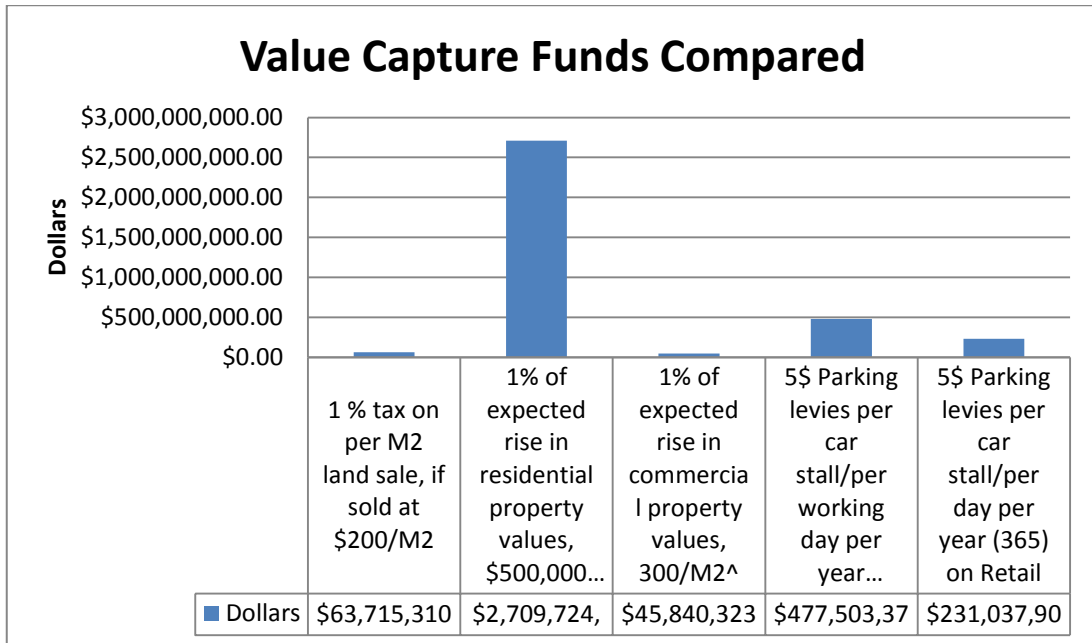
Figure 161 Value captured in the Perth region, expected

5.1.2   IMPLICATION FOR OECD AUTOMOBILE-DEPENDENT CITIES

With rare exceptions, cities in the OECD are growing. There are few cities which are actually decreasing in size and population. Even if they are shrinking, they have aging infrastructure and likely an over-emphasis on highways. Meanwhile, land-use changes as industry departs leave behind swaths of brownfields. Automobile dependence has cut scars along almost all collector and arterial roads leading through our neighbourhoods. These brownfields and scars can be used to our advantage if planned for.

This research proposes using the site's capacity for urbanism multiplied by the possible public transport capacity per hour; it not pretend to radically change cities and regions, but rather leverage what they have and make them aware of their potential. This leveraging can be summarised in a simple formula represented below.

$\text{Capacity}^l \text{(spare land)} \times \text{capacity}^t \text{(transport)} = \text{Potential Yield (opportunity)}$

In collecting, collating, shifting and combining data on many local and global 'fears' (Work Architecture Company, 2009) (climate change, obesity, urban ugliness, automobile-dependent lifestyles, fossil fuel consumption of the GDP) these models frame real-world solutions. However, what is proposed in this research is not a single solution, but a method to be used in balancing the priorities and values of such things as density, mix of use, transport provision, automobile parking ratios, design priority and others to achieve the goals they seek.

The implication of this research is that, at least for wealthy OECD cities, the best option is to decide what kind of place they want to be via an exercise like Model 1, calculate the land-use capacity in their urban fabric such as in Model 2, and explore the Yield possibilities as a result of the transport capacity impacts on built fabric as in Models 3.1 and 3.2.

5.1.3   IMPLICATIONS FOR NON-OECD WORLD CITIES

As primary industries contribute less to measured GDP globally, soon everyone will be providing a service for someone else. As the globe shifts its resources away from labour-intensive rural industries, farming, forestry, mining and towards the service sector based in

urban areas (UN, 2011) the need for access is not an aesthetic or a theoretical construct, but a practical necessity in all global cities. Access does not imply highways, as there simply is not the money, space or reason to build highways in cities like the US and Australia have when other options are available.

In non-OECD countries the future might still, as in China's lead example of high-speed rail and underground metro capacity building (Newman, P et al., 2013), be built upon high capacity transport networks of rail-based transport. There is much to be gained from the urbanising of the world's population, so long as the local environmental limits are understood and ameliorated (Grimm et al., 2008).

5.2 POLYCENTRIC URBAN ENVIRONMENTS

Perth is a highly mono-centric conurbation. It wasn't always this way: at one point the plan was called Plan for the Metropolitan Region Perth and Fremantle – 1955 (Stephenson & Hepburn, 1955) signifying that there were two cities to plan for. However, this has now changed to a plan for Perth and Peel (Western Australia Department of Planning, 2011) with Peel being a largely rural area with Mandurah, a retirement settlement, its largest urban area. However, the latest planning calls for a dispersed series of Activity Centres where, anchored by retail shopping outlets, there is anticipated to be a net growth in population density, commercial office space and liveability amenities. However, as a diagram the plan leaves much detail to be decided. These details, it must be restated, are attempted to be illustrated in these models.

The future of most urban areas around the world depends on a complex mixture of land availability, transport and other utilities giving access to that land, capital markets, societal desires and fears, and government planning for the best and highest uses of the land.

As Marc Jacobs (Jacobs, 2000) has stated, multi-modal urban structures optimise infrastructure as a product of the 'multi-directional demand for public transport', and 'multi-functionality', or mixed-use fabric, better fulfils multiple objectives for the travelling public thereby making better use of the transport network's capacity (p.53). Multi-nodal structures, polycentric urban form, are self-reinforcing and create local services and cross city transit linkages. This multi-polarity decentralisation is derived from the work of Howard, Corbusier and Wright, and is a kind of 'de-concentration' from the dominant Central Business District; however, it is designed to create a series of smaller CBDs. In theory and in emerging urban forms in practice, a new series of concentrations at various scales and with various tasks has begun to appear (Jacobs, 2000 p.42).

In Australian cities there has been a tendency towards mono-centricity, yet in our urban history there has been debate that a multi-nuclei model of development is more appropriate:

> ... based on the premise that urban growth occurs around several nodes (or nuclei). These nuclei may include ports, railway junctions, industrial regions, regional

shopping centres and major highway intersections in addition to the CBD (Dent, 1996 p.287).

More recent authors making use of the internet and open-accessed journals to disseminate their theories have written:

> Development of satellite cities and urban infill projects constitutes the best strategy to accommodate population growth while preserving open space and farmland. All new cities, regardless of size, must be planned to minimize their impact on the environment (Laursen, 2012).

And that the new urban future lies in the 'megapolitan' polycentric urban structures.

> ... the settled parts of America are often as densely built as Europe. A big difference, however, is that Europe has stopped growing, while the United States is on track to gain 90 million more residents between 2010 and 2040. That is the equivalent of adding a nation more populous than Germany — and the vast majority of the increase will be in megapolitan areas (Lang & Nelson, 2011).

Figure 4   Development Patterns (Meijers and Burger 2009)
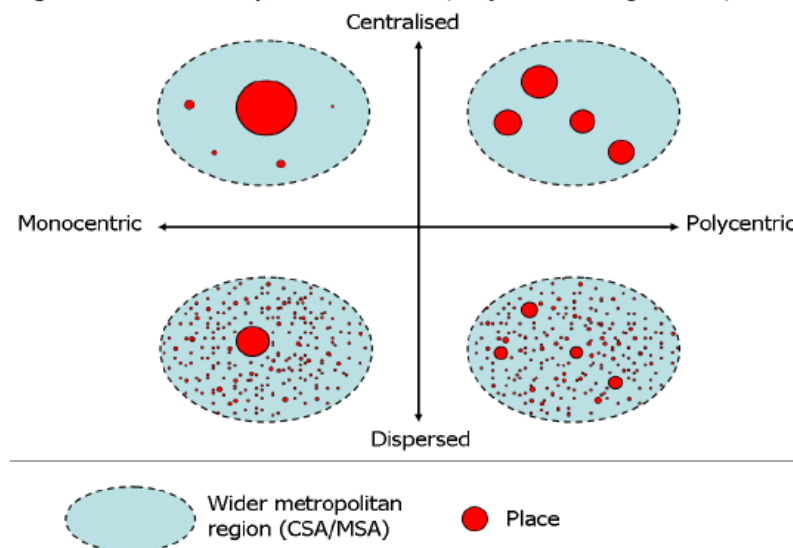
Most metropolitan regions are polycentric, with various business districts, cities and towns. Sprawl consists of dispersed, low-density, automobile-dependent development outside any urban area.

SOURCE: (LITMAN, 2014) AFTER MEIJERS AND BURGER 2009 "MOST METROPOLITAN REGIONS ARE POLYCENTRIC, WITH VARIOUS BUSINESS DISTRICTS, CITIES AND TOWNS. SPRAWL CONSISTS OF DISPERSED, LOW-DENSITY, AUTOMOBILE-DEPENDENT DEVELOPMENT ...."

Figure 11: Growth patterns for cities around the world
Source: Vanderschuren (2003), after: Pressman (1985), Minnery (1992), Newton (1997)
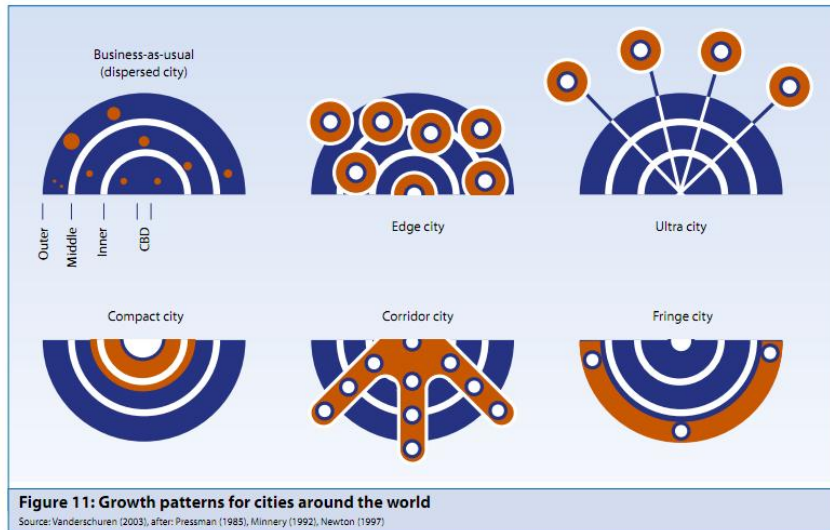
Figure 162 Growth Patterns for cities around the world

Source: UNEP, 2011a, after Newton 1997
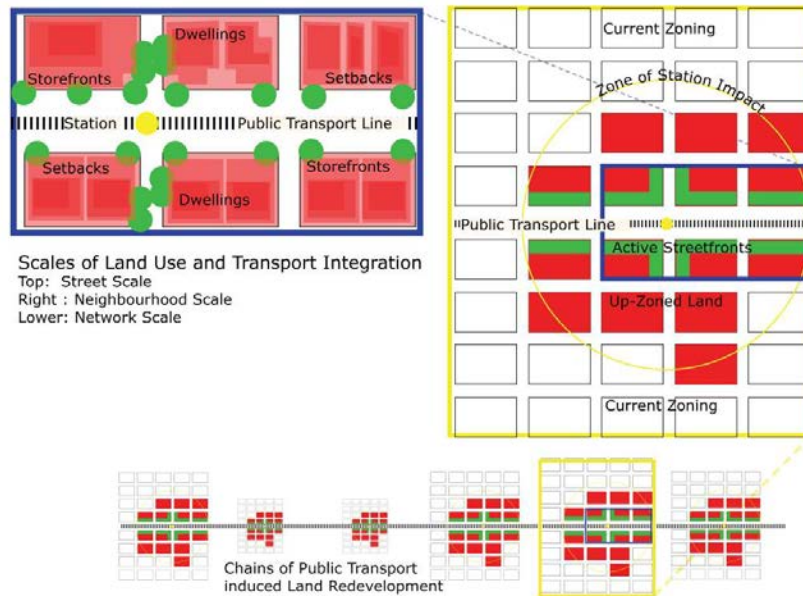
Figure 163 Nested scales of Transit Oriented Region

SOURCE: AUTHOR, 2014. THE FIRST THREE NESTED SCALES OF A TOR

Reasons to Invest in Rail

Rail Transit investments, aside from providing for regional trips by mass transit, can spur these benefits:

- redevelopment of ideally suited sites to house the changing demographics,
- supply affordable housing in an increased housing stock,
- Avoid costs to personal and LGA pocket-books,
- lower GHG and VKT,
- Value Capture to pay down rail expense,
- task the current infrastructure, already built, to provide more service
- increase Global Competitiveness,
- improve local air and global atmospheric quality,
- be a globally significant shift for Western free-market car-based cities,
- be an incentive to build less single occupant vehicle infrastructure,
- gain social amenities such as public parks and swimming pools, and
- protect and maintain ecosystem services of farm and forest

Region

Region with Transit

Regional Transit Line

Condo with Resident

Mid-Rise Redevelopment on amalgamated lots

Transit Oriented Development

Cadaster with Lots

Figure 164 Nested Scales: Reasons to Invest in High Capacity Transit for regional targets

SOURCE: AUTHOR 2013.

Rail Transit investment, aside from providing for trips by mass transit, can have many benefits. It can provide incentive to re-urbanise ideally suited sites for better jobs and housing balance and, in so doing, supply affordable housing to the market through an increased housing stock and developer contributions /density bonus schemes. Preparing such sites near high-capacity transit avoids costs to individuals and LGAs, is an incentive to build less single-occupant vehicle infrastructure; creates a real-estate market to use Value Capture to pay down new infrastructure over time, and better equips the current infrastructure to provide more service. It also lowers GHG and VKT while improving local air and global atmospheric quality. It increases global competitiveness, provides social amenities such as public parks and swimming pools, and protects and maintains the ecosystem functions of farm and forest by consolidating more growth in previously urbanised areas.

The results of Model 2 show that across the new rail transport network there may be a range of polycentric, dispersed but concentrated, transit-activated re-urbanisation projects. Stations along the five current rail lines, two new proposed heavy rail lines and six proposed light rail lines can achieve a wide variety of land masses and locational advantages (see Figure 46), with several being large areas. It is envisioned that the larger inland parcels, such as the airport, are being better rated as commercial office and light manufacturing spaces due to the desirability of the smaller areas on the coast for living, while others, such as in Spearwood in the south or Stirling in the north, are best suited for a balance of housing and jobs. Places closest to the river or beach are preferred for residences but with a significant improvement in commercial and retail space, more third spaces / services /amenities than currently.

At a closer examination of a local area, such as in Model 3.1 of Victoria Park, we can see more clearly the heights required by each node or centre in the polycentric urban fabric. Victoria Park would need to build to 10 stories and reduce parking by a great deal to achieve its part in the regional effort to infill the incoming population. Even by so doing, it should be pointed out that 5440 new housing units may only account for less than half a year of housing requirements. This reflects the *scale of the operation* to house new residents according to the theory of polycentricism and the policy of infill development in automobile-dependent fabrics, outlined in Perth's current, though modest, Directions 2031.

