Curtin University Sustainability Policy Institute

Framework to Facilitate Urban Regeneration in the Middle Suburbs of Car-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 acknowledgement has been made.

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

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Date: 27 May 2019

ABSTRACT

The 'urban fabric' (or urban structure) of a city is formed through the city's transportation infrastructure and, more specifically, through the mode of travel to work. Car-dependent cities with large urban footprints suffer from a lack of planning mechanisms to regenerate their middle suburbs, referred to as 'greyfields'. Current redevelopment models have been developed for brownfield and greenfield sites, and these are being found to be inappropriate when applied to the 'greyfields' of the middle suburbs of Australian cities. In some European cities, what might be seen as 'greyfields' are being gentrified to become attractive suburban neighbourhoods. However, the debatable process termed as 'income displacement' as it replaced or displaced a lower-class population by one of a higher categories that resulted in changed social character of the places. Among the principle methods for redeveloping the middle suburbs, extensions, alterations, and piecemeal infill via 'battle-axe' subdivisions have been found to be sub-optimal solutions. Redevelopment initiatives incorporating activity centres, transit-oriented development (TOD) and mass transit corridors have proved to be more acceptable. However, the capacity of transit corridors to instigate redevelopment that will facilitate urban regeneration in the middle suburbs is yet to be explored to find a convincing method. The impacts of transport infrastructure on urban regeneration are always difficult to measure. It becomes even more challenging when considering that inhabitants of the low-density middle suburbs of car-dependent cities have already displayed an affinity with a particular travel mode. There is a growing body of literature on how existing mass transit corridors are making an impact on their surroundings as a transit option, especially regarding the boosting of land values, but very few have pointed to the significant contextual factors that work as moderators before commencing any transport infrastructure development, or their contribution to urban regeneration.

This research examines the socio-technical parameters of urban planning associated with the redevelopment potential of low-density, car-dependent, middle suburbs. In response to the identified research gap, this study conceptualises a framework to assess the inherent potential of any proposed transit corridor to facilitate urban regeneration in the middle suburbs of car-dependent cities. A web-based multi-criteria evaluation tool, Envision Scenario Planner (ESP), and Land Use and Transport Integration (LUTI), a spreadsheet-driven tool, have been used to analyse the appropriateness of a particular transport mode for the chosen transit corridors. Like other car-dependent cities with low density suburbs that have developed in the United States, United Kingdom, Canada or

Western Europe during the post-war period, Perth, Western Australia (WA), has a big need for this research and is investigated as a typical case, to explore the potentiality of developing a transit corridor based on contextual attributes that dominate the surroundings in order to facilitate urban regeneration.

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DEDICATION

I would like to dedicate this thesis to my mother, Nurun Nahar Begum, who had to give up her own study dream in secondary school for an early marriage but who encouraged me to finish this doctoral thesis until the last day of her life.

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TERMS AND ACRONYMS

ABS	Australian Bureau of Statistics
AHP	Analytic hierarchy process
AI	Accessibility Instrument
AHURI	Australian Housing and Urban Research Institute
AURIN	Australian Urban Research Infrastructure Network
BRT	Bus rapid transit
CBD	Central Business District
CI	Consistency Index
CoS	City of Stirling
COTS	Commercial off the shelf
CRCSI	Co-operative Research Centre for Spatial Information
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoT	Department of Transport
DSS	Decision support system
ELECTRE	Elimination and choice-translating reality
ESP	Envision Scenario Planner
ESRC	Economic and Social Research Council
FAR	Floor Area Ratio
GIS	Geographical Information System
GLA	Gross Lettable Area
GLU	Gross Land Use
GtG	Greening the Greyfields
GTGD	Guide to Traffic Generating Developments
HII	Home indemnity insurance
HKSAR	Hong Kong Special Administrative Region
JTW	Journey to work
KDR	Knock down and rebuild
LGA	Local Government Area
LRT	light rail transit
LUTI	Land Use and Transport Integration
MADM	Multi-Attribute Decision-Making
MAUT	Multi-attribute utility theory

MCDM	Multi-Criteria Decision-Making
MCE	Multi-criteria evaluation
MODM	Multi-Objective Decision-Making
NHSC	National Housing Supply Council
NSW	New South Wales
PCM	Pair-wise Comparison Method
PMA	Perth Metropolitan Area
PNR	Park and ride
PROMETHEE	Preference-ranking organisation method for enrichment evaluation
PRPI	Property Redevelopment Potentiality Index
PSS	Planning Support System
R-AC	Residential (Design Code) for Activity Centre
R-Code	Residential Design Code
RI	Random Index
RMS	Roads and Maritime Services
RPI	Redevelopment potentiality index
RTA	Road Transport Authority
SA	Statistical Area
SDS	Spatial Decision Support
SDSC	Spatial Decision Support Consortium
SEIFA	Socio-Economic Indexes For Areas
SYPYE	South Yorkshire Passenger Transport Executive
SYS	South Yorkshire Supertram
TMIP	Travel Model Improvement Project
TOD	Transit-oriented development
UK	United Kingdom
USA	United States of America
VKT/capita	Vehicle Kilometres Travelled per capita
WAPC	Western Australian Planning Commission
WPM	Weighted-product model
WSM	Weighted-sum model
WWII	World War II

CHAPTER 1: INTRODUCTION

1.1 Background

The fabrics of our urban areas have evolved over time. The function and form of a city is generally a result of the evolution of its transport system. Journeys to work and other premises, and the modes of transport in between, are reflected in the density of the surrounding suburbs. After the 1950s, cities developed with a dependence on cars as the dominant transport mode, resulting in low-density sprawling suburbs with larger footprints than ever before. As cities grew more prominent, the middle suburbs, those that lie between the inner and outer suburbs, started losing their radiance. These are referred to as 'greyfields' in the academic literature, mainly describing a residential belt that is under-performing as a demographic absorber, housing supplier and job attractor. The greyfields, over time, have experienced physical and economic decay, particularly of their built structures. In addition, the lack of strong urban planning policies and statutory support to reduce urban sprawl has made the situation even worse. However, the geographical advantage of the middle suburbs remains.

In Australian and United States context, the middle suburbs, largely developed in the 1950s and 1960s, are the prime areas for current redevelopment because the redevelopment potential in the older 'brownfields' (previously used as industrial sites) and inner suburban areas are soared and in general do not have sufficient policies or practices in place to address this issue (Barrella, 2012). Being close to the Central Business District (CBD), the redevelopment potential of the middle suburbs is assisted by the advantage of being located close to a concentration of jobs and major services. Residents in these areas enjoy access to the jobs that are located in both the inner and outer rings.