Victoria Park

	Years of housing suppy (HIFG, 2012)	% of regional population growth
■ Victoria Park	0.3	1.28%
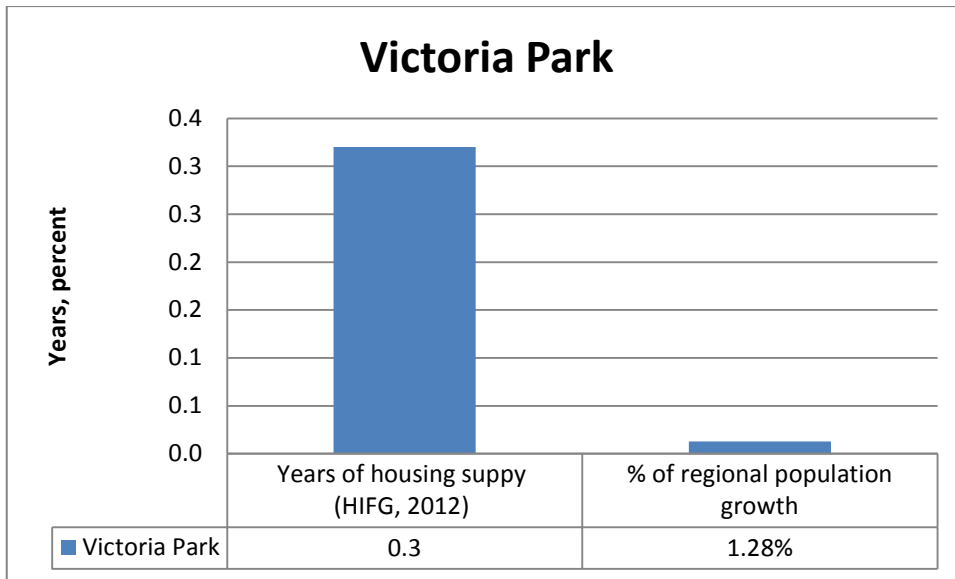
Figure 165 Victoria Park, re-urbanisation contribution to population growth housing

This result does not mean that we shouldn't implement the policy. Rather, it demostrates the seriousness of the task ahead and why the processes of re-urbanisation must be coordinated at a broader scale with explicit goals and expectations for the future. All areas in the conurbation must contribute to the task.

Ideally, in exploring how best to satisfy the population with jobs and access to places in the urban area in a balanced sustainable manner, we need a few new concepts. The following disucssion on urban matters expands on trends in global literature.

5.3 A COUNTRY OF TRAINS, TOWERS AND TREES

Ultimately, after all the opinions and charts, the aim is to make cities work better. This is not dystopian or utopian, controversially NIMBY-provoking or needlessly academic proposal. The modelling is not about perfecting the style or the ultimate design of places. It will mean a profound change to automobile-dependent cities in how residents walk to corner stores, meet people on foot, recognise faces, see new trends, catch a train or take a bus, hear the birds, scratch a dog's neck and admire the artful manner in which the shopkeepers in the ground floor retail have arranged their displays. In short, as outlined in the chapter 'A Country of Trains, Towers and Trees' (Chakrabarti, 2013), the aspiration is nothing less than for private soundproof homes with access to light and air in cities dense enough to provide excellent public and private amenities including beautiful parks, safe tree-lined streets and efficient public transport.

This sounds pleasant enough. However there is growing concern over global car dependency as the prosperity of Asia and Africa begins to match the wealth of the OECD countries, leading to widened streets to accommodate through traffic, rampant parking of private automobiles on public sidewalks and open space, dangerous walking and cycling conditions and additional local air pollution. Though there are attempts to curb the growth of automobile dependence in OECD countries with greater Land Use and Transport Integration (LUTI), the scale of operation to bring about significant reductions in local and global air pollution, along with a significant increase in public transport mode share and walking to evenly distributed third-places, is daunting and greatest in the non-OECD countries. It has never been so important that we set the right goals for service provision and amenity even if they seem optimistic. The alternative is unacceptable.

As the author of *The Geography of Hope* (Turner, 2008) related in personal communications:

> Communities that reorganize their value systems, putting people first, are those which can be evaluated for resiliency.

> We need to craft a new narrative about our common vision and the way we live. To tell a different story about who we are. (Turner, 2009)

The first change we need to make isn't one of changing an assumption in a model, such as presented here, but one about the visions we want for our lives in cities. As an urban nation we must admit that there are opportunities for change, that there are patterns of living which are more interesting, delightful and resource-conserving, and indeed preferable to the myth of the suburban Arcadia. We need to appreciate the opportunity of public life, life between buildings, over the loneliness of private life between walls. In short, we need to tell a different story about what we want from our cities.

5.4 A HIERARCHY OF URBAN NEEDS

For a city anywhere there are needs. Under any governance type, with any orientation to a particular mode of transport or with aspirations to transform into a globally ranked city, there are obligations to provide safety and a foundation for prosperity. Though it may be possible to leap from one level of transformation to the next, or to invest in a technology in advance of the urban fabric readiness, it is eventually imperative that several basic elements are taken care of. For example, it is hard to have a policy to preserve ecosystems when basic sanitation is not available to citizens; likewise it is difficult to generate top-tier university researchers if the local education system fails to promote the best minds from all levels of society. To illustrate the needs, a chart has been prepared with the following primary to TOR levels described below.

Primary needs for residents in cities include having clean water sources, sewerage and communication systems, a source of energy to provide light and power, employment, some form of transportation operated by private or public agencies, and stability. While this seems obvious, several cities around the world do not provide even these basic levels of services (Grosvenor, 2014; Mercer, 2014). For these cities, the question of how to optimise transport infrastructure needs to wait until security and sanitation are provided.

Secondary needs are those which most developed world cities have met, with good local education at all levels, responsive police forces not likely to demand bribes, a free and independent judiciary with an uncensored press to report on proceedings, responsible local governments who can at least raise reliable annual taxes or rates to collect rubbish and repair local infrastructure, sufficient and equitable distribution of park space for recreation, and the provision of mostly safe streets and public spaces.

The tertiary level of needs includes having universities able to provide talent and skills to the local job market, provision for high-capacity public transport on frequent rail and bus networks, safe pedestrian and bicycle networks which interlink to the larger public transport networks, security throughout public and private spaces, clean flowing rivers and creeks, clean air to breathe, ecological reserves, and, in addition to annual tax bases, access to secure long-term capital funds. This level of service is evident in some, but not all, developed nations' cities.

Global City, those on Liveability rankings, needs are slightly more complex; there must be a very high level of sanitation, networks of frequent public transport of all modes with priority for pedestrians and cyclists linking many destinations especially their global city information centres, and excellent education provision that feeds these employment centres. Cities at this level will begin to require a level of autonomy in raising sufficient funding mechanisms to provide for at least these services. New York, London, Paris, Singapore may be thought of as belonging to this group but all cities including Perth have some of these features and aspire to more.

At the top, with all the lower level items taken care of, the fabric of the 'conurbation' (Mumford, 1961) of dispersed parts and centres begins to be woven together to create a Transit-Oriented Region. In this TOR will be low levels of daily automobile use as highway and parking capacity is not increased, or is even reduced, thereby lowering the inducement to drive; there will be high mode splits between rail, bus, taxi, walking, cycling across the region for all trips; high density of residences and employment areas with mixed-use amenity such as parks and retail especially located at high-capacity public transport stations; low carbon emissions from transport as fewer internal combustion automobiles will be required; lower carbon emissions from buildings from shared-wall cooling and warming, along with increases in solar and geothermal power, that together lead to reduced need for energy consumptive built form; and ecological services that are repaired or maintained via rebuilding hydrological processes within and throughout the urban area. This will make for a highly liveable, desirable, comfortable, efficient, productive Transit-Oriented Region, or TOR. Very few places have achieved these lofty goals, however Ranstad in Holland and Copenhagen in Denmark perhaps come closest. Many automobile-dependent cities aspire to this form, like Vancouver and Salt Lake City; perhaps Perth can become a model in the next few decades.

Hierarchy of Urban Needs

Low car use, high non-motorised mode splits, well located mixed use and high density urbanism, low carbon emissions from transport or buildings, ecological services maximised

Livable Transit Oriented Region

High rates of sanitation, frequent public transportation networks, excellent education, safety concerns alleviated, pedestrian and cycling networks prioritised, autonomous funding solutions

Global City

Universities, high skills and knowledge employment, high capacity transportation networks, security, clean water and air, a low level of pedestrian and cycling infrastrucuture, ecological reserves, secure long term funding

Tertiary

Education, police, free judiciary, responsible local government, recreation centres, sufficient parks spaces, safe environments, annual tax base

Secondary

Water, transport, sewerage, communication, energy, employment, stability

Primary

Cole Hendrigan, 2014 Adapted from: Maslow, A. H. (1943). A theory of human motivation. Psychological Review, 50(4), 370-396.

Figure 166 Hierarchy of Urban Needs

SOURCE: AUTHOR. ADAPTED FROM 'A THEORY OF HUMAN MOTIVATION' (MASLOW, 1943) AND THE HIERARCHY OF HUMAN NEEDS DIAGRAM IN WHICH 'SELF-ACTUALISATION' IS RELIANT ON A SUPPORT SYSTEM OF OTHER NEEDS BEING MET AND RETAINED. THE BEST OF CITIES HAVE AT LEAST THE TERTIARY LEVEL OF SERVICES AND THE VERY BEST OF THOSE QUALITIES FORM A LIVEABLE TRANSIT- ORIENTED REGION.

A similar version of this diagram, unbeknownst to the author beforehand, was presented during a lecture in Adelaide in June of 2014 by Dr Larry Frank of UBC in Vancouver, Canada. It shows Quality of Life being dependent on: a foundation of the Built Environment's transport and land use options; Human Behaviour within that environment making possible positive urban characteristics; and the quality of the air, water and open space. Getting the details right at all levels makes for a quality of life with opportunity, safety and access.

Figure 167 Quality of Life Hierarchy

SOURCE: AUTHOR, 2014. AFTER DR LARRY D. FRANK, 2014

At the core of both these diagrams is the series of nested questions:

- If we can't make our streets safe for pedestrians and cyclists, how will we encourage people to walk to the train?

- If we can't supply the trains, how do we expect people to be mobile and seek new opportunities if not by private automobile?

- If we can't supply the trains, what chance do we have of urban consolidation with higher density and mixed use, walkable, interesting, enriching precincts?

- If we can't do these things, which should be relatively inexpensive and economically generative, what chance do we have as a city, or at a point in time, of wrestling with any other significant challenges ahead of us?

The answer to these questions is not revealed in this research, but they are at the core of the modelling.

5.5 AN APPROACH TO URBAN RENOVATION

This research presents an approach to retrofitting, or renovating, the urban area that enables reduced footprint, better economic productivity and improved liveability. It has prepared a methodology to predict these outcomes using tools and processes, data and aspirations, freely at our disposal.

What has been uncovered indicates that minor changes to policy, politics and engineering standards can achieve a Transit-Oriented Region. The techniques required to make these changes are used daily and in front of us to choose from; zoning, density bonuses, and infrastructure investment. This is not radical or idealistic; however the results show that an even more radical shift is possible. The good life may be redefined as providing equal access to public space, education, healthy lifestyles and health care; options for travel to all the important daily places by a shared mode of transport; and the satisfaction of being able to make choices.

This approach requires respect for the existing urban footprint with its under-utilised spaces and capacities; relatively small parcels of land may produce many benefits if re-urbanised with the correct levels of services such as public transport. The methods also leverage traffic engineering standards to prove that high-capacity public transport is the way forward. This is not a radical redesign of the entire urban form to comply with an overall aesthetic plan; rather it is encouraging market forces to take up where public policy leaves off. It also asks public policy to provide space for the market to act.

Rather than being a radical departure this simply allows the market to provide what it knows how best to do: provide quality housing and commercial office spaces. A modest amount of government oversight is necessary to ensure that services such as parks, schools, hospitals, libraries, recreation centres, clean streets with trees, buildings which contribute to urban public realm, are provided to achieve the best for the region. The result will be a region of urban life which is remarkable, prosperous and transit oriented.

To answer the question of how we get there we assessed a fairly broad range of literature on the topics of global car dependence, current land use and transport

integration schemes, and optimal city shaping. The research established that Perth, Western Australia, is a suitable living laboratory, a petri dish, so we reviewed the history of how this one conurbation evolved into its current status of an automobile-dependent region that is now trying to become a polycentric transit-oriented region.

Most of the literature sees cities as an ever-evolving physical series of edifices and streets, buildings and transport lines, in constant formation and reformation. The best we can do is to permit this to happen, but to manage the process for the best outcome. Several ideal urban forms, as espoused by Sitte, Howard, Lloyd Wright, Corbusier and others, never found their way from the drawings to the construction site fully fledged. However, their authors have become instrumental in how they predicted capital flows and resource allocation. For example, Frank Lloyd Wright's Broadacre City has never really been built, but it is present almost everywhere in the low-density automobile-dependent cities of single-family homes(Hall, 2002). Likewise, Corbusier never was able to demolish Paris for his *Ville Contemporaine*, but his predictions for urban habitation have come to fruition in places as diverse as the Soviet Union, China and Vancouver. Furthermore, although Howard was never satisfied with the outcomes of his Garden Cities, which were intended to be as much about poverty alleviation and sanitation as physical aesthetics, the informal plans for mixed use, moderate density, local food production and public transport access have been in and out of favour, informing great swaths of low-density high-end suburban areas, to reappear most recently under the rubric of New Urbanism. Even more recently, 100 years after Howard, in the British Government's announcement in 2014 in regards to the housing shortage in Britain:

> Development at a large scale creates the opportunity to secure real and important benefits: attributes that people most value – such as quality design, gardens, accessible green space near homes, access to employment, and local amenities – can be designed in from the outset. In short, Garden Cities are about far more than houses alone: they are about creating sustainable, economically viable places where people choose to live (DCLG, 2014).

It appears that what was old is new again.

Eventually, by casting backwards and forwards, we will be able to illustrate where we want to be in the future. Due to demographics and costs, cities of the future will include a range of scenarios including a variety of 'tools' to achieve goals: reduced and paid-for

parking; charges for congestion and pollution; high-capacity transport modes; higher densities with more jobs and amenities close to home; increasing land values in the inner and middle suburbs due to congestion, distances or restriction of edge greenfield developments; zoning to retain the natural environment close to home; and an overall emphasis on walkable urban centres and sub-centres along these transport corridors.

1.Begin with the end in mind.

2. Understand the past.

3.Move backwards from the vision to the present.

4.Move step by step towards the vision.

The Future

The Present
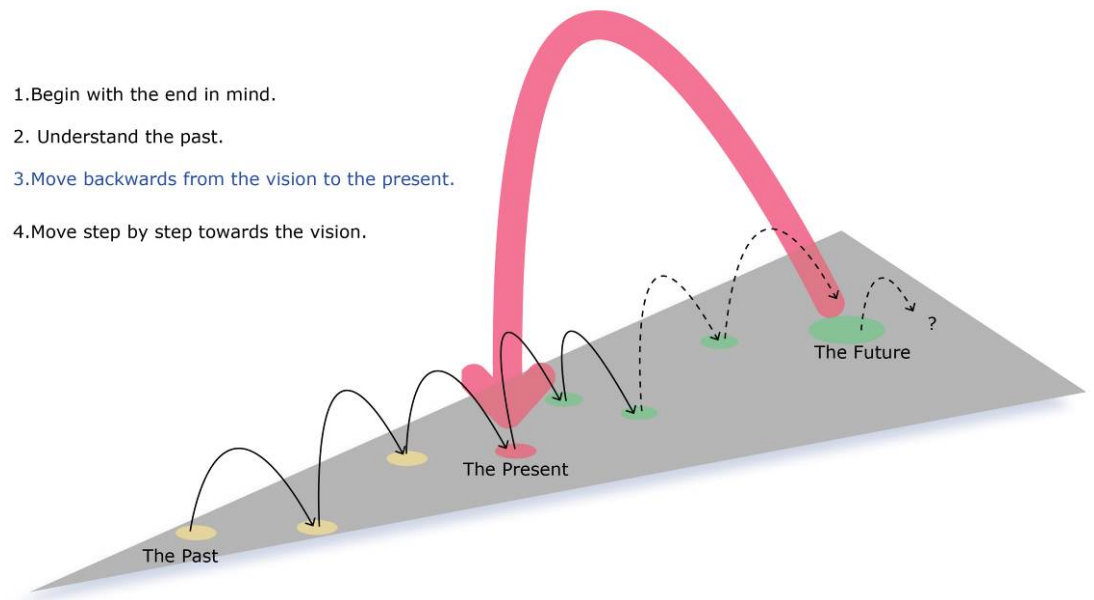
The Past

Figure 168 Backcasting Diagram

SOURCE: AUTHOR. THE RESEARCH WILL BACKCAST FROM THE PAST THROUGH TO AN ANTICIPATED FUTURE AND BACK TO THE PRESENT TO BETTER ARTICULATE THE VISION FOR TRANSIT ORIENTED REGIONS

5.6 AN APPROACH TO URBAN SCIENCE

An important area for further research is the scientific discipline of urban design itself. The question is how design research should be elaborated. Is it better to refine the traditional method of trial and error? Or can modelling play a bigger role in research, in one way or another? Research along these lines is a necessary step in hammering out a scientific method for urban design research (Jacobs, 2000 p.200).

To paraphrase the eminent urban designer Jan Gehl, we know more about the habitat of apes in forests than the habitat of humans in cities.[47] Similarly, we spend millions more dollars to study the surface of distant planets, in hope a few people may walk there, than we do on the surfaces millions walk every day.

This research is a call for a scientific approach to understanding our cities. It does not call for more statistical analysis, but aims to propose solutions and evaluate them statistically. A leaky roof needs more than an analysis with a new terminology; it ultimately needs a solution, to be fixed, from within the ceiling cavity. This is a call to aggregate knowledge, have the confidence to make assumptions, make choices and go forward with design proposals that match set goals. This is a call to be creative and to design innovative solutions with it. Indeed, some authors are already uncovering the relationships between city scale, growth, services and policy.

Scaling relations predict many of the characteristics that a city is expected to assume, on average, as it gains or loses population. The realization that most urban indicators scale with city size nontrivially, implying increases per capita in crime or innovation rates and decreases on the demand for certain infrastructure, is essential to set realistic targets for local policy. New indices of urban rank according to deviations from the predictions of scaling laws also provide more accurate measures of the successes and failures of local factors (including policy) in shaping specific cities. (Polzin et al., 2014)

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[47] "Interview with Jan Gehl" http://www.asla.org/ContentDetail.aspx?id=31346 Accessed May 21, 2014

This project took a fairly blank canvas of a flat, sprawling, automobile-dependent region and looked to find the opportunities latent in the detritus of an automobile-dependent conurbation, to uncover the capacity (C) and to describe the built form yields (Y) possible by the different modes (M) available. We know what automobile mode delivers: low density, low amenity, high VKT and high GHG lifestyles.

This research aims to enumerate the outcomes of a strategic and region-wide plan. It assumes this cannot be achieved by a scattering of TOD precincts, but rather by applying details to the policy rhetoric on smart-growth and 'compact city' ideals. If we did it, what would be the outcomes? How much is enough before we can achieve a reduction in resource intensity and sprawl?

The results of this inquiry are not the numbers or the charts; they are a by-product of the process. What has been tested here is whether and how a dynamic, living, complex region may be broken down into precincts in designated locations, and goals set and plans developed to rebuild the region to be more walkable, transit served, and with reduced automobile dependence. The results are interesting, but it is the *methodology* which is important. Perth, Western Australia, served as testing ground for this scientific approach as the author was residing there and participating in formal and informal discussions on the future of the smaller precincts in the urban region.

In *The Landscape Urbanism Reader*, Richard Weller argues that after understanding the limits and opportunities of positivist forces, such as engineering standards or guides to traffic-generating developments, the artistic designer of spaces has the opportunity to 'subvert' the 'bland data' into 'novel and innovative solutions'. This is called Datascaping:

> Datascaping, as a methodology is, to use a less fashionable word, planning. It is also potentially ecological (Waldheim, 2006 p.82).

While this research is not about Datascaping, per se, it takes a flexible and open approach asking the reader/user to create the city they wish for. The models presented here do give data in terms of metres of living space, park space, parking space, working space; persons; jobs; tonnes of GHG and others which may serve to inform the process of designing walkable, transit-served, mixed-use dense-enough precincts, if only to give the sense of scale to the operation. The reader/user may then know how strongly to pull the policy levers to achieve new goals and arrest the aimless downward drift of the status quo.

Most importantly, this model *is ecological*, as Waldheim explained it: much as science did not know of the food web as a fundamental part of ecosystem's multi-layered rationale until it was observed and measured, this research's models seek to uncover the hidden rationale, the web of interactions, that explain much extant urban form.

Further to the quest for an Urban Science, Richard Florida writes:

> **…Because better research and data-gathering is needed to make cities more effective, so that we can establish a true "science of cities."** Science and clear-eyed data analysis enabled dramatic improvements in agricultural yields and health outcomes in the emerging world. We all want better cities, but we are in many ways still flying blind. There is virtually no systematic or comparable data to compare the most rudimentary economic functions. Without reliable measurements of income, output, and other basic metrics like we have for nations, we can't tell which cities are growing or by how much, where incomes are going up or down, where productivity is increasing or not, where jobs are being created, or where slums are income traps or centers of mobility. A UN Goal could help develop the data and research infrastructure which is absolutely critical to developing deeper understanding that can guide more effective urban strategy, policy and city-building writ large (Florida, 2014).

This is not a finished suite of models which sets definitive levels for density or transport service across a regional metropolis, but it does enable options to be compared, and the models do identify thresholds which must be crossed if we are ever to arrive at genuinely Transit-Oriented Regions.

5.7 CONCLUSION TO ANALYSIS AND DISCUSSION

This chapter 5, Analysis and Discussion, has set out to answer: **How best may we analyse the outcomes of the methods and results within academic and professional practice in the expanding field of Urbanism?** By examining the results of the models comprehensively for stand-out numbers we can see that there are costs and these are further elaborated, but there are also numerous benefits to the Triple Bottom Line of Sustainability. The numbers of dollars, persons, VKT, GHG and others have implications not just for the Perth region but for many OECD countries' cities where there is a misbalance between automobiles and 'alternative / traditional' modes of transport as city building tools. However, there is also great potential for the application of these models in non-OECD cities where high population and urban growth is expected over the next century. Getting the correct balance of private and public mobility in these cites is a pressing issue for the world's efforts to combat poverty, improve life quality, and to curb GHG emissions.

What this research ultimately leads to is a new narrative around what cities are expected to provide. The research also proposes a new way to examine cities more scientifically as urban systems with preferred service levels of parks and transit to improve life quality. This will ultimately be but a modest new contribution to the discussion, but hopefully an effort worth consideration as this research moves beyond the rhetoric to describe the meaningful details of positive metropolitan growth.

6 - CONCLUSIONS TO RESEARCH

The point of cities is multiplicity of choice (Jacobs, 1961).

By defining our goal more clearly -- by making it seem more manageable and less remote -- we can help all people to see it, to draw hope from it and to move irresistibly towards it. JFK[48]

THESIS QUESTION: Following from the rhetoric and promise of compact cities, how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?

The concluding chapter will first review the promise and limitations to a Transit-Oriented Region. Second it will compare what the Introduction has outlined as the significance, scope, aims, goals and results of the study with the outcomes from the research and modelling. Third it will suggest further research on this topic.

6.1 THE TRANSIT ORIENTED REGION

Indeed, another way forward towards a greener economy is emerging, and investment in sustainable transportation is increasingly recognised as one of the most efficient ways not only to stimulate the economy but also reinforce the benefits of metropolitan agglomeration. Driven by the global climate crisis, the coming investment in high speed rail, commuter railways, trams, streetcars and busways, alongside the reconfiguration of urban street networks for all users will help create a

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[48] "American University Speech, June 10, 1963" President J.F. Kennedy
http://www.pbs.org/wgbh/americanexperience/features/primary-resources/jfk-university/ Accessed May 18, 2014

new skeletal framework for more sustainable cities (Hank Dittmar in (Schiller et al., 2010).

One cannot hate sprawl but also hate density, and neither can one hate tax dollars being spent on public transit while highways remain un-tolled and parking is free. There are costs and benefits to all choices and having a model to see the scale of the operation and volume of opportunity helps decision makers, including the interested public, to make better informed decisions.

Ultimately, having goals and targets make us more aware of the impact on the smaller and larger scale of urban design of every choice we make. This is not novel, but having a model to elucidate targets such as GHG, VKT and POS is new and, potentially, useful as cities and regions become more complex and populous.

The Transit-Oriented Region (TOR) has been identified in this research as an ideal goal. The TOR will comprise the totality of the urbanised and non-urbanised (ecological) areas in a region. It will be composed of many overlapping jurisdictions which have been able to provide all the quality of life aspects including safety, sanitation, clean air, maintained ecosystem services, and such, while continuing to grow and prosper. To achieve the TOR level will also mean that the region has made hard choices regarding the mobility of the automobile and access of the individual to reach goods and services. With this growth will be challenges, not least of which will fall on local residents and local decision makers. However, there will also be opportunities for an urban region to become something more than the sum of its parts. The models proposed in this research reveal the relationships between disparate factors in planning for our local areas. Hundreds of local areas will comprise the totality of capacity and yields in a regional strategy reaching for goals such as improved health, wealth, local air and global atmospheric quality.

6.1.1   REVIEW OF MODELS FOR A TRANSIT-ORIENTED REGION

The Global Scale Model: asks 'What kind of urban fabric do we want?' It uses examples from around the world which correspond to the   policy levers leveraged for **parking** ratios, **mix** of use, activity **density**, **safety** for pedestrians, **public transport** level of service provision, the physical land **area**, and ideal **location** for re-urbanisation. The *lower* the parking ratio and the closer to an historic urban core a project is (with typically finer-grained street grids and existing social amenities/services), along with *higher* mix of use, increased density, pedestrian-oriented design, public transport service and public land, the higher the scores are. The score then corresponds to a suite of images in a linked folder in Google Earth to better view the physical outcomes of choices and policy. This model may then inform the following Regional Scale's goal formation.

The Regional Scale Model: looks at the opportunity and capacity for re-urbanising plots of land around a conurbation, and the potential yield. It is structured so that any global city could apply its formulae so long as the operator is aware of the goals (from Model 1) and the spirit of the planning to this point in time. Is there a genuine desire to have Smart Growth practices, or to have clusters of innovative Knowledge Economy, or to have a higher ratio of sustainable transport alternatives? If the answer is 'no', this model may not reveal informative data. However, if the answer is 'yes' this model will elucidate the pay-offs and trade-offs of comprehensive planning for a metropolitan region with real targets and strategies to achieve them. This model does not give design direction, *per se*, however it does set targets for a region to know what **density, transport mode, jobs, public open space, and reduced parking ratios will be required of its urban fabric.** This model also illustrates the **co-benefits** of planning for public transport and density across a large expanse of urbanised land, such as reduced **GHG emission, lowered VKT, improved health and productivity, social infrastructure upgrades, sprawl reduction** with concomitant **ecosystem services** preserved and other potential outcomes.

The Local Scale Model: are two local scale models which work independently but effectively show what Models 1 and 2 mean at the scale at which daily humanly interactions occur. The **height of the density, the parking ratios, the number of shops and**

amount of commercial office space required to create enough destinations within a re-urbanised precinct can be best understood at this level. However, as the product of Model 2 is derived in part from Model 3.1 (using Victoria Park as a case study) we can see the impact this level of activity will have on the **overall regional goals of housing, jobs and carbon reduction.**

The three scales of these models provide a platform for frank and open dialogue with community and between government departments. Currently, the 'silos' between professions in the consulting sphere and even between departments *within* local and state governments serve as an intransigent barrier to implementing strategies.

- In the first instance, the community cannot be expected to have the patience to learn about all the options comprising all the stakeholders and likewise government departments can easily overlook the daily and long-term needs of communities.

- In the second instance, the so-called 'aligned' professions within private and public practice of engineering, architecture, urban planning, urban design and landscape architecture have similar views on urban growth, but often very divergent language, standards, philosophical grounding and priorities, which leads to miscommunication and misalignment of goals.

- In the third instance, for governments policy approach must be grounded with at least a few measured elements from physical space.

These models may not ultimately solve the issues facing urban regions or resolve conflicts of urban design, however hopefully they will begin to bridge the gap between policy and practice, planning and implementation so that there can be clarity on 'transport and land use' policy.

TOD by itself is a great idea, as is LUTI, but they are not up to the task of comprehensively or significantly improving the urban planning outcomes of a region's mode split, densities or walkability. A TOR enables the whole urban system to change, to create a whole new urban fabric that can overcome automobile dependence.

In conclusion the TOR has to include many TODs, of varying scales and with a variety of land use mixes to complete different residential, employment or industrial tasks. Beyond this, there has to be a concerted effort to shape an urban form across the broad urban region, and not just in one place, through:

- incentivising height and density along rail corridors,

- reducing the ratios of automobile parking,

- reducing the investments in highways in favour of high capacity public transport,

- providing excellent Public Open Space and setting aside ecological reserves in fragile ecosystems,

- providing superior public services and encouraging private amenities in all locations, and

- planning around the pedestrian and cyclist everywhere (not just in special zones).

This will reduce the carbon footprint, increase productivity and make for a healthier and wealthier city; it is the strategy to become a Transit-Oriented Region.

The research has demonstrated what is to be gained by applying policy and logic to transport and land use planning **across the entire region**, and not just in specialised zones, and how this can be done.

To answer the question '… how best may we accurately model the interactions of local land-use plans with public transportation provision to transform automobile-dependent metropolitan regions?' it is necessary to follow a method similar to that above: taking a holistic and non-nostalgic approach to land use patterns to deliver urban fabric worthy of the city, its people and its environmental setting. For this to happen a car-dependent city must increase transit services; reduce incentives to drive by limiting highway and parking space; and up-zone land to permit higher activity density around station precincts. However as outlined in this thesis it requires a regional planning approach in order to create a regional system of TODs synergistically linked.

6.2 EVALUATION

6.2.1 SIGNIFICANCE

The significance of the research is that it is based on existing literature, develops a novel approach, and provides a new method to uncover new information. The table below summarises what has been done:

Table 17 Significance of the research into Urban Transformation

Significance	Respective Chapter	How it is demonstrated
Based on existing Literature	Chapter 2 - Literature Review	Review of automobile dependence, land use and transport modelling, case study of City of Perth, and city shaping.
Novel Approach	Chapter 3 - Research Design	Takes the land available and applies a Smart Growth approach to urban transformation to test the opportunities and outcomes on a global, regional and local scale. Proposes a TOR as the solution.
Provides new Method	Chapter 4 - Results	Devises a flexible and transparent model to find capacity, yields and co-benefits of the Smart Growth TOR approach.
Provides new Information	Chapter 5 - Analysis and Discussion	Discusses the results of the modelling, but suggests a 'scaling up' of urban futures aspirations to match the population, transport and economic tasks ahead. Shows a range of tools that can effectively enable cities to plan for a TOR.
Limitations & Suggestions	Chapter 6 - Conclusion	Makes suggestions for further research.

6.2.2   RESPONSE TO SCOPE, AIMS AND GOALS

6.2.2.1 RESPONSE TO SCOPE

As described in the Introduction's 'Thesis Scope, Aim and Goals' (p.38), this research's models will make use of these base information sets to the left, and were resolved in this manner, to the right.

Table 18 Response to Scope of the research

Base	Resolution	Where demonstrated
Make use of existing base-line data	Used the lot and block survey to make measured land area assessments along with transport corridor and parks reserves to find practicable public transport networks and land to remain untouched to make accurate AutoCAD drawings of the land where increased housing and jobs might be provided.	Methods section in Research Design Methods section in Results of Model 2
Make use of population projections	Used the Australian Bureau of Statistics	Methods section in Research Design Methods section in Results of Model 2
Make use of housing demand forecasts	Used HIFG (Housing Industry Forecast Group) forecasts for the current and expected rates of home building.	Methods section in Research design Methods section in Results of Model 2

Use published Traffic Generation numbers and Parking Ratios to highlight the severity of the problem of automobile dependence	Used the New South Wales Roads and Transport Authority's 'Guide to Traffic generating Developments' and applied their rates of trip generation and parking to the mixed-use /TOD precincts.	Methods section in Research Design Methods section in Results of Model 2
Use existing survey and current planning documents as a base level of information	Made use of every master plan and Structure Plan available from all cities in the Perth Region. Made use of the spirit (and letter as much as possible) of the State planning policy frameworks.	Methods section in Research Design Methods section in Results of Model 2
Provide answers to some basic questions regarding how much development, where and how high for whom?	Applied a set of mixed-use ratios and an IF proposition to limit building heights to between 4 and 10 storeys.	Results Sections of Models 1, 2, 3.1 & 3.2

The models of this research have been developed so that they can be used in any global city with different means of data collection and with, perhaps, restricted data. They will be particularly useful in car-dependent cities that have recognised their inadequacies and want to plan for a significantly less car-dependent future.

The goals of the methods are shown on the left, with the outcomes listed to the right.