In the post-Second World War period, passenger cars became a dominant urban transport mode in most cities, where urban sprawl depended on private vehicles, rather than trains, trams and buses, in order to function. As many have pointed out (Banister & Lichtield, 1995; Thomson, 1977), this dependence on automobile-based transport in global cities has gone hand-in-hand with a dramatic increase in the negative impacts of associated factors, such as congestion, environmental emissions and excessive fossil fuel consumption. The rise of the car has also led to a decline in the demand for public transport (lower transit provision per capita, or service km per capita), as well as reduced investment in infrastructure for walking/cycling (McIntosh, Trubka, Kenworthy, & Newman, 2014). It is a common perception that transport investment plays an essential role in the urban regeneration process, improving accessibility and increasing economic activity in the surroundings. However, contributing to those specific impacts there are other factors outside the transportation system, such as the property market and local policies for land use and building density. Since smart growth and sustainable development should always be a concern for transport investment, in practice, it is always difficult to identify precisely which factors are the most relevant for achieving a regeneration goal.

Despite the redevelopment potential of greyfields, the current redevelopment models applied around the world are for brownfield sites, and these are being found to be inappropriate for greyfields. The market-led solutions for redeveloping these areas mainly have been confined to subdivision, one lot at a time, leading to a sub-optimal development option. This raises the question: ”How can you undertake urban regeneration in the middle suburbs?” If the desire is to make the city less car-dependent and more walkable and transit-oriented in nature, an urban redevelopment model needs to be aligned with an appropriate transit model.

1.2 Problem formulation

1.2.1 Definition

The global population living in urban areas will likely increase from 3.5 billion to 6.3 billion between 2010 and 2050, which is an increase of 80% (Clapson & Hutchison, 2010; Department of Economic and Social Affairs, 2010). Many of these new urban dwellers will live in areas that are suburban (Forsyth, 2014), although there is no exact definition of what constitutes a suburb. However, the mode of transportation that a city chooses forms the shapes and sizes of its interconnected suburbs (Levinson & Wynn, 1963). Newton, Newman, Glackin, and Trubka (2012) characterise middle suburbs as being predominantly low- to moderate-income suburbs, created between the late 1930s and the late 1960s, that were mostly developed due to the post-Second World War housing boom. Those suburbs are generally characterised by the single-family household on the iconic ‘quarter acre block’ and are sandwiched between the gentrified, revitalised inner cities and the newer and increasingly up-market post-1980 outer suburbs.

The process associated with the revitalisation of the built environment is referred to in many interchangeable terms, such as ‘urban regeneration’, ‘redevelopment’ and ‘retrofit’. Generally, regeneration is considered to be a process that involves a complete re-creation into a better form or condition than in the past, extending beyond the individual dwelling to the neighbouring properties and infrastructure (Couch, Sykes, & Börstinghaus, 2011; Lawless, 2010; Roberts, 2000).

1.2.2 A global perspective of the problem

The trend in car dependency has been reversing globally, and the most developed and developing cities are now rapidly shifting towards mass transit system use, especially in rail (Newman & Kenworthy, 2011; Newman, Matan, & McIntosh, 2015). The vital justification for investment in a mass transit system such as light rail is the modal shift in peak hour travel, presuming that it reduces traffic congestion due to its greater ability to attract car users when compared to buses. Additionally, as a travel alternative, light rail reduces transport costs for the inhabitants living nearby, as well as the commuting costs of those living further from the city centre, which attracts new dwellers to locate themselves near the transit corridor. Developers also become enthusiastic to build denser housing and establish business infrastructure to serve newly relocated households (Hurst & West, 2014). As an important indicator of economic profitability, the positive outcomes of investment in transport systems such as heavy rail or light rail transit (LRT) have been well documented in the literature.

Regarding land value uplift of surrounding properties, heavy rail transit is leading the march, but light rail transit is also competing and not far behind, considering other impacts that contribute to economic gain. However, no research has provided a firm basis on which to judge the future impacts on land value provided by a transit corridor (Hess & Almeida, 2007). Local factors play a vital role in varying premiums across locations. The feasibility of any transit proposal mostly depends on the economic profitability of the project itself and the positive impacts it will bring to its surroundings, while other impacts justify its viability. Apart from location factors, there are other contextual factors that can critically influence the future impacts of any proposed transit corridor.

Cunningham (2008) sees urban regeneration and redevelopment as the basis for a restoration of the economy, generating significant wealth and creating new jobs in the market. The core areas of large cities in the United States of America (USA) are proving to be more resilient, economically, following the various global financial crises over the past 60 years (Frey, 2009). Principles like ‘smart growth’ and ‘green urbanism’ in the urban planning process are challenging the dominant model of low-density greenfield development, which is highly unsustainable regarding a range of critical metrics associated with resource consumption and environmental degradation (Newton, 2011, 2012; Rees & Roseland, 1998). Newton (2013) mentioned that, as in many other cities, over 250,000 middle suburban properties in Melbourne can be classified as underutilised assets because they have a high but untapped potential for regeneration, particularly in localities where the residential building stock is falling and the infrastructure needs to be upgraded. The reason Newton (2013) labelled these areas as underutilised is that the value of the land represents 80% or more of the total value of the residential properties.

Awareness of the need to make cities more sustainable in form has triggered the urgency to make cities more compact. The redirection of both population and investment to the middle suburbs is a radical shift of thought to be adopted because it has usually been associated with suburban sprawl. A very distinct calculation was completed by Trubka, Newman, and Bilsborough (2008), which revealed that each new greenfield fringe block incurred an extra $85,000 in infrastructure costs compared to urban redevelopment, plus $250,000 extra in transport costs over 50 years. While this was applied to a specific case, it is generally appropriate to better understand the monetary value of urban redevelopment.

In addition, Dodson and Sipe (2008) supplemented the growing body of literature by identifying reasons to regenerate middle suburbs and exposing the socio-economic vulnerabilities of the outer suburbs of major Australian cities, like Melbourne and Sydney (Baum & Woolcock, 2008; Timmins, Graf, & Bhatia, 2008). They mentioned that residents living in car-dependent outer suburbs are exposed to an additional layer of socio-economic disadvantage because the rising price of oil will always be an issue for these residents. Any cities that fail to recognise this will suffer in respect of their resilience, competitiveness and livability. Moreover, the suffering of such cities will be further accentuated by emerging realities regarding energy.