Table 19 Response to Goals of the research

Goals	Outcomes	Where demonstrated
Analyse the capacity of land, in volume and persons, to accommodate higher activity densities with each change in public transport levels of service;	Results in chart format in Results of Model 2, especially	Results section of Models 1, 2, 3.1 & 3.2
Calculate the public transport mode capacities, in persons per hour per lane, to serve compact polycentric region policies;	Results in chart format in Results of Model 2, especially, which quantify the trip generation and parking requirements. Also, Appendices B, C & G discuss roadway design and capacity.	Results section of Models 2 & 3.2
Enumerate the direct and indirect economic costs and benefits of high-capacity public	Results in chart format in Results of Model 2, especially, which quantify the co-benefits of integrating higher activity	Results section of Models 2 & 3.2

transport as a part of the growth of opportunity in the Green Economy;	density with higher-capacity public transport.	
Quantify the costs of construction, social benefits, economic productivity, traffic generation and parking requirements in a manner which is meaningful; and	Results in chart format in Results of Model 2, especially, which quantify the co-benefits of integrating higher activity density with higher-capacity public transport.	Results section of Models 2 & 3.2
Map and visualise the changes as they occur in one scenario, at various scales, in an urban region currently among the lowest density urbanised areas on the planet: Perth, Australia.	Results in chart format in Results of Model 2, especially, which has several illustrations at the end of this chapter. Also, Appendices H, I, L & K discuss different forms on the topic of comparative densities.	Results section of Models 2 and 3.1

The goals were to have a defensible method and operational model that is transferable to other global cities planning their future for higher rates of density and public transport service levels. Three models have been created to produce programmed (target-reaching) master plans for neighbourhoods and regions.

These models may be considered as a set of tools to help realise strategic plans and a means to revise or formulate a strategic plan. They shows ways towards achieving political

aims, revealing the economics, and building the infrastructure needed to support further population growth for a net positive outcome via a strategic planning approach. The models are presented in a way that makes them useful to anyone interested in the future of their region, providing a regional planning approach.

The set of tools is flexible and transparent in that it uses the widely available software of Microsoft's Excel and Google Earth.

6.2.2.3 RESPONSE TO AIM

The aim of this research has been to develop a working model which is both flexible and transparent to illustrate the pay-offs and trade-offs of shifting automobile-dependent cities to higher and greener land use and transport integration (LUTI) within a transit-oriented region (TOR). The modelling has been prepared so that the input variables are clearly shown, making for *flexibility* for any local area or urban region. The assumptions used are *transparent,* with citations to a source document in the model. Ideally the models may be used, with very little instruction necessary, by any decision maker (i.e. financier, investor, politician, planner, urban designer or concerned citizen) *as a tool* in delivering high-performing public transport capacity to accommodate increased patronage from high-density precincts. In this way, the research has been successful, though not used by others yet. The thesis has demonstrated that there is potential for use by almost anyone.

6.2.3   RESULTS

As identified in the Introduction, there is a gap in both academic and professional practice between strategic and statutory planning. Long-range strategic planning is often moderated by the rules that govern the day-to-day statutory planning and transport engineering standards. These often stand in the way of visionary approaches assessing the future benefits for an urban region which attempts to achieve 21st century goals such as lowered VKT and CO_2. This thesis explored how strategic planning may borrow from the rationalist approach of statutory and transport planning to craft an optimal region-wide

approach to walkable, transit-oriented, mixed-use, creative, knowledge-based, urban transformations.

The results are quantified whole numbers of cars, persons, jobs, dollars, kilometres, trains, parks, parking and services. These numbers are usable and understandable to the lay public, politicians and policy writers, amongst others. Ultimately, the models are useful in uncovering capacity and yields of the urban lands to deliver 21st century goals of carbon reduction and higher equity in quality of life. The models uncover the pay-offs and trade-offs of changing the use and permitted density by up-zoning urban lands or investing in high-capacity transport technologies The descriptions of each model in the Results chapter explain these thresholds and the relationship between public transport and land use changes.

The core of the thesis is summarised in the table below:

Table 20 Core of the Thesis

The region must have comprehensive planning policies to: • Lower parking ratios – liberate urban surface and capital for real estate in addition to limiting induced driving, heat-island, sullied storm water runoff   • Increase mixed-use precincts – provide shorter walks to more services and amenities   • Increase walkability – safer and desirable footpaths and crosswalks   • Increase density – increase the 24 hour activity levels to make the most of land up-zoning and make transport investments more worthwhile   • Increase transport network – to make multi-directional travel a part of opening more land in a polycentric manner   • Increase public transport capacity with more trains, better signalling, more limited stops and more direct bus routes that improve accessibility.   To achieve these goals for these reasons: • Lower Greenhouse Gas Emissions – from shared-wall housing, lowered transport emissions, and installation of best-practice technology (solar PV, geothermal and tri-generation power sources) in the re-urbanised precincts   • Lower Vehicle Kilometre Travel – so that health and productivity may be improved   • Increased Liveability – to foster innovation, not complacency

- Increase Accessibility – drives up land values which increases options for Value Capture to help pay-down the cost of the increase in capacity and network, and makes polycentric, 'human-scaled' nodes of activity more viable

- Increased Public Open Space – for urban life to thrive

- Preserve farms, forest and wetlands – so that ecological systems may thrive

- Improve the jobs/housing balance – to reinforce residential areas so that residents make more trips over shorter distances, preferably without an automobile.

While none of this is entirely new, it has been modelled to quantify, in legible detail, the pay-offs and trade-offs of matching rhetoric with policy-levers in simple to use tools.

An alternate vision of improved quality of life …is a world where accessibility is favoured over mobility, where amenities, services, and neighbourhoods are advantaged over highways and bypasses, and where green modes are designed to be convenient, reliable and ubiquitous. Above all, it is a vision of the world where mobility is seen as a means to an end, not an end in itself (Hank Dittmar in (Schiller et al., 2010)).

This research anticipates a change in the culture to a more urban lifestyle promoting greater use of public amenity and public transport accessibility over private property and private mobility. This change is occurring, as noted in the literature review, and the advantages of urban life will be apparent to those who seek places of higher diversity, innovation and opportunity, so long as there are places in the urban fabric which are *urbane* and offer a walkable, mixed-use, transit-oriented lifestyle.

The research into target-achieving regional planning for automobile-dependent cities has uncovered several results, including the expected reduction in tonnes of GHG emissions per person per year from transport and shared-wall living, expected kilometres of walking with a concomitant decrease in health care costs and increase in economic productivity, amount of land to be set aside for quality public open space, expected service levels of social infrastructure, the right-sized public transport mode suited to the task of matching the expected population growth and jobs, dollars of revenue to government treasuries from the up-zoning and paid parking in these new transit oriented developments, and how to visualise the required density in the best transit-oriented places.

The core of the research is based in the land and the capacity of the land to deliver yields: urban yields in meters squared and cubed, and where is the land to achieve these high level goals. Then, given the promising results, are the building heights tolerable? What are the correct numbers of parking spaces to garner the urban results written about in the planning policy? Though the research reveals a suite of results based on different scenarios, the answer to these questions lies with potential future users of the model as they pull on several transparent policy levers to see the costs, benefits and spatial requirements of these goals being achieved. In this way, what are revealed are a method and a model to comprehend urban planning and design at the scale of a Transit-Oriented Region for any global city.

6.3 FURTHER RESEARCH

There remains much to do in this field. Certainly there are many people active in transport modelling, in land use planning and in urban design but rarely do they come together except, often, in an adversarial manner when there is an issue to be resolved, such as one regarding 'style of development' or traffic analysis. Further research does need to be accomplished in bridging the 'aligned professions' and their professional prejudices.

More research should be undertaken in proving the land uses for Model 1 from town centre or other urban fabrics from around the world to catalogue the actual data on mix-of-use and parking ratios, pedestrian counts and fatalities, density and accurate location description to assign the corresponding whole number to each Google Earth 'place'. The main point of this exercise would be to groundtruth the model and to expand on it with a reliable source of data indicating which of the levers contributes the most to the success of these places as successful transit oriented places. However, given the limitations and the timeframe, this was not possible to accomplish in this research.

More research could be put into improving the spectrum of assumptions used in Model 2. One could make a very extensive Multi-Criteria Evaluation of the academic scientific sources and average the results to improve the assumptions given in this model. Indeed, one could develop another suite of assumptions to uncover other co-benefits. However the assumptions made are mainstream enough to ensure a broad understanding of the quantitative benefits of TOR – and they are substantial.

Most importantly the whole model needs to be trialled on many more cities to see if the results shown in the Perth analysis can be further replicated and hence the case for a more sustainable urbanism can be more clearly defined.

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8 - APPENDICES
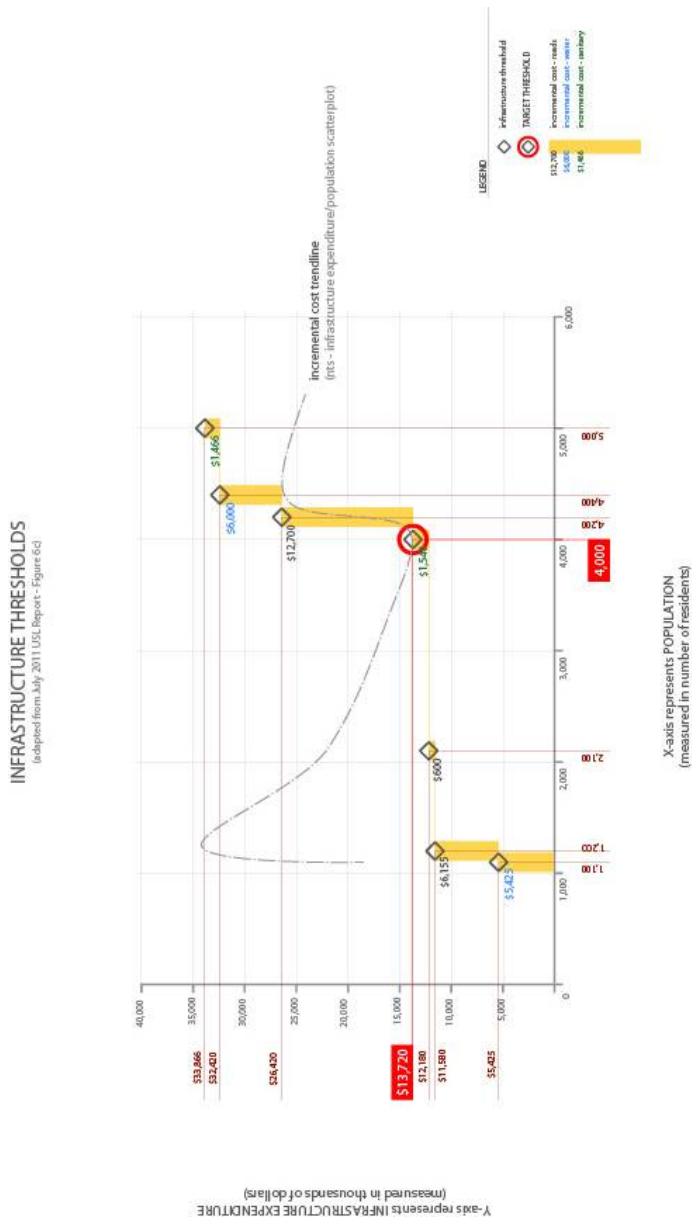
Appendix A.   Developer/Amenity Calculator

Figure 169 Infrastructure Thresholds

SOURCE, EDWARD PORTER, PER COMMS.

The potential for land developers to contribute to the public realm amenities or services, such as public transit or even stations, is modified significantly by an understanding of what is demanded and provided by land developers, generally. The expectation that higher density is always a preferred planning outcomes may be true to local governments who look to lowering per person servicing costs, but the same is not always true from a developer's perspective. To make the land saleable, they must first bring in the entire required infrastructure, as per the population expected to be placing demands, as shown in the diagram above. What we can see is the infrastructure expenditure /population curve which initially rises due to the first number of homes on a land parcel it the trends down not in cost, but cost per person as the population increases. However, there are population thresholds at which require greater numbers and sizes of pipes to different depths; road lanes, widths and geometries; other factors such as schools and parks; or any combination thereof. Such is shown in the diagram in that between 4,000 and 4,2000 persons, in this specific project, the infrastructure expenses get so high that the optimum threshold is reached.

The diagram is not a hard set fact of development, but rather a site specific project for a target demographic in a particular setting under the regulations and engineering standards of one local government. However, it does show the types of relationships which limit the ability of some development's, and their developers, fiscal capacity to return a density along with a profit. The capability to then contribute towards funding other region wide infrastructure may therefore be limited.

To see the relationship a little more opaquely, with a model which has flexible assumptions, the author created the "Developer/Amenity Curve Calculator" below. It has not been tested with developers of governments for veracity. Any box coloured may be changed according to one's assumptions.

Developer Amenity Curve

Density (beds per hectare)	Scenario	Amenities Contributed (Per Bed)	Amenity factor	Gross Profits to Developer (per Bed)	Profit factor	Net Profit to Developer	Price Point per bed	Who Pays Premium	Who Gets Operations	Who Gets Taxed	
		$200	1.1	$600	1.3		200000				
10	a	$2,000		$6,000		$4,000	$200,000	D - HO	C	HO	D = Developer
20	b	$4,400		$15,600		$11,200	$200,000	D - HO	C	HO	HO = Home owner
30	c	$6,600		$23,400		$16,800	$200,000	D - HO	C	HO	C= City
40	d	$8,800		$31,200		$22,400	$200,000	D - HO	C	HO	
50	e	$11,000		$39,000		$28,000	$200,000	D - HO	C	HO	
100	f	$22,000		$78,000		$56,000	$200,000	D - HO	C	HO	
200	g	$44,000		$156,000		$112,000	$200,000	D - HO	C	HO	
400	h	$88,000		$312,000		$224,000	$200,000	D - HO	C	HO	

Change Density	Change Amenity Contribution $	Change Factor	Change Profits $	Change Factor

(Water, Sewer, Power, Parks, Rec Centres, Trails, Waterfronts, Trees)

(x$/bed with factor after first 10 as amenities will have been contributed at lower threshold)

(x$/bed with factor after first 10 due to higher risk)
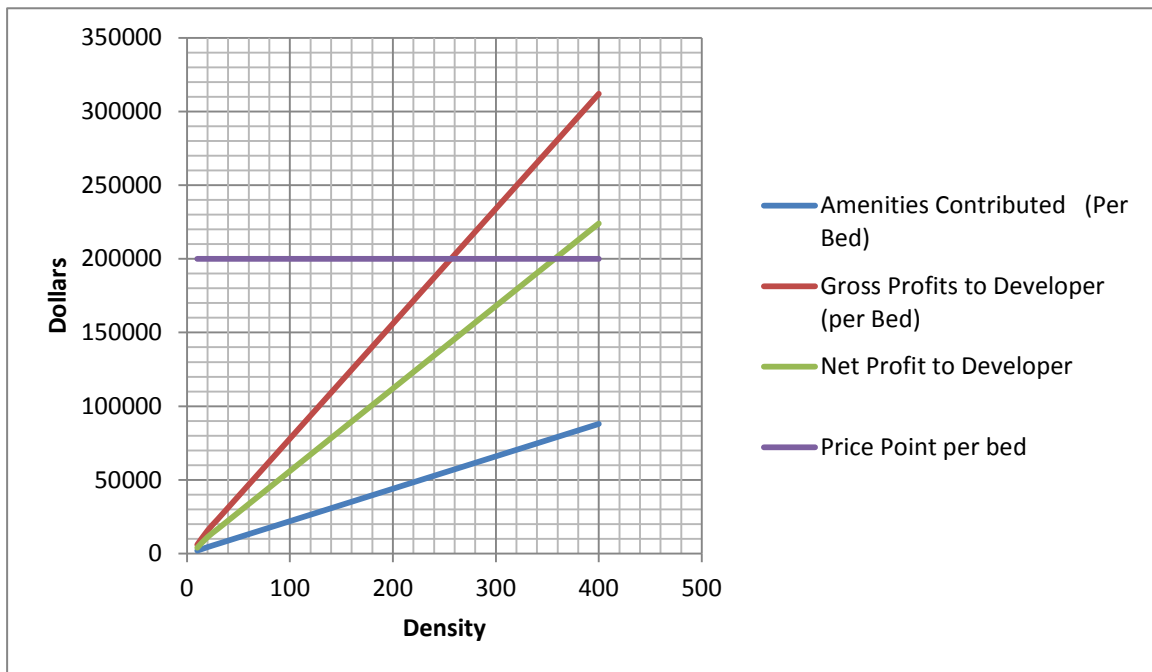
Figure 170 Developer/Amenity Curve Calculator