The central city and inner suburbs have the highest concentration of jobs (Newton & Glackin, 2013) and the middle ring of suburbs are geographically well placed to access those jobs that are located in both the inner core and outer ring. Therefore, the redevelopment of ageing, detached housing in this region, (urban regeneration of the middle suburbs), will not only deliver more housing stock, but also more housing choices. The ongoing process of regeneration will support local jobs while creating a more desirable density with diversified demographic profiles that are now markedly different than during the period in which they were constructed.

Newton (2010, 2011, 2012) refers to these regions as the 'greyfields' of metropolitan areas. It is challenging to redevelop these regions, in every sense but equally these regions have enough potential to make them worthwhile to regenerate. It is a necessary step to reduce pressure on fringe developments, along with a suite of other metropolitan planning strategies such as transit-oriented intensification, transport arterials and revitalisation of brownfield areas. Greyfields usually do not need site remediation, as brownfields do. Furthermore, they predominantly lie between the more vibrant inner-city housing market and the recently developed, greenfield, outer suburbs, providing greater access to employment, public transport and services than the fringe zones. Consequently, greyfields have become a key target for more intensive redevelopment by state government planning agencies in their future capital city development strategies (Newton, 2010).

Greenfields, brownfields and greyfields constitute the three arenas of contemporary urban development, and each of them is progressively more challenging for planning and implementation. Developments in greenfields are the most straightforward because they are processed by well-established development models. Progressively reviewed performance benchmarks help these processes to be undertaken in a sustainable manner (Calthrope Associates, 2011; Yang, Brandon, & Sidwell, 2008), especially in relation to the density of development, increasing local employment opportunities and public transport provisions. Developments in brownfields impose a more significant challenge for redevelopment because they often incur additional costs (such as for decontamination) for site remediation. Development models and performance benchmarks for brownfields are also well established (Hollander, Kirkwood, & Gold, 2010). Greyfield redevelopment, however, has to deal with sites that are concentrations of underutilised but occupied land parcels. Greyfields are generally situated in inner and middle suburban locations where the building stock is deteriorating physically, technologically and environmentally, with the unavoidable but growing need of upgrading the basic infrastructure. Moreover, greyfields redevelopment, to date, has been piecemeal in Australia (Newton, 2011; Pinnegar, Freestone, & Randolph, 2010) as well as in North American (Lucy & Phillips, 2000; Searle & Filion, 2011) and the United Kingdom (UK) (Batty, 2007; Dixon, 2011) and, more importantly, there is currently no development model that is appropriate for precinct regeneration involving medium density in either greyfields or middle suburbs.

Newton and Glackin (2014) highlighted a project called the AHURI[1] Greyfield Project, which addressed the findings of over 70 academics and practitioners involved in city development in regard to the challenge of regenerating the middle suburbs of big cities. The findings of this research bring forth a strong base for this study, outlining the relevant areas to be addressed. The suggestions encompass a variable range of thoughts that include planning policy and economics, possible areas of statutory reform and the emergence of a design for a decision support tool. They recognise the importance of intensive regeneration in underperforming middle suburbs struggling with a sub-optimal solution. Their opinion was that the struggle will continue as long as a suitable supply of brownfield land exists and external greenfield land supply remains unlimited. New design models for medium density precinct regeneration, incorporating visualisation and performance assessments, are required to engage multi-stakeholders in the process. New finance models could be expected to emerge in order to facilitate greyfield precinct regeneration, including the possibility of incorporating residents as partners or co-investors in neighbourhood-scaled projects.

Market-driven solutions like battle-axe and 'gun-barrel' redevelopments, or spot redevelopments like knock down and rebuild (KDR) slightly increase the density of an area by redeveloping one lot at a time, which is considered to be just another ad-hoc solution, leading to sub-optimal housing options. According to the Western Australian Planning Commission (2010), 'infill' has been identified as a means by which more compact cities can be realised, by redeveloping the built environment at higher densities in established suburbs (Landis, Hood, Li, Rogers, & Warren, 2006; McConnell & Wiley, 2010). The term 'infill' has become integral to all of the latest Australian capital city future-planning strategies, and each metropolitan area has been set an infill target to be achieved over an outlook period, typically spanning 20–30 years (see Table 1.1).

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[1] The Australian Housing and Urban Research Institute (AHURI) is a national not-for-profit independent network organisation. - See more at

http://www.ahuri.edu.au/#sthash.eMApaExD.dpuf

Table 1.1 Infill development targets adapted from National Housing Supply Council (2010)

City	Strategic Planning Document	Timeframe	Total number of dwellings	Proportion from infill development (%)
Sydney	City of Cities: A Plan for Sydney's Future	2005–31	640,000	60–70
Melbourne	Melbourne 2030: A Planning Update—Melbourne @ 5 million	2009–30	600,000	53
South-East Queensland	South East Queensland (SEQ) Regional Plan	2009–31	754,000	50
Perth	Directions 2031 Spatial Framework for Perth and Peel	2009–31	328,000	47
Adelaide	The 30-Year Plan for Greater Adelaide	2010–40	258,000	50–70

These projected targets clearly show an attempt to move away from greenfield development, which has been the primary means of delivering new housing for metropolitan residents. The main objective of this initiative is to ensure that 50%-plus of new developments are to be built within established residential areas, principally within the inner core and middle ring suburbs. Newton et al. (2012) suggest that the challenge of meeting these infill targets will be tough to overcome, especially in the middle suburbs under current processes used by industry, government and the community. They argue that the existing built environment could be regenerated to the expected infill target if there is a significant transformation in the scale of development and the process by which it is going to be implemented.

A precinct approach to infill redevelopment in the middle suburbs could provide a diversity of housing types which can respond better to market needs. Flexible and adaptable designs that accommodate a mix of household types and life stages could provide affordable alternatives that are currently not available. However, research acknowledges that a transit corridor is one of the major pathways for redevelopment

(Newton, 2013) because of its capability of working as a district circulators facilitate movement within an "activity node" – typically a downtown or a commercial, medical or educational centre. Circulators extend the walkability of these districts, making it easier to access amenities without a car (Thorne-Lyman & Wampler, 2010). According to Banister and Berechman (2002) *'Corridors are often used as a way of directing urban development and principles of sustainability to achieve a more public transport oriented process to a spatial strategy in a wider region and as a way of redirecting development to areas in need of regeneration*' .

This study aimed to explore a conceptual framework in order to assess the potentiality of any proposed transit corridor in relation to its possible contributions to urban regeneration. This research conducted a review of the past studies that are available in published form to develop a list of attributes that impact local regeneration processes. A multi-criteria evaluation tool, Envision[2], has been used to develop visual scenarios based on the attributes derived from an extensive literature review. The weights of the set of variables were assigned according to the opinions of experts in relevant fields via a questionnaire survey and used to assess the potential future routes for establishing a mass transit corridor. Land Use and Transport Integration (LUTI) is a spreadsheet-driven tool developed by Hendrigan (2015). This was used to analyse development yield, ridership and the optimal transport mode for a chosen transit corridor.

1.2.3 Local standpoint

Since the end of the Second World War, unlike in other US, UK and west European suburbanised cities, much of the growth in the levels of personal affluence of the average Australian has been channelled into the possession of at least one family car. Perth, Adelaide and Brisbane are rated among the most car-dependent cities in the world, with Sydney and Melbourne close behind (Commonwealth Scientific and Industrial Research Organisation, 1992). Therefore, Perth and more specifically the City of Stirling, being the biggest local government by population (over 215,000 living in 30 suburbs which is expected to reach 230,000 by 2030) and only 8 km away from the central business district, was an obvious choice for investigation as a case study.

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[2] ENVISION is a decision support system for strategic planning. It has been designed to enable users to quickly and easily interrogate disparate datasets in order to identify potential precincts for urban regeneration. (https://envision.aurin.org.au/).

The City encompasses a total land area of about 100 square kilometres and incorporates 30 suburbs. Key employment sectors include retail, manufacturing, health and education. Currently, only 8% of all trips in the Perth Metropolitan Area are by public transport (City of Stirling, 2009). Like many other cities of the world, the urban fabric of Perth is characterised by a reliance on cars that has led to the growth of low-density suburbs. The City of Stirling is no different; cars are the regular mode of transport used by most of the residents.

The dependence on motor vehicles is particularly noteworthy in the case of the City of Stirling because more than 70% of trips to work are made using motor vehicles, and only a small proportion of people walk, cycle or telecommute. There has been a significant increase in the total number of trips to work made by a single occupant driver while it is also evident that there has been a decrease in trip sharing over recent years (Australian Bureau of Statistics, 2006).

The City of Stirling has approximately eight job opportunities for every ten people who wish to work, yet only 30% of the City's workforce work within the City. This suggests that opportunities exist for greater employment of city residents within the City's boundaries to reduce travel demands in the future. Significant increases in patronage on all train lines has occurred over the last two to three years, caused by rising fuel costs and the doubling of the railcar fleet, which suggests a growing demand for alternative transport modes like light rail (City of Stirling, 2009).

The Council has already shown its keen interest in the potentiality of introducing light rail in the vicinity, producing many publications that evaluate the strategic vision they have endorsed. A few corridors have been proposed by the Council, based on the findings of the study they have already produced. In their study, they assessed physical properties like road reserve width, the requirement of widening sites to set up LRT, the necessity to relocate installed infrastructure underneath sites, traffic patronage, etc. Consequently, Wanneroo Road, Main Street and Amelia Street have been prioritised for consideration. This study examines these three transit routes to make a relative analysis of their potential in facilitating urban regeneration.

1.3 Research aims

The overarching question that this research seeks to answer is:
"How can urban regeneration be facilitated in the middle suburbs of car-dependent cities?"

Answering this overarching question requires a multi-disciplinary approach that draws on insights from research fields including transport economics, transport planning, land-use planning and land-development planning.

To address the overarching research question, the primary research aims are:

1. To examine the socio-technical parameters of redevelopment that are significant for urban regeneration in the middle suburbs of car-dependent cities;
2. To examine the relationship between transit infrastructure and urban redevelopment to facilitate urban regeneration;
3. To determine the contextual factors that play important roles in the instigation of urban regeneration by transport infrastructure and services; and
4. To determine the potentiality of particular infrastructure and transport services based on contextual factors derived from both qualitative and quantitative models.

Urban transit and land redevelopment is not an uncommon agenda item in many global, car-dependent cities. However, the role of urban transit to facilitate urban regeneration and to make car-dependent cities more walkable and transit-oriented is less well defined.

Aim 1: To examine the socio-technical parameters of redevelopment that are significant for urban regeneration in the middle suburbs of car-dependent cities.

The research in this thesis begins with a comprehensive investigation to analyse the causes of car–dependence, focusing on the influential factors such as metropolitan functions (population, CBD employment, car ownership, etc.) and forms (urban density, road and neighbourhood design, etc.) to explain the cause of automobile dependence.

Aim 2: To examine the relationship between transit infrastructure and urban redevelopment to facilitate urban regeneration.

This research also investigates the role of transit infrastructure in urban redevelopment and conceptualises the interrelationships of urban regeneration that is instigated by transport infrastructure.

Aim 3: To determine the contextual factors that play important roles in the instigation of urban regeneration by transport infrastructure and services.

This thesis encompasses a comprehensive overview of the available published literature to develop a list of contextual factors and their direct and indirect relationships with transit options that can facilitate urban redevelopment by boosting the land value of surrounding land parcels of an established transit corridor.

Aim 4: To determine the potentiality of particular infrastructure and transport services based on contextual factors derived from both qualitative and quantitative models

Finally, this research develops a methodology to assess the roles of the identified contextual factors in facilitating urban regeneration via a conceptual framework that uses a combination of qualitative and quantitative analyses.

1.4 Research objectives

The overall aim of this research is to develop a conceptual framework that can assess the potential of a transit corridor (with an appropriate transit mode) to facilitate urban regeneration in car-dependent cities. Therefore, the practical objectives of the research are:

a) To develop a methodology to assess the roles of contextual factors that facilitate urban regeneration in the middle suburbs of car-dependent cities;
b) To identify the potential of transport infrastructure to regenerate the middle suburbs of car-dependent cities; and
c) To establish a conceptual framework that can be used to facilitate urban regeneration in the middle suburbs of car-dependent cities.