SOURCE: AUTHOR, 2014

Typical Street Hierarchy based on automobile travel speeds
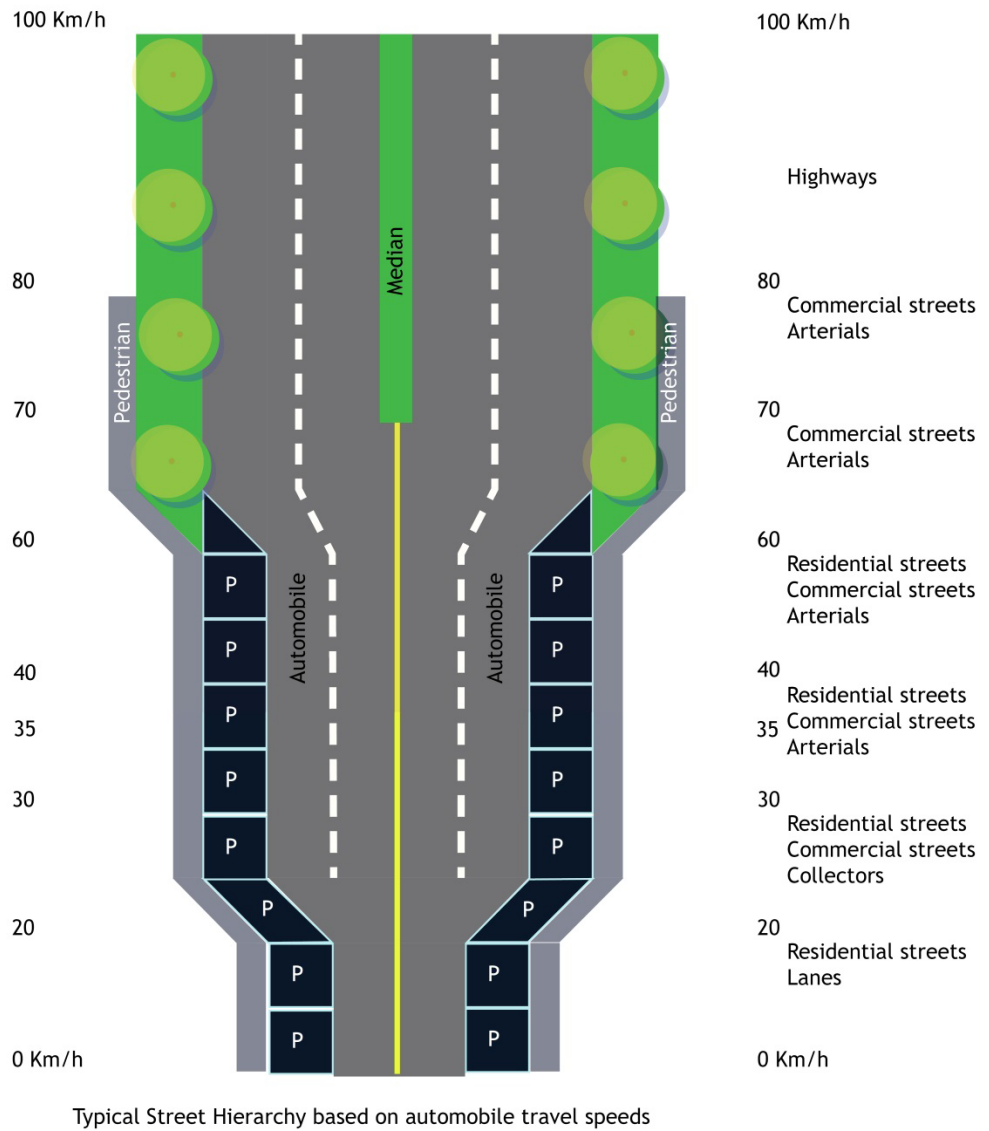
Figure 171 Typical Street Hierarchy based on Automobile travel speeds

SOURCE: AUTHOR, 2014. THIS DIAGRAM SHOWS LITTLE TO NO REGARD TO THE PEDESTRIAN, CYCLIST OR TRANSIT USER
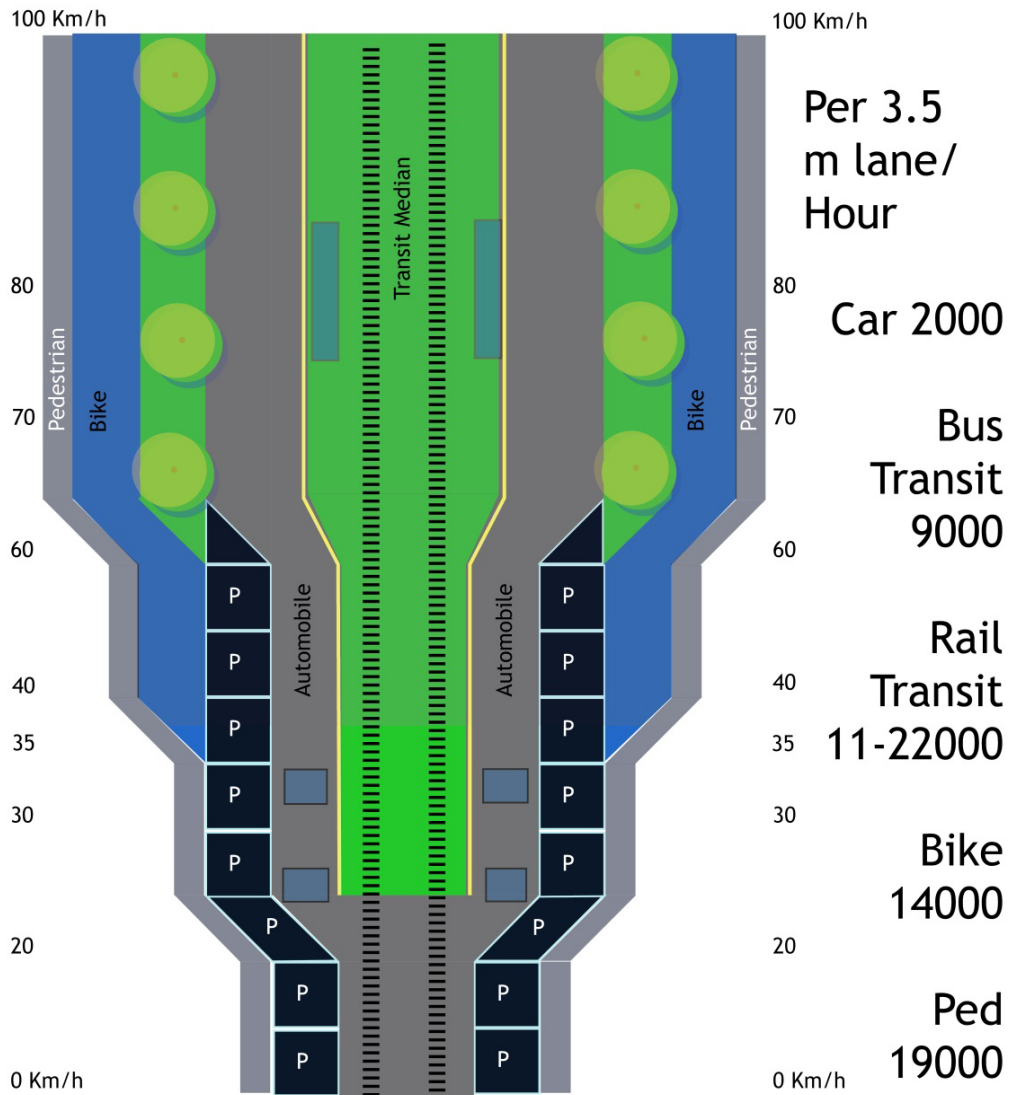
Best Practice for Multi-Modal urban transport based on automobile travel speeds between
Car @ 2000 Per hour on four lanes = 16,000
Car @ 2000 Per hour on two lanes = 4,000
Bus @ 9,000 Per hour on two lanes = 18,000
Train @ 20,000 Per hour on two lanes = 40,000
Bicycle @ 14,000 Per hour on two lanes = 28,000
Pedestrian @ 19,000 Per hour on two lanes = 38,000
Based on Botma & Pependrecht, Traffic operation of bicycle traffic, TU Delft, 1991

Figure 172 Best Practice for Multi-Modal Transport

SOURCE: AUTHOR, 2014. THIS DIAGRAM SHOWS HIGH REGARD TO THE PEDESTRIAN, CYCLIST OR TRANSIT USER AS THERE ARE SPEED TABLES ON STREETS DESIGNED FOR BETWEEN 20 AND 35 KM/H; WITH PROTECTED BICYCLE INFRASTRUCTURE FOR STREETS OVER 35 KM/H, LANDSCAPE BUFFERED AND SEPARATED BICYCLE AND PEDESTRIAN REALMS FOR STREET DESIGNS OVER 60 KM/H. PUBLIC TRANSPORT RECEIVES A SEPARATED ROW FOR STREET DESIGNS OVER 25 KM/H.
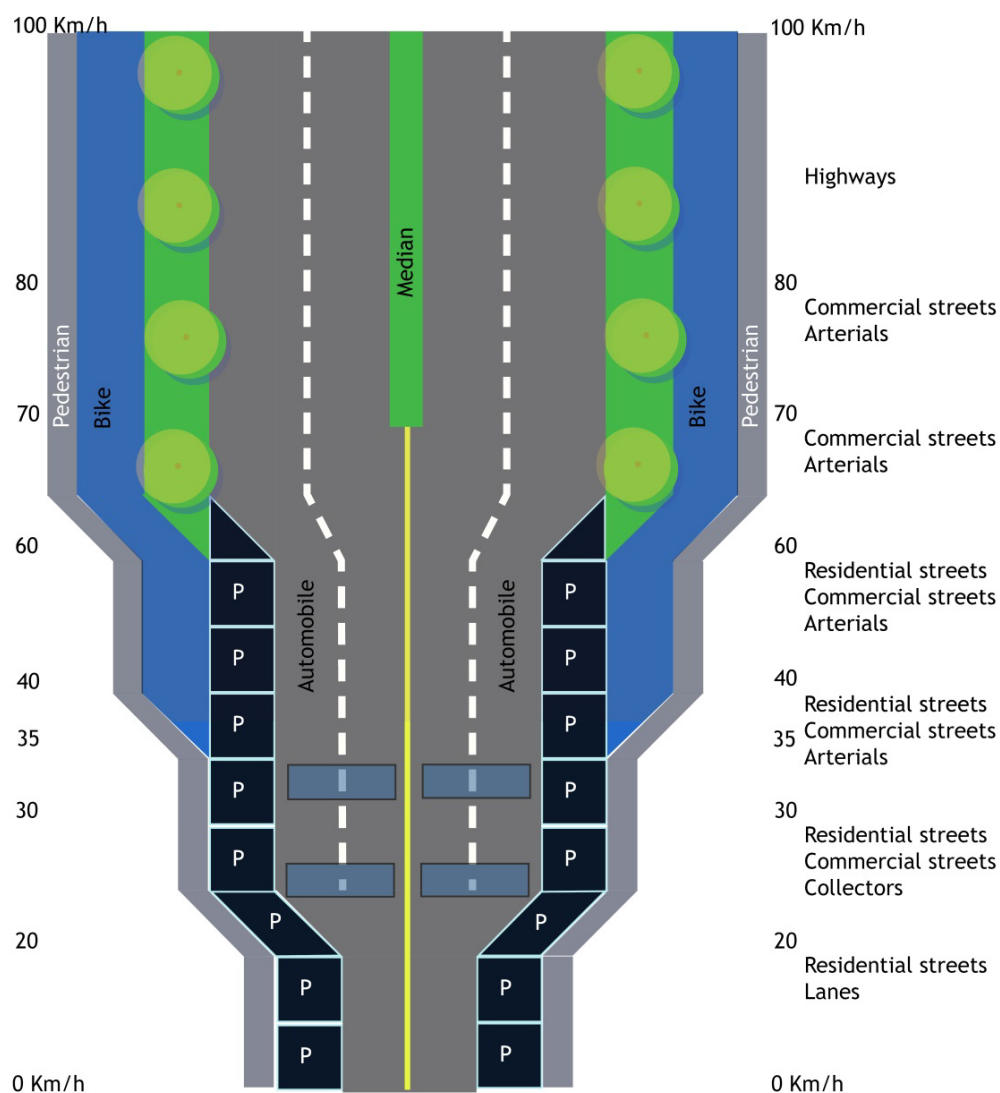
Best Practice for Bicycle Infrastructure based on automobile travel speeds between
0-20 Km Per hours: no physical separation required
20-35 Km Per hours: no physical separation, speed tables installed
35-60 Km Per hours: physical separation advised between parking and sidewalks
60-100 Km Per hours: physical separation with landscaped boulvard andd median

Figure 173 Best Practice for Active Transportation

SOURCE: AUTHOR, 2014. DESCRIPTION OF THIS DIAGRAM REPEATS FROM DIAGRAM ABOVE.

Appendix D.   Ecological Services

"Ecosystem services are goods and services of direct or indirect benefit to humans that are produced by ecosystem processes involving the interaction of living elements, such as vegetation and soil organisms, and non-living elements, such as bedrock, water, and air.

"Researchers have come up with a number of lists of these benefits, each with slightly different wording, some lists slightly longer than others. The members of the Sustainable Sites Initiative's committees and staff have reviewed and consolidated the research into the list below of ecosystem services that a sustainable site can strive to protect or regenerate through sustainable land development and management practices." (ASLA, 2009 p.6)

GLOBAL CLIMATE REGULATION

- Maintaining balance of atmospheric gases at historic levels, creating breathable air, and sequestering greenhouse gases

LOCAL CLIMATE REGULATION

- Regulating local temperature, precipitation, and humidity through shading, evapotranspiration, and windbreaks

AIR AND WATER CLEANSING

- Removing and reducing pollutants in air and water

WATER SUPPLY AND REGULATION

- Storing and providing water within watersheds and aquifers

EROSION AND SEDIMENT CONTROL

- Retaining soil within an ecosystem, preventing damage from erosion and siltation

HAZARD MITIGATION

- Reducing vulnerability to damage from flooding, storm surge, wildfire, and drought

POLLINATION

- Providing pollinator species for reproduction of crops or other plants

HABITAT FUNCTIONS

- Providing refuge and reproduction habitat to plants and animals, thereby contributing to conservation of biological and genetic diversity and evolutionary processes

WASTE DECOMPOSITION AND TREATMENT

- Breaking down waste and cycling nutrients

HUMAN HEALTH AND WELL-BEING BENEFITS

- Enhancing physical, mental, and social well-being as a result of interaction with nature

FOOD AND RENEWABLE NON-FOOD PRODUCTS

- Producing food, fuel, energy, medicine, or other products for human use

CULTURAL BENEFITS

- Enhancing cultural, educational, aesthetic, and spiritual experiences as a result of interaction with nature

Appendix E.   Checklist for Landscape Architects

From the "Cities Alive' Report. (Arup, 2014)

LANDSCAPE CONTEXT AND ASSETS

- Acknowledge geographic setting and landscape
- characteristics
- Take account of water catchment/supply
- Note current land uses and design responses to locality
- Consider ecosystem services and implications for biodiversity
- Review history of area and any heritage implications
- Note social and economic factors influencing landscape
- Review implications of climate change, energy needs, population growth
- Consider plans and any design proposals to date
- Review similar projects/case studies and project approaches

SUSTAINABLE MASTERPLANNING

- Conserve historic landscape, built form and significant aesthetic features
- Prioritize development on disturbed land wherever possible
- Protect natural heritage and enhance biodiversity of site
- Reuse redundant structures and adapt existing landscapes for new uses
- Design for socially inclusive community and neighbourhood safety
- Plan compact development to optimize land development potential
- Cater for wide spectrum of users and communities
- Site buildings to minimize energy use
- Ensure site is part of green and blue infrastructure
- Develop design rooted in local context
- Encourage local use through ease of access
- Design networks for walking and cycling and permeable space
- Ensure connections to public transport
- Respond to the ecology of the place
- Design social gathering spaces and active frontages
- Integrate overall vision with detail design
- Engage local community/stakeholders