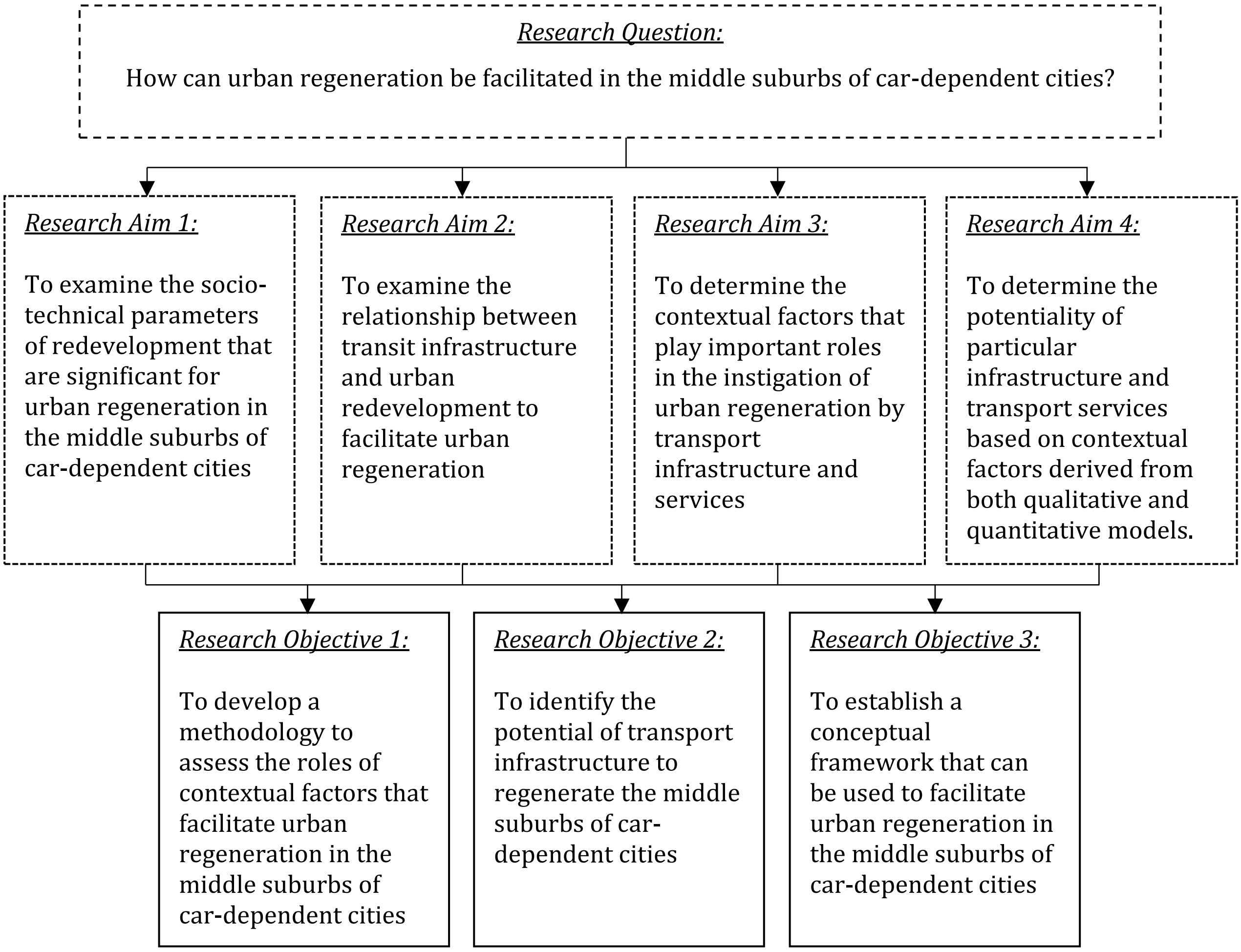

Figure 1.1 The relationships between the research question, aims and objectives

1.5 Significance and benefits of the research

This research will contribute to the academic discussion by reducing some of the gaps identified in the literature and by providing thoughtful feedback that will be of significance to the policy-makers and stakeholders.

On a larger scale, this research will be a significant stepping stone by providing a perspective for planning professionals who are interested in transit-oriented intensification around designated activity centres, transport arterials and areas that suffer from too many brownfields and greyfields. More importantly, it will present grounds for arguments related to planning processes for stakeholders, who are the catalysts for reducing the pressure of urban sprawl by developing on the fringes.

The relationship between people and their chosen mode of commuting to and from work is a vital factor to make a city thrive. Other benefits stemming from this research include:

- The ability to locate an area that potentially would benefit from urban regeneration through identifying and categorising the contextual factors.
- Provision of a dependable, Multi-Criteria Decision-Making (MCDM) model that can be used to judge the level of the interdependency of relevant contextual factors in order to assess the potentiality of any proposed transport infrastructure and the appropriateness of the transport mode.
- The available literature suggests that there is a need for an innovative framework to address several aspects of urban regeneration in the middle suburbs. This research addresses the current research gaps in planning policies concomitant to the redevelopment of greyfield precincts in the middle suburbs, especially those that are acting as deterrents for developing good outcomes, locally as well as nationally.
- This research contributes to the fields of urban and transport planning policy by linking density needs, regeneration potential and the possibility of mass transit options in urban regeneration projects.
- Similarly, it also contributes to the field to find potential areas for redevelopment by proposing to support urban regeneration

The economic perspective of this research is also valuable because this study substantially addresses the benefits of redirecting investment inwardly, by introducing initiatives to attract more businesses to the middle suburbs, resulting in a vibrant neighbourhood in which to live. The relationships between different land uses and their capabilities to generate patronage via a proposed transit option have been detailed in this research to provide food for thought to the planning professionals and related stakeholders.

1.6 Research methodology

The study is comprised of three major stages: determination, evaluation and decision. The principal applied methods are outlined below:

- Determination of the contextual factors that encourage urban redevelopment in car-dependent cities through:
    1. reviewing relevant literature on car dependency, urban redevelopment and urban regeneration;

ii. determining appropriate multi-criteria, decision-making methods to analyse the relative importance of the contextual factors and sub-factors, based on collected opinion from the experts;
iii. determining an appropriate Planning Support System (PSS) tool to analyse the potentialities of the factors and, thus, produce a thematic map for investigation; and
iv. determining an appropriate tool to evaluate land use and transport integration.

- Evaluation of contextual factors and integration of land use and transport infrastructure services by:
  i. analysing thematic maps developed from the contextual factors drawn from the values selected by the surveyed experts;
  ii. identifying lots and precincts in the walkable surroundings of the proposed transit corridors; and
  iii. assessing the appropriateness of a transport service by evaluating the projected density of the adjacent lots for each route in respect to the patronage capacity offered by a particular transport mode.
- Reaching a decision about the potential of the proposed transit corridors to facilitate urban regeneration after:
  i. determining the weights for each criterion using the survey responses and applying the Pair-wise Comparison Method (PCM); and
  ii. establishing a conceptual framework that integrates a Multi-Criteria Decision-Making (MCDM) model and analysis of thematic maps produced by a PSS with a land use and transport integration model.

1.7 Thesis structure

This thesis is comprised of seven chapters. The schematic diagram in Figure 1.2 outlines the content of each chapter.

1.7.1 Chapter 1: Introduction

This briefly introduces the problems and provides relevant background information on the automobile dependency of cities, the difficulties faced by middle suburbs and the challenges of urban regeneration. After introducing a global perspective of the problem, this chapter follows with a discussion of the aims, objectives and significance of the research.

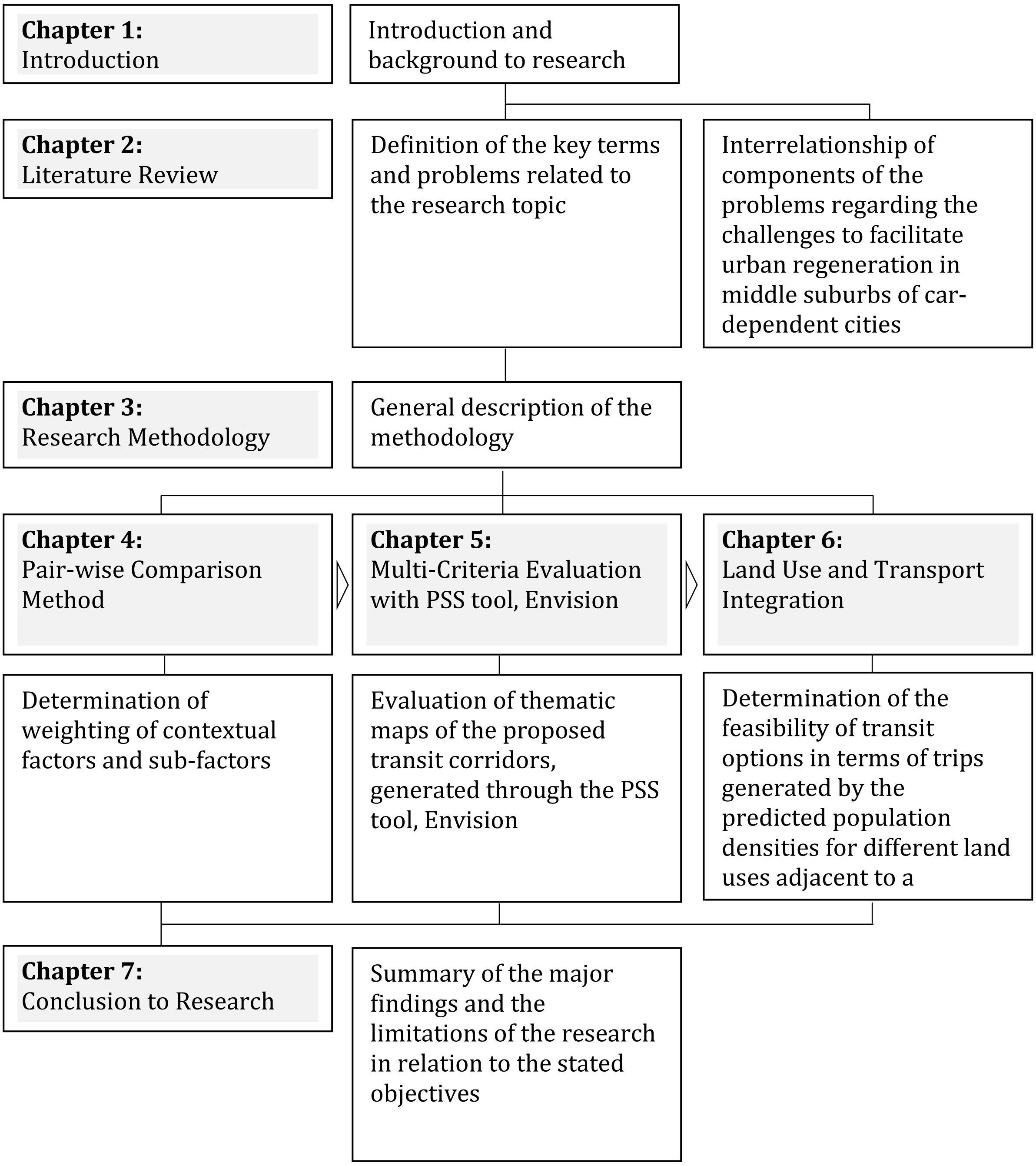

Figure 1.2 Schematic diagram of the research structure and relationship to the chapters

1.7.2 Chapter 2: Literature Review

This chapter comprehensively but concisely reviews the causes behind the problems, defining minute details of the components that are relevant to the research and investigating the possible factors that instigate urban redevelopment due to transport infrastructure projects. The justifications for using specific analytical processes, methods and computer-aided tools (web-based PSS) are detailed in this chapter.

1.7.3 Chapter 3: Methodology

In this chapter is a thorough description of the methodology utilised to conceptualise a framework that will facilitate urban regeneration in the middle suburbs of car-dependent cities. Also included are the characteristics and problems of the selected case study area and their relevance to this research, drawing from a worldwide perspective on the persistent problems to justify the selection of the City of Stirling, Perth, as a case study. The methodology chapter is an overarching chapter that depicts the interrelationship of the methods and tools used in the research, which then are detailed in the following chapters.

1.7.4 Chapter 4: Determination of Individual Weights of Contextual Factors and Sub-factors

The first method to be presented is a Multi-Criteria Decision-Making (MCDM) model that integrates the identified criteria (contextual factors) and sub-criteria (sub-factors) to evaluate the potential of the proposed transit infrastructure and services to facilitate urban regeneration in the middle suburbs of car-dependent cities. This chapter includes the theory behind the Pair-wise Comparison Method, and the analysis of survey results collected from chosen experts in relevant fields.

1.7.5 Chapter 5: Determination of the Potentiality of Proposed Transit Corridors

This chapter describes the concept and capabilities of the Envision tool, which is used in this research to identify land parcels along a proposed transit corridor that would be suitable for redevelopment to facilitate urban regeneration. This chapter also includes a description and the operational workflow of the PSS tool, the exporting process for data to the LUTI model (detailed in Chapter 6) and an evaluation of the results, based on the judgements derived from the survey of experts.