- Enhance biodiversity

- Incorporate productive landscapes

- Create unique, comprehensible and memorable places

- Plan for the inclusion of public art

- Encourage local business opportunities

- Design for multiuse and range of uses

- Sustain landscape from economic and social perspectives

- Design for health of all ages

- Connect people to places/destinations

- Include information and interpretative facilities

- Provide amenities for diverse range of users

- Provide for flexible space for future change of uses

- Provide shelter and shade with large trees

ECOLOGICAL SITE DESIGN

- Generate green energy on-site

- Use indigenous and/or non-invasive plant species

- Use ecosystem services and enhance site ecology

- Minimise night light pollution

- Incorporate homes for wildlife

- Extend local plant communities

- Balance cut and fill of soil on-site

- Minimise floodplain development

- Use water-sensitive urban design

- Maximize water retention on-site

- Restore and create wetlands

- Reduce impervious surfaces

- Take measures to reduce air pollution

GREEN TECHNOLOGIES

- Use recycled materials

- Green structures/buildings

- Use timber from sustainable sources

- Use durable products

- Minimize mowing/use of machinery

- Use organic compost, fertilizers and mulches

- Decompose waste on-site

- Use phytoremediation on contaminated sites

- Use porous paving

- Procure local construction products

LANDSCAPE MANAGEMENT

- Facilitate education for sustainability

- Establish a landscape management plan

- Incorporate site nursery and composting

- Ecological monitoring to inform change

- Ongoing design and conservation

- Minimize use of pest/herbicides

- Site-based maintenance/park manager

This guide/checklist was developed initially with particular reference to the Sustainable Sites Initiative developed by the Lady Bird Johnson Wildflower Centre / American Society of Landscape Architects in 2007. (ASLA, 2009)

List provided courtesy of Chris Royffe, Leeds Metropolitan University

ALL OF THESE NUMBERS WERE TAKEN FROM RECONNECTING AMERICA WEBSITE'S

HTTP://WWW.RECONNECTINGAMERICA.ORG/RESOURCE-CENTER/JUMPSTARTING-THE-TRANSIT-SPACE-RACE-2011-INTERACTIVE-MAP/AND GOOGLE DOCS FILE:

HTTPS://DOCS.GOOGLE.COM/SPREADSHEET/CCC?KEY=0AMPHBZBSLLZDEFSEHBNZ1NXVELQZK12WV FIRDVCQWC#GID=0 WHICH HAS THE UP TO DATE 2013 COSTS ON PROJECTS. (RECONNECTING AMERICA, 2013)

The data was filtered for all those projects which are at the Engineering and Construction phase; not including 'Process Level' concept design "Future Plan", stalled or AA so that only actively worked on projects were considered.

The numbers seem large, but this is for all the current construction projects across the United States of America.

A Passenger KM: (Projected Ridership / Distance)/Estimated cost in Millions.

Capital Cost Per Kilometer

Millions US $

	BRT	Commuter Rail	Heavy Rail	LRT	Rapid Bus	Streetcar
Capital Cost Per Kilometer	$11.1	$20.2	$412.7	$110.5	$2.3	$29.1
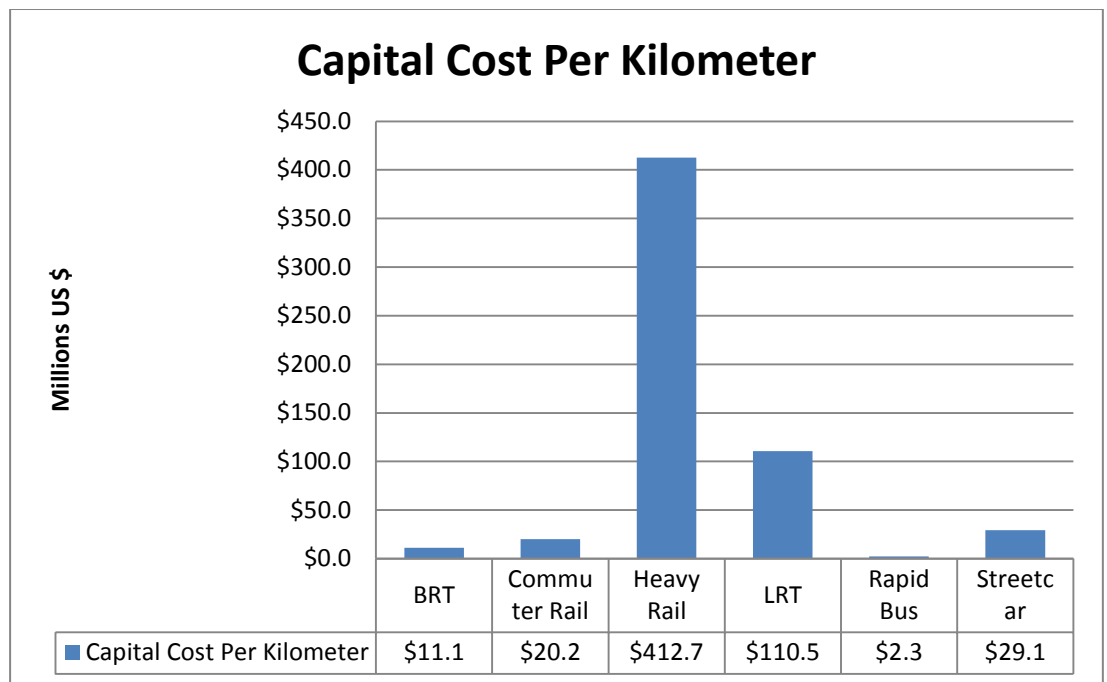
Figure 174 US Capital Cost per km by mode

This graph demonstrates the very high cost of constructing Heavy Rail (sub-surface metro), which is skewed here by the expensive LIRR East Side Access and Second Avenue

Subway projects in New York among others. The cost of LRT also stands out as the cost to realign underground services and surface infrastructure through inner city urban shared Right-of-ways is borne out.

Capital Cost to Passenger KM ($ Millions)

	BRT	Commuter Rail	Heavy Rail	LRT	Rapid Bus	Streetcar
Capital Cost to Passenger KM ($ Millions)	$19.6	$1.3	$3.6	$7.9	$16.4	$15.4
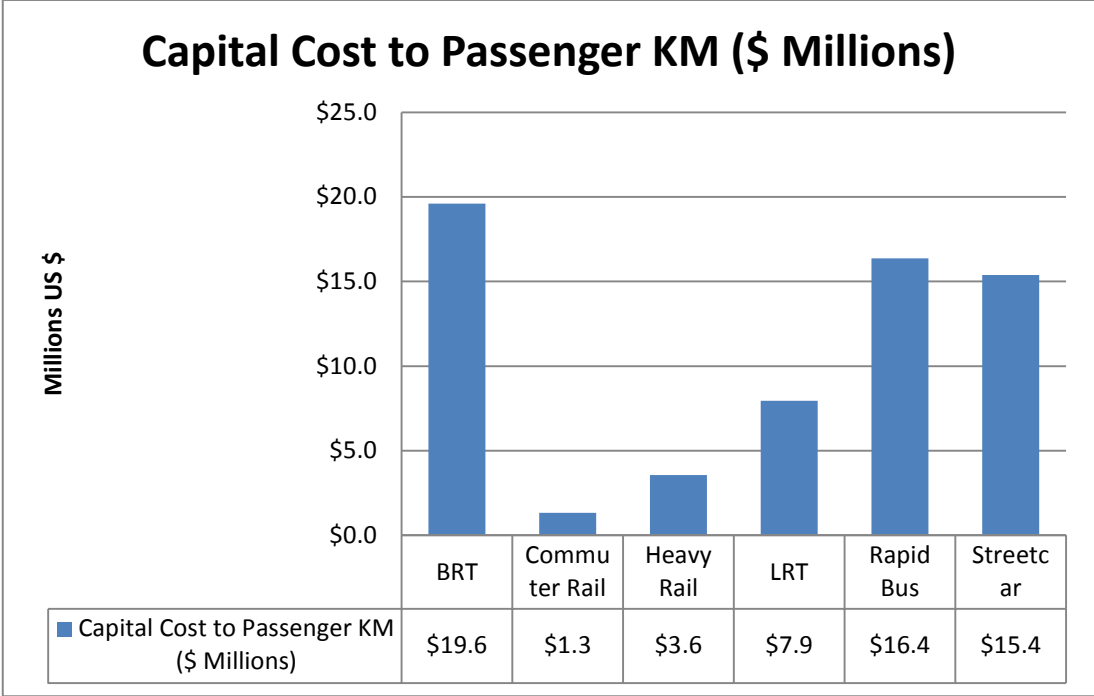
Figure 175 US Capital Cost per Passenger km by mode

However, once passenger capacity is applied to see the value per person of a kilometre of transport infrastructure, we can see that Commuter rail is the least expansive as it is inexpensive to expand service existing corridors through low-density areas, Heavy Rail (sub-surface metro) falls as it can accommodate many persons per km, LRT looks acceptable in the middle position, but Streetcars Rapid Bus and BRT do not look favourable as the cost to construct – while lower – service far fewer passengers.

Operating Cost to Passenger KM (for 250 working days)

	BRT	Commuter Rail	Heavy Rail	LRT	Rapid Bus	Streetcar
Operating Cost to Passenger KM (for 250 working days)	$0.9	$0.3	$1.2	$0.4	$1.6	$1.5

Y-axis: Millions US$
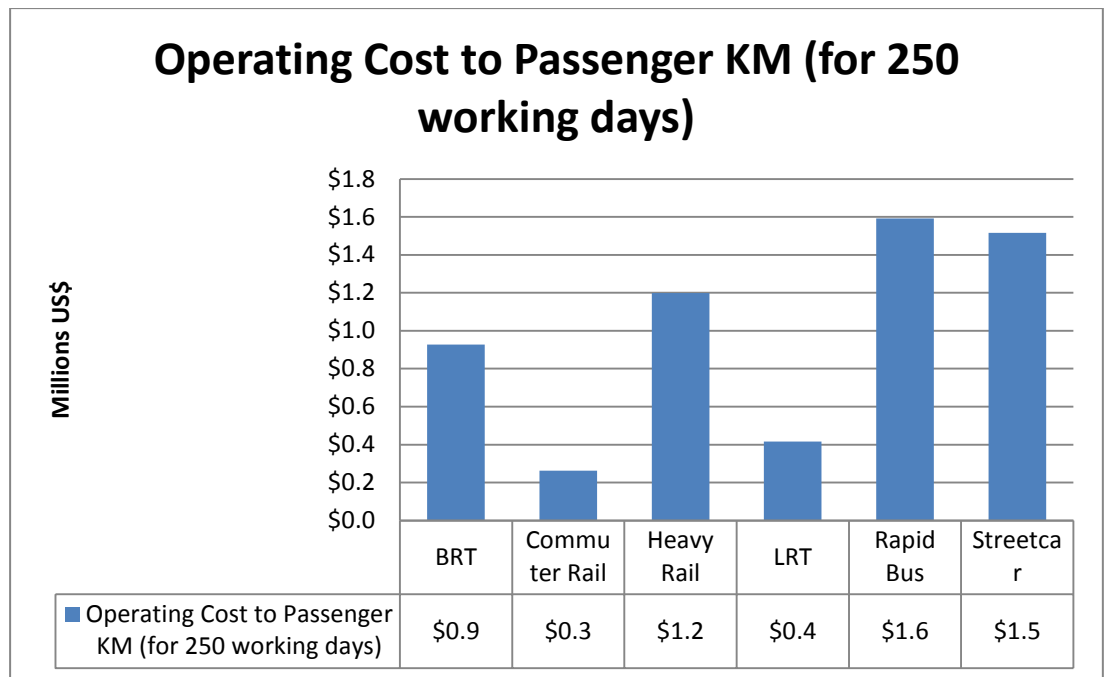
Figure 176 US operating cost to total passenger km by mode

This graph shows how LRT and Commuter rail are among the least expensive to operate once in use. Heavy Rail is far more expensive as labour requirements are increased to drive the train, maintain the electric circuits and tracks in confined spaces, collect tickets and police the stations. Rapid Bus, Streetcar and BRT show themselves to be relatively expensive compared with other modes as again, the labour units per hour are higher per passenger km.

Operating Cost to Passenger KM (for one day)

	BRT	Commuter Rail	Heavy Rail	LRT	Rapid Bus	Streetcar
■ Operating Cost to Passenger KM (for one day)	$247.4	$65.7	$299.9	$104.0	$398.2	$379.2

Y-axis: Millions US $ (ranging from $0.0 to $450.0)

Figure 177 US One-day Operating Cost to Passenger km by mode

This figure shows the same data as above, but broken down per day. The numbers seem large, but this is for all the current construction projects across the United States of America.