1.7.6 Chapter 6: Determining Projected Density for Each Mode of Public Transport for a Transit Corridor

This chapter describes both the rationale behind the Land Use and Transport Integration (LUTI) Model and its workflow method in order to speculate upon the desired density scenarios to establish a corridor that is most suitable for a specific transit option, regarding trips generated by the projected population densities for different land uses.

It also describes details of the tool, followed by a discussion of the results for three chosen transit routes.

1.7.7 Chapter 7: Conclusion to Research

The final chapter concludes with the overall findings of the research and recognises generic and context-sensitive lessons for future planning of major transport infrastructure projects that will facilitate urban regeneration in the middle suburbs of car-dependent cities. It summarises the significant findings and the limitations of the research relating to the stated objectives and provides recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews the definitions of urban regeneration, middle suburbs and car-dependent cities, including all their contextual variations over time and their relationships to each other. From the many options identified in world literature to regenerate urban spaces, this chapter identifies the contextual factors that dominate the establishment of a mass transit corridor as an option to regenerate the middle suburbs of car-dependent cities. A review of the literature, concerning contextual factors that have an impact on the surroundings of the established mass transit corridor (along with their influences from initiation stages) are presented in this chapter. This research utilised the Envision as a multi-criteria evaluation tool and the Land Use and Transport Integration (LUTI) Model to integrate transport modes with land uses. Therefore, in addition, this chapter also reviews the literature concerning multi-criteria evaluation tools in planning scenarios that integrate buildings, transport and land use. The review prepared the ground to formulate a new framework that is capable of assessing potential transit corridors with appropriate transport options to regenerate the middle suburbs of car-dependent cities.

2.2 Background

As a fundamental technological force, the evolution of transport has transformed cities from places where walking was predominant into being almost completely dependent upon automobiles. Since the early 20th century, once the car became a dominant force, cities started to spread out in every direction, resulting in low-density sprawling suburbs with larger footprints (Newman & Kenworthy, 1989, 1999). Newton et al. (2012) characterise middle suburbs as being predominantly low- to moderate-income suburbs, created between the late 1930s and the late 1960s but mostly developed through the post-Second World War housing boom. Those suburbs are generally characterised by a single-family household on the iconic 'quarter acre block,' sandwiched between the gentrified and revitalised inner cities and the newer and increasingly up-market post-1980 outer suburbs. As cities grow larger, the middle suburbs start losing their radiance and, over time, experience physical and economic decay, particularly of the built structures. In addition, the lack of strong urban planning policies and statutory support to reduce urban sprawl has made that situation even worse. However, being positioned near central business districts, the geographical advantage of the middle suburbs is still present, and that creates the basis of the urgent need for regeneration.

There is no single formula to achieve success in any urban regeneration policy because the exact response of a local economy to the chosen policy measures is quite challenging to predict. It is equally difficult to identify a specific contribution from transport to its surroundings. It is a common perception that transport investment plays a vital role in the regeneration process by generally improving accessibility and increasing economic activity. However, the effects are not only confined to these specific impacts. Other factors outside the transportation system itself, such as the property market, land use, density and local land policies can modify the outcomes. Since smart growth and sustainable development should always be a concern for transport investment, in practice, it is always difficult to identify accurately which factors are the most relevant for achieving those goals through regeneration.

More recently, the trends in car dependency have been reversing globally, and the most developed and developing cities are now rapidly shifting towards mass transit use, especially by rail (Newman & Kenworthy, 2011; Newman, Kenworthy, & Glazebrook, 2013). In car-dependent cities, the compelling justification for investment in transit corridors was the effect on peak hour traffic, presuming that transit options like light rail will reduce traffic congestion due to its greater ability to attract car users, when compared to buses. Additionally, as a travel alternative, a mass transit corridor reduces transport costs of the inhabitants living nearby while also reducing the commuting costs of those living further from the city centre. This attracts new dwellers to locate near the city and encourages developers to build denser housing and business premises to serve newly relocated households (Hurst & West, 2014). As an important indicator of economic profitability, the positive externalities of any transport investment such as heavy rail or light rail transit (LRT) have been well documented in the literature.

Regarding land value uplift of the surrounding properties, heavy rail transit is leading the march, but light rail transit is not far behind, considering other impacts that contribute to overall economic gain. However, there is no research that provides a firm basis on which to judge the future impacts of any transport mode on land values (Hess & Almeida, 2007) because many local factors can play a central role in varying premiums across locations. The feasibility of any mass transit proposal mostly depends on the economic profitability of the project itself and the positive impacts it is going to make on its surroundings, while other impacts underpin its viability. Apart from the location factors, there are other contextual factors that researchers consider to be influential deciders of the future of any proposed transport project.

This research explored a conceptual framework to assess the potentiality of a mass transit corridor with an appropriate transit mode from the perspective of its possible contribution to urban regeneration. This chapter reviews past studies that are available in published form to develop a list of attributes that have an impact upon local regeneration processes.

2.3 Evolution of automobile dependence

Car dependence can only be understood as a dynamic process that has developed over time, in accordance with the options open to travellers and their changing personal circumstances (Goodwin, 2012). A large body of research has recognised that components of daily life like employment, education, residential household structure and travel choices are always interdependent, and that all individuals and households have to adjust their lifestyles by collectively adjusting their behaviours, while varied aspects of transport and land use policies act around them. Once a transportation system has been built or a land use policy has been enacted, it influences the lifestyles and travel behaviours of people for a greatly extended period (Eliasson & Mattsson, 2000; Scheiner, 2007; Waddell, 2002; Xiong & Zhang, 2014; Zhang, 2014).

"In the post-war era, falling energy prices and rising car ownership have transformed cities, allowing the increased physical separation of activities and the progressive spread of urban hinterland at lower densities. The dispersal of employment, retailing and service facilities creates an equivalently dispersed pattern of trips that is anathema to public transport operation. Lower average densities mean a decline in pedestrian accessibility, longer trip lengths and reduced catchment populations for public transport routes. The result is increased car dependence, profligate energy use and global pollution" (Barton (1992, p. 67).

The term 'car dependence' or automobile dependence was first coined by Newman and Kenworthy (1989) based on a range of parameters from 32 cities in their Global Cities

Database[3]. The database was used to analyse 26 global cities over the period 1960 to 2000 by developing an understanding of their function and form, and explaining their varying levels of car dependence (McIntosh et al., 2014). Drawing a metaphorical relationship with ecosystem-shaping components like temperature, rainfall or nutrients, Newman, Matan, and McIntosh (2015) described transport as a fundamental technological force that shapes cities.