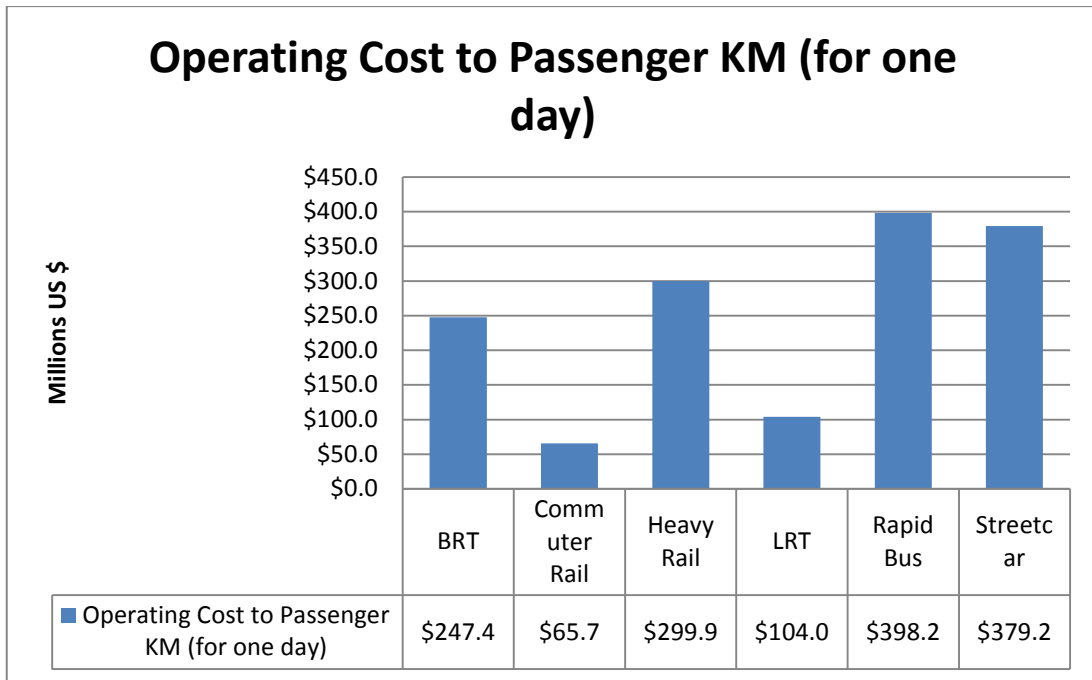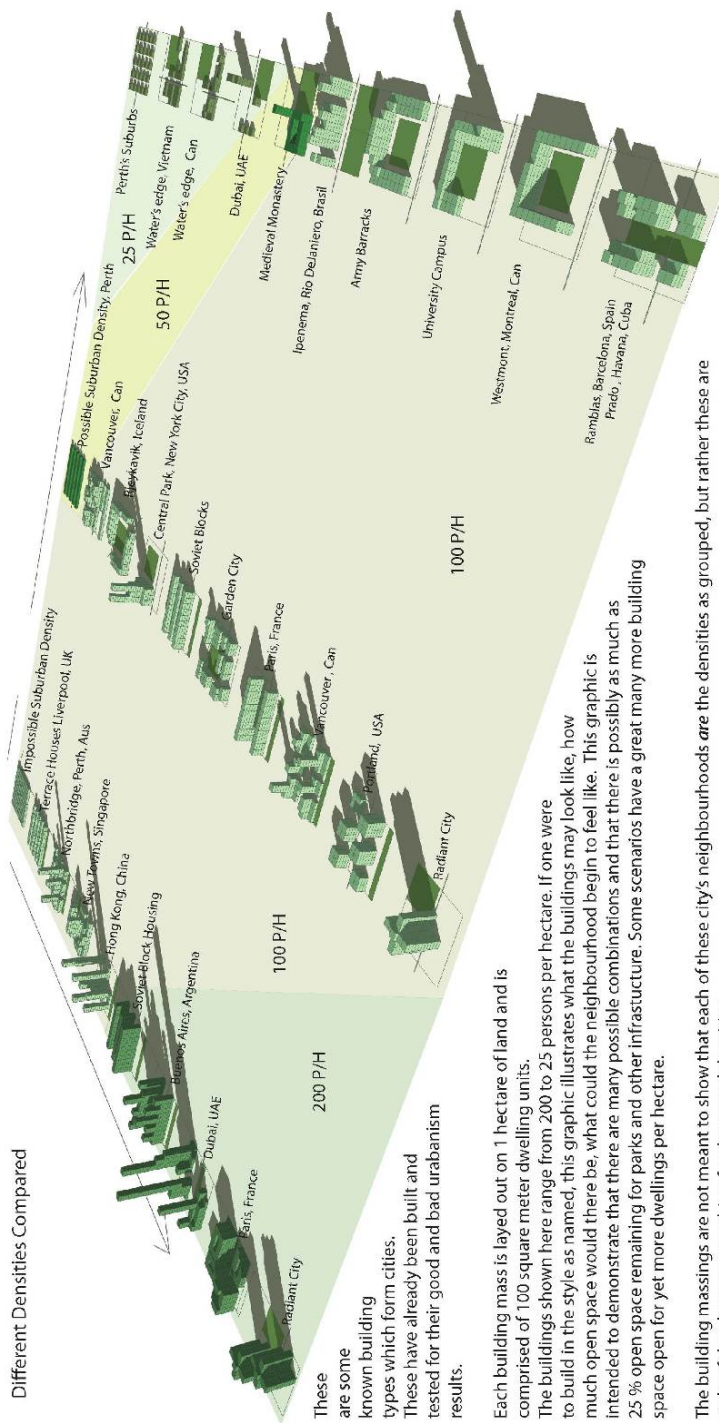| Transit Option	Optimal Operating Conditions	Passenger Capacity per TU	Capacity at Rush Hour per Lane	Average Speed	Distance between Stops	Frequency of Operation – Headway	City Shaping Capacity	Value Uplift Capacity	Storage requirements	Cost to Construct per Passenger KM
Regional Rail (5 M)	Separated ROW; for long distance between cities	100 per car +	50,000[2] 30,000[3] 50,000[5]	100–120 KM/H	5–20 kms[1]	0.5–1 hours	CBD 2 Outer City	McIntosh & Trubka, forthcoming [10]	Rail Yard -20x3 x 1 total = 30 M	$28 million per Km (new with no tunnel)[6]
Commuter Rail (Metro, Subways) (4.5 M)	Separated ROW; for travel between suburbs to central cities	100 per car +	50,000[2] 30,000[3] 50,000[5]	50–80 KM/H	1.5 – 8 Kms[1]	15–30 minutes	CBD 2 Inner City Outer City	McIntosh & Trubka, forthcoming [10]	Rail Yard -20x3 x 1 total = 30 M	$41 million per Km (with tunnel)[6]
Urban Rail (LRT, Streetcar) (3.2 M)	Separated ROW, own or shared lane; for travel within urban areas and to link a network together.	90 per car +	40,000[2] 13,000 – 30,000[3] 9,000 – 32,100[4] 4,050 – 8,100[5] 7,000–10,000[5] 7,000[3]	10–50 KM/H	0.5–1 kms[3] 120–240m (tram) or 240–5,000m (LRT)[4]	10–20 minutes 17 p/hr[4]	CBD 2 Inner2 Middle2 Outer City	...property values can increase by as much as 40%... Office and retail space rent can be as high as 50% greater. [4]	Rail Yard -20x3 x 1 total = 30 M	$17 million per Km (at grade)[c] between $10m and $100m [4]
Bus Rapid Transit (3.7 M)	Own or shared lane with priority; for travel within urban areas and to link a network together.	60 (+30 standing)	20,000[2] 20,000[3] 1,350 – 2,700[4] 5,000[5] 26,000[5]	10–60 KM/H	3–5 Kms[3] 400–800m[4]	5–20 minutes[3] 60–80 p/hr[4]	Moderate CBD 2 Outer City	up to 20%[4] 5–10 % [5]	Parking Spots -20x3 x 1 total – 30 M	$39 million per Km (at grade)[c] "queue jump lanes and signal priority ~ $0.75m to just under $2.0m"* "grade separated crossings, elevated structures or tunnels ~$158m /Km"[4]
Bus (3.5 M)	Shared lane in mixed traffic; for travel within urban areas and to link to a network.	45 (+15 standing)	10,000[2] 4,000–6,600[4]	10–40 KM/H	0.3–1 km[4] 250–400 m[4]	10–20 minutes[4] 60–80 p/hr[4]	Moderate CBD 2 Inner 2 Middle City	little attraction of new development investment[4]	Parking Spots -10x3 x 1 total = 30 M	Minimal infrastructure costs
Bike (1 M)	Separate ROW, own or shared lane; for travel within urban areas and to link to a network.	1–2 depending on configuration	8000[7]	10–50 KM/H	2–5 kms[1]	Ubiquitous - corridor dependent	CBD 2 Inner City		Parking Spots -1.5x1m x 3 total = 4.5 M	$20,000–100,000 (marking bike lane on existing road)[9]
Pedestrian (0.5 M)	Separate ROW or own lane; for travel within urban areas and between cities.	1–2 depending on configuration	5777 on 2 meter wide sidewalk	4–6 KM/H	0.1–1.5 kms[1]	Ubiquitous - corridor dependent		High level of walkability has strong correlation with high real-estate values	One Bed - 1x2m One Workplace 1x2m total = 4 M	
Private car (3.5 M)	Grade separated, limited access or shared lane; for travel within urban areas and between cities.	1–5 depending on configuration	1,000 on Street or 3,000 on Freeway[7] 2,500[1] 1000[1]	10–40 KM/H	1–50 kms[1]	Ubiquitous - operator dependent	Moderate CBD 2 Outer City	Short lived uplift on land, maintains in pace with market unless deteriorating.	Parking Spots -2.5x5m x 3 total = 37.5 M	$13 million per lane[8]

SOURCE: AUTHOR, 2014

Figure 179 Densities Compared

SOURCE: AUTHOR, 2013

Appendix I.   Densities of the World Cities

The Demographia group is led by Wendell Cox, a well-known advocate for laissez-faire housing market policy. Demographia maintains that policies restricting land supply for such notions as transport integration and reduced Vehicle Kilometre Travel and wrong and damaging to housing affordability.

> ...the differences in urban density profiles make only marginal difference in urban transport planning. This is because with the geographical expanse of nearly all modern, high-income urban areas, automobiles provide by far the greatest coverage, with considerably shorter travel times than public transport. (Cox, 2014)

None the less, they have prepared a report from which the author has extracted the numbers and reassembled to show in graphs. While they show the densest cities are in Asia, Africa, and Latin America, with the assumption that Americans (of the United States) won't accept density – it is 'foreign' to their well-being. However, they also show that the largest urban areas tend to be in America which, perforce, makes it easy to be low density. When high rates of highway km and automobile ownership are contributed it is no wonder that American's live the lifestyle they do, but correlation does not equal causation.
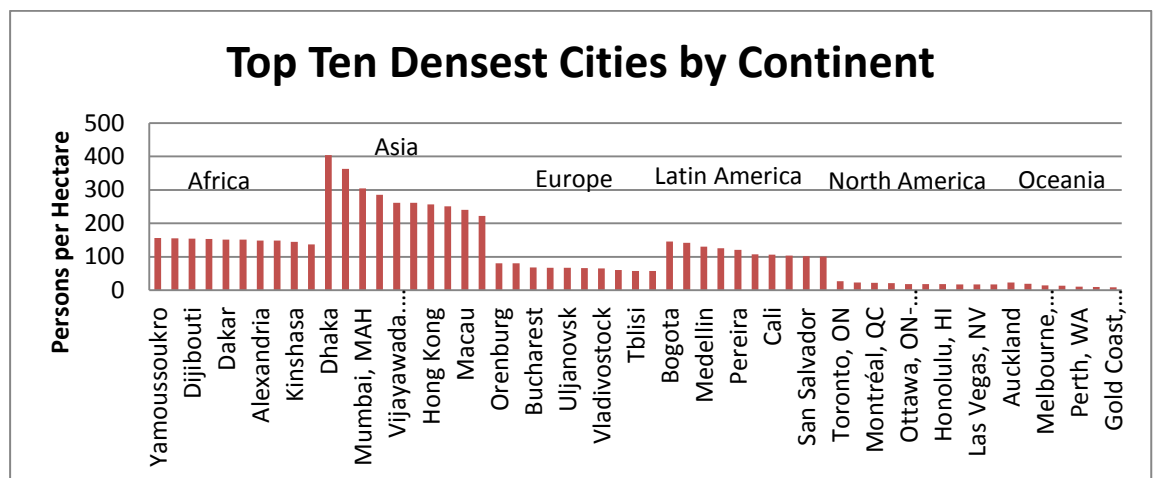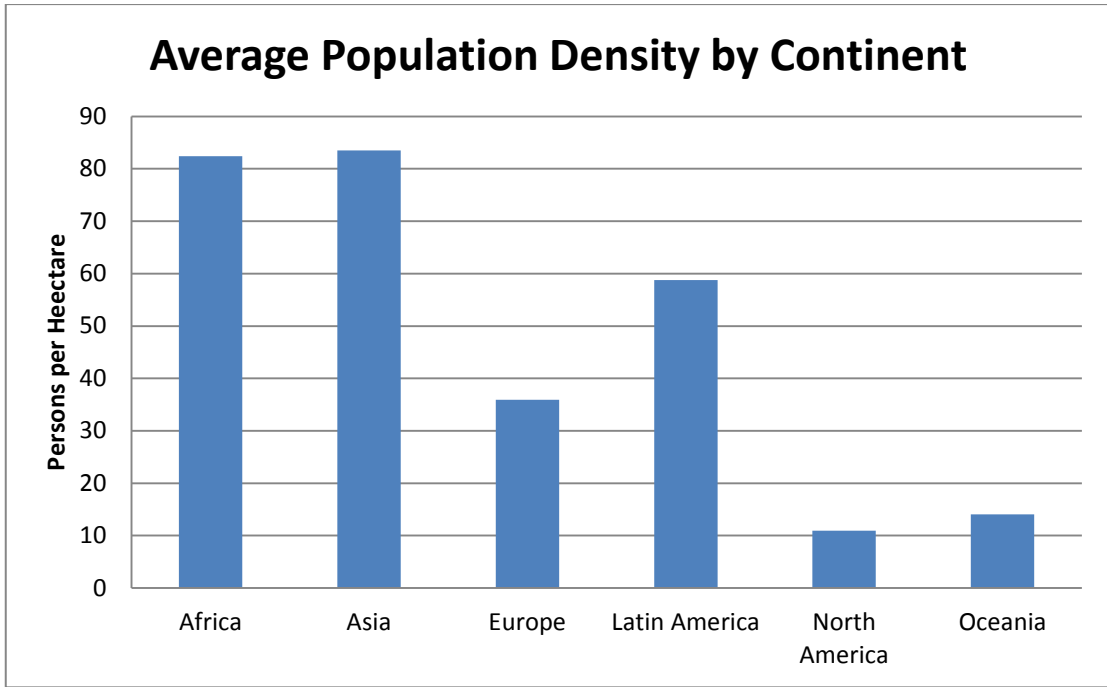

Figure 180 Top Ten Densest Cities by Continent

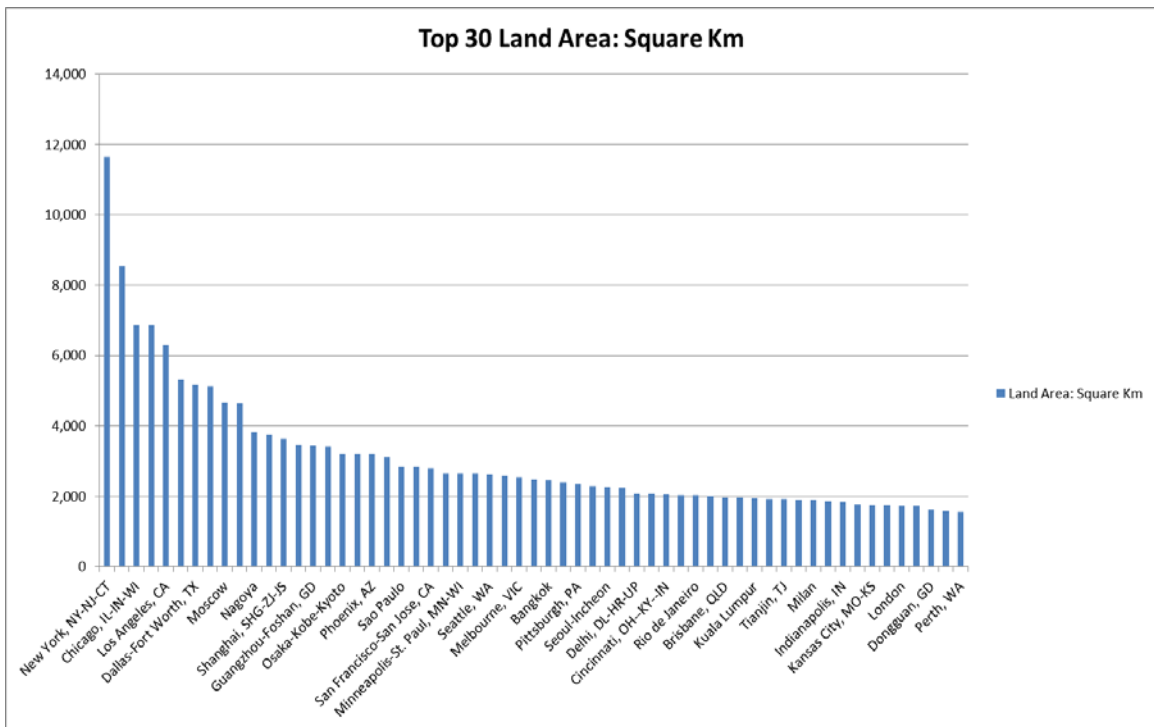**Figure 181 Average Population Density by Continent**

Figure 182 Top 30 Cities by Land Area

Appendix J.   Select cities from the Global Cities Database

Selected data from "An International Sourcebook of Automobile Dependence, 1960-1900"(Kenworthy & Laube, 1995)
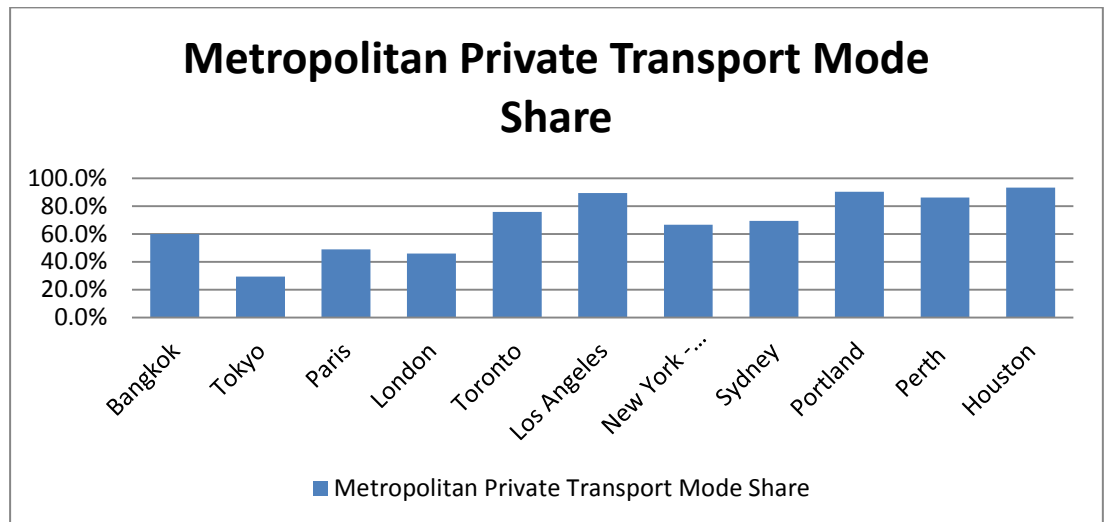

Figure 183 Private Transport Mode Share, Metropolitan

Mode share by Private Mode includes automobiles, motorbikes or other motorised devices which are privately owned. Taxis are excluded. We can see that American metropolitan areas (cities plus all the urban areas surrounding in the labour market) are the most reliant on Private modes, followed by Australian and Canadian cities with Tokyo and London having the lowest rates of private motorisation due in part to a mixture of density and public transport levels of service.
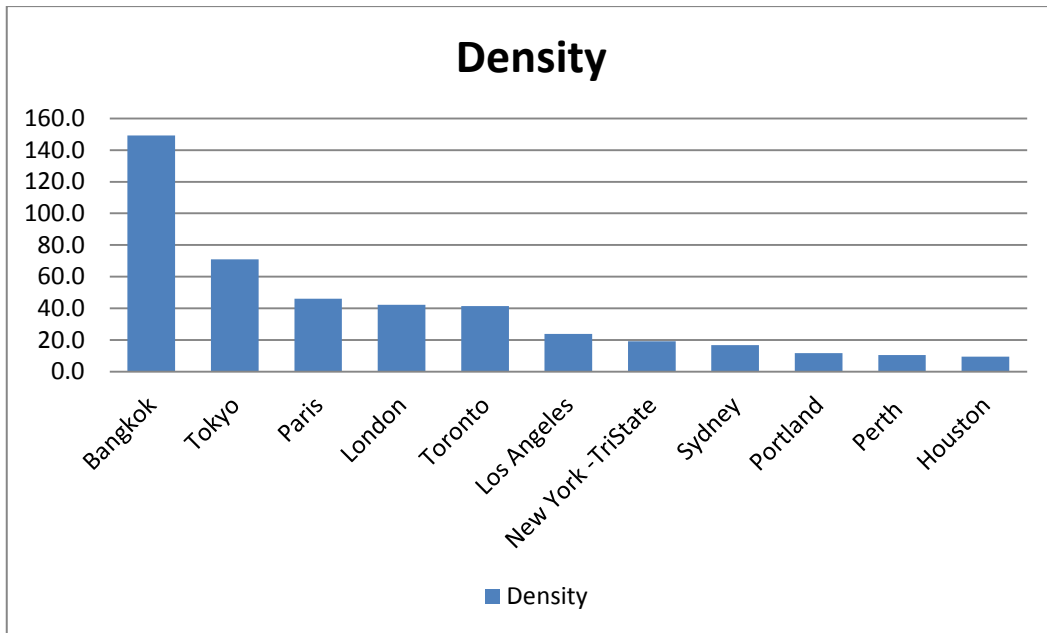
Density

Figure 184 Urban Density

From this selection we can see that, as per the previous figure, density has an inverse relationship with overall metropolitan mode share splits. Generally, the higher the density of a metropolitan area the lower the rate of private automobile use will be observed.
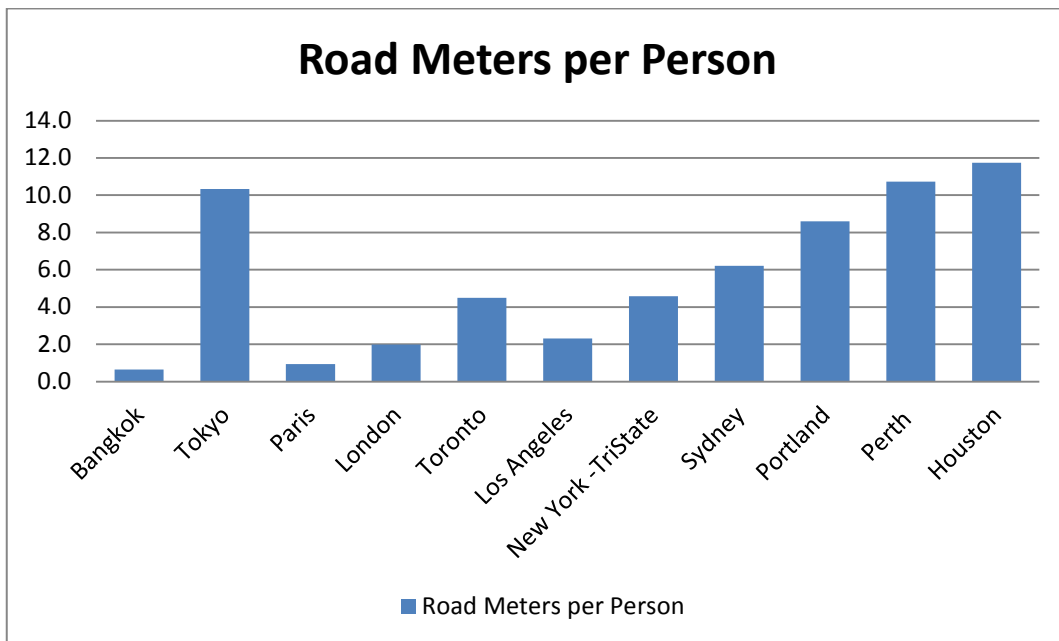
Road Meters per Person

Figure 185 Road meters per Person

Another factor which may be somewhat explanatory is the road meters per person as an indicator of the level of investment by governments in particular transport modes and, inadvertently, lifestyles. Tokyo is an outlier, most likely a result of the American Occupation post World War Two which sought to reconstruct Japan.[49]
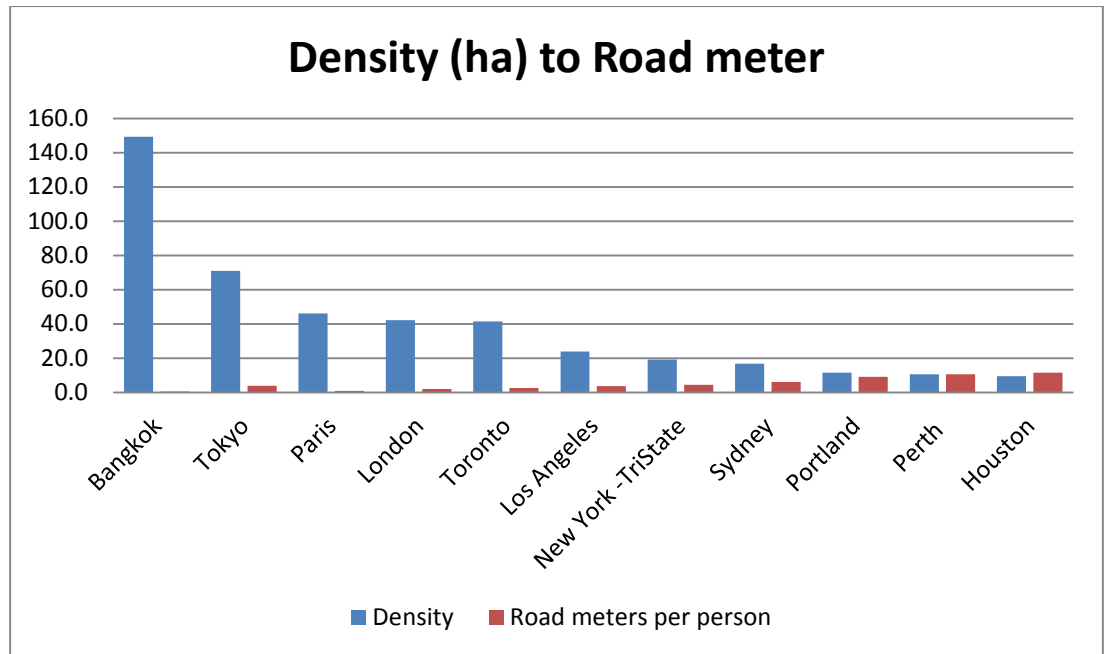

Density (ha) to Road meter

Density, Road meters per person

Figure 186 Density to Road Meter

This graph shows how, relative to density, there is an inverse relationship between density and the meters of road constructed on the people's behalf.

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[49] 2009. "Japan's many roads to ruin" Jones, Colin P. Japan Times.
http://www.japantimes.co.jp/community/2009/04/21/issues/japans-many-roads-to-ruin/#.U2r7KfmSySo
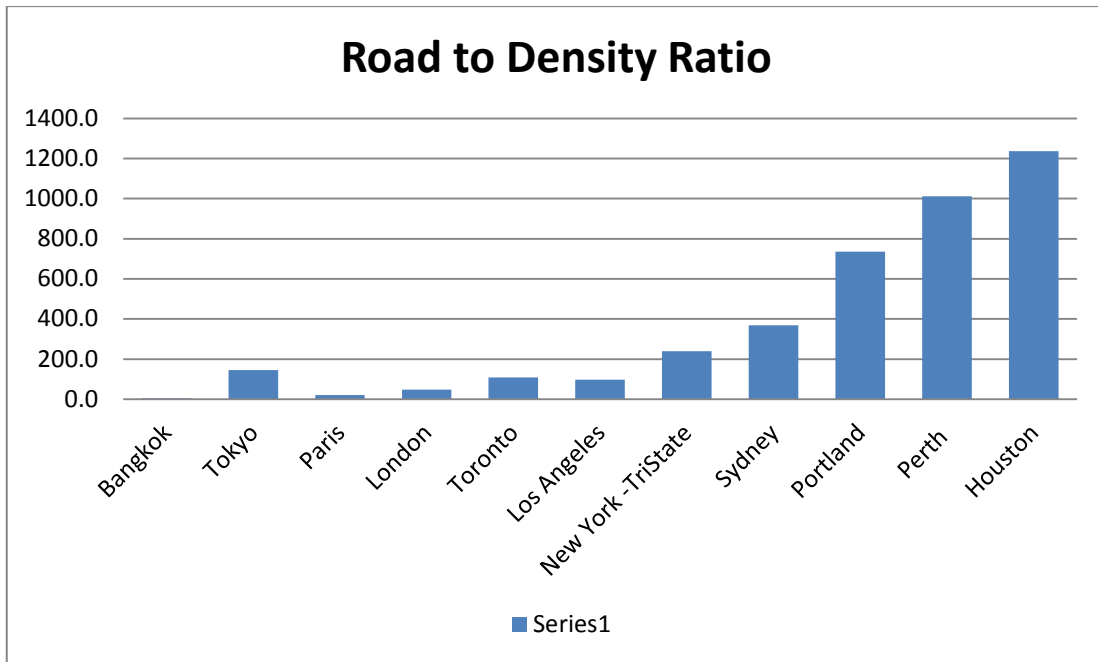
Road to Density Ratio

Figure 187 Road to Density Ratio

Another way to look at the data is to create a ratio of the road to density to observe the realtive prevalence of roads in the urban environmetns. This contributing to the overall character of the city as "automobile dependent' or transit-oriented. Houston, Perth and Portland lead in tis regard while London and Paris show up as relatively road-poor, which contributes to the desirability to use the transit services provided.

Density and Transit Provision

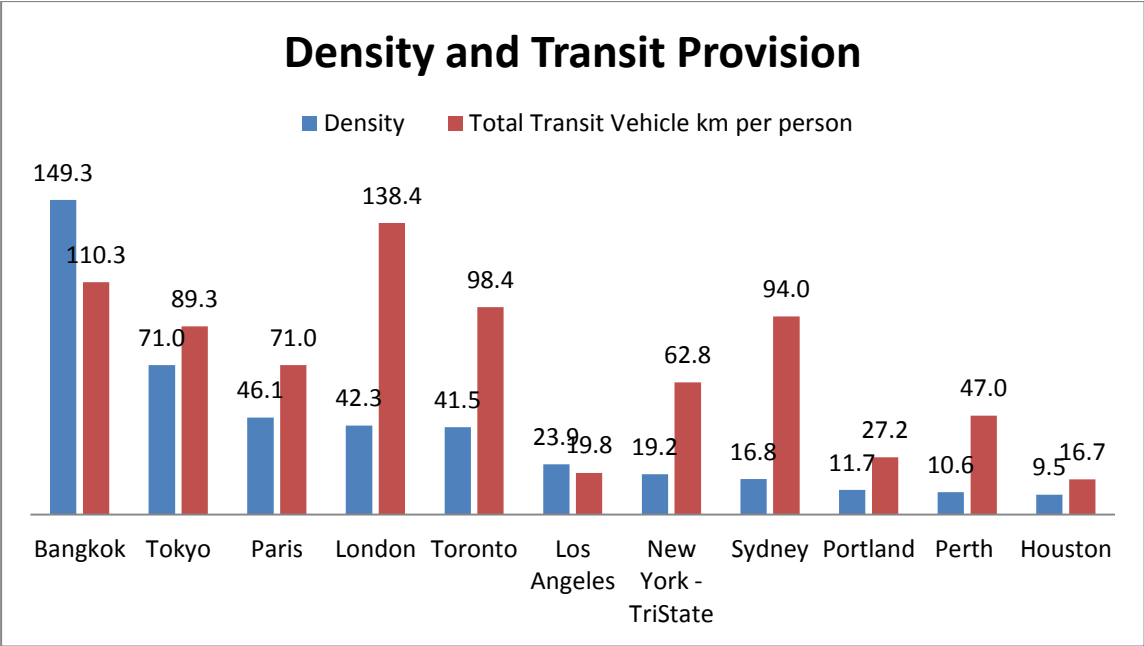■ Density   ■ Total Transit Vehicle km per person

Figure 188 Density and Transit provision

This graph, above, shows very little correlation between density and transit km per person, with London, Toronto and Sydney supplying more than might be expected given the Density trend line. However, there can be made a relationship between those cities which have responded extremely well to the needs of their city and those which are failing in providing sufficient public transport to their respective urban fabrics.
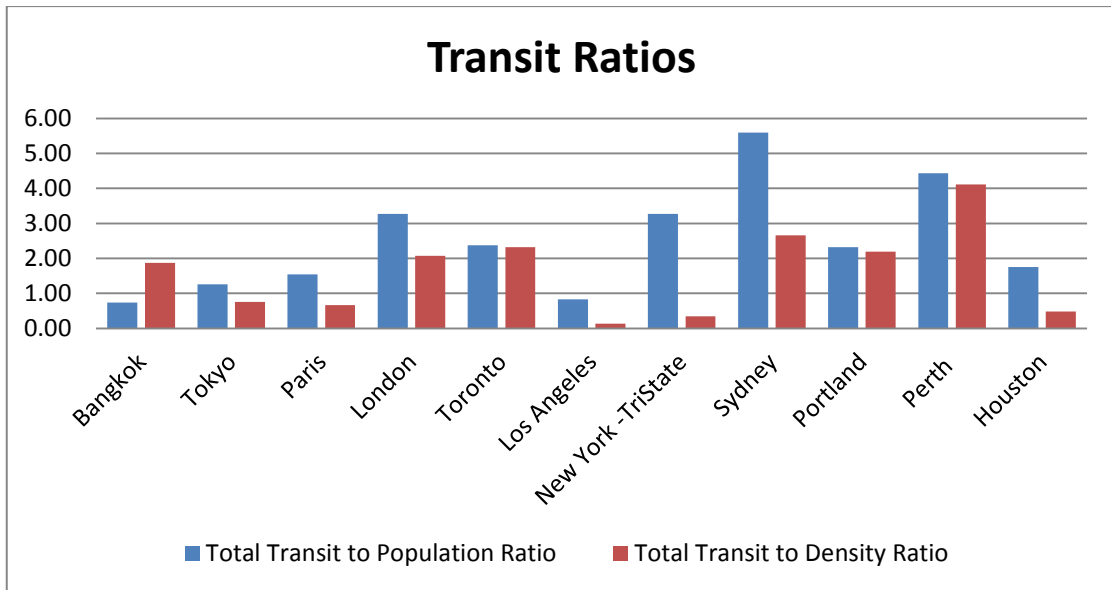
Figure 189 Transit Service Ratios

Transit Ratios graph illustrates two different ratios taken on similar data to reveal the difference between total transit (of all modes – bus, BRT, LRT, Metro, commuter rail, ferry) and the total population and their densities. Los Angeles, for example, offers almost equal transit to its population by ratio as does Bangkok, but far fewer public transport km relative to its density. On the other end, Perth and Sydney appear to offer high rate of total transit service km by both population and density.

Figure 190 Selected Global Cities measured for visible urban extents

SOURCE: AUTHOR, 2014

The measurements of the first chart were taken from scaled Google Earth images in AutoCAD by drawing closed polygons around urban conurbations. The urbanised area was thus found and when crossed with the most recent United Nations Population data an 'urban density' could be described.