Cities are grown to be 'one hour wide' because humans do not like to travel the distance that is more than one hour for journey to work, on average (Marchetti, 1994; Newman & Kenworthy, 1999; Zahavi & Ryan, 1980). As average walking speeds are around 3-5 km/hr, the catchment of traditional walking cities[4] stays within this permissible limit. In the 19th and early 20th-centuries, trains and trams with an average speed of 20 km/hr penetrated the transport industry, creating opportunities for cities to spread out to 20 km. However, in such cases, cities used to develop following the tracks of the pre-existing routes. The dominance of the car then introduced 'automobile cities' that could spread more than 50 km, based on the average car speed being 50 km/hr. Most importantly, the automobile cities were not tied to train and tram lines, nor to the time and speed limitations of walking. They became free to spread in every direction that a road could be built. Cities started to develop focusing on the technology and infrastructure requirements of cars to the extent that people became reliant on using cars for their daily needs, in other words, creating *automobile dependence* (Newman & Kenworthy, 1989, 1999).

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[3] The choice of cities for the analysis dates back to the original study by Newman and Kenworthy (1989) that selected a set of major cities in each region covering a range of population sizes. The data for this research from the time periods 1960, 1970, 1980 and 1990 were sourced from Kenworthy et al. (1999), while taking the mean values for some cities between the 1995 (Kenworthy & Laube, 2014) and 2005 (Kenworthy, 2014, unpublished data set for UITP) updates of the database, to create a set of observations for the year 2000, in order to ensure standardised time periods (10 years) for the econometric analysis (McIntosh et al., 2014).

[4] Walking, until the popularity of motorised transport, was the dominant form of travel in cities since urban settlements began (Crawford, 2002; Kostof, 1992; Newman, 2003; Newman & Kenworthy, 1999) and cities have traditionally developed around walking ("the slow pedestrian") as the dominant mode of travel (Burchard, 1957). Within this historic city type, all goods and services needed for daily life had to be within a walkable area and, therefore, cities developed in quite dense and compact ways in order to facilitate this form of social and economic interaction (McIntosh et al., 2014).

No city has been found to be shaped in any other way than via these primary movement functions, which eventually establishes transport as a decider in shaping future cities to satisfy the multiple needs of sustainability. To improve the liveability of a city, an association between its urban form and transport system is a major challenge for the design of urban transport. It is equally essential to make a significant improvement in the technological efficiency of motor vehicles and greater use of more sustainable fuels as well (Newman, Matan, & McIntosh, 2015). Car dependence will only impact adversely on both the ecological footprint and liveability of cities. Therefore, city expansion relying on the automobile, especially personally-owned cars, means stepping ahead into an unsustainable future (Asian Development Bank, 2012; UN-Habitat, 2013).

2.4 Factors relating to automobile dependence

In their book, “Cities and Automobile Dependence”, Newman and Kenworthy (1989) analysed 32 global cities with urban metrics that included gasoline consumption, modal split of public and private transport, degree of infrastructure provision for the automobile (road supply and parking) relative to mass transit and a measure of urban density and centralisation. One of the key metrics used to define car dependence was passenger car vehicle kilometres travelled per capita (VKT/capita). As per traditional urban location theory, access to basic employment prompts the formation of households and increases dwelling densities. This increased demand for access to employment in dense city fabrics is associated with lower VKT/capita (Alonso, 1964; McIntosh et al., 2014; Muth, 1969).

Corpuz, McCabe, and Ryszawa (2006) analysed Sydney, Australia, and explored an inverse relationship between car ownership and the mix of locations for land use. They argued that the car ownership rate was the most influential factor to increase car use per capita but, on the other hand, the mix of locations for land use was the factor that dominated a decrease in car use. Similarly, Cervero and Kockelman (1997) also found a positive relationship between car ownership and their use, whereas both transit provision and land use diversity maintained a negative relationship with car use, which is consistent with the findings of Vance and Hedel (2007) from their study in Germany. In support of this statement, Cameron, Kenworthy, and Lyons (2003) found the city structure (e.g., Canadian/US gridiron pattern vs. Australian dendritic system) is a critical determinant of car dependency. However, Boarnet and Crane (2001) mentioned that the interrelationship between car dependency and city structure could not be concluded as making them deciders for each other. Neighbourhood design also influences the travel decisions of the occupiers, but it is not as important as the location or changes to the socioeconomic make-up of the neighbourhood. The 'macro' urban structure is more important than the 'micro' neighbourhood design (Canada Mortgage and Housing Corporation, 2000).

Cervero and Murakami (2009) found, in their study of 370 American cities, that car use per capita possesses a negative relationship with population density. Conversely, a positive association between population density and roadway density was also evident, leading to the worst combination of high density and high car use. Although in Australian cases it has been found otherwise (Trubka, 2011), Zegras (2010) found a positive relationship between increasing car use and higher household incomes in his study of Santiago and Chile.

In his book "Great Cities and Their Traffic", Thomson (1977) developed five city archetypes based on the transport systems of worldwide cities and their interrelationships with urban structure and form, summarised in Table 2.1.

Table 2.1 Global city archetypes, adapted from Thomson (1977)

Archetypes	Description	Example Cities
Full Motorisation Strategy	▪ Small to no city centre (<120,000 jobs) without a radial transport system ▪ Employment in single storey buildings with extensive parking ▪ Low-density single storey suburbs ▪ Large format shopping with extensive parking ▪ Grid format freeways (4-10 lanes) ▪ Buses on secondary highways, poor pedestrian environment ▪ Car is dominant and cheaper in generalised costs than public transport (PT) to centres	▪ Los Angeles ▪ Detroit ▪ Denver ▪ Salt Lake City
Weak Centre Strategy	▪ City centre (> 250,000 jobs) with radial road and mass transit network ▪ Significant peripheral and suburban employment served by car ▪ Requires PT to attract passengers in order to limit intolerable congestion ▪ Ring and radial freeways, commercial/industrial developments attracted to intersections ▪ Strategy is unstable due to requirements for high transport accessibility to centre without full PT access ▪ Car is marginally cheaper than PT in generalised cost of travel to centres	▪ Melbourne ▪ Copenhagen ▪ San Francisco ▪ Chicago ▪ Boston

Strong Centre Strategy	▪ Very high levels of CBD employment (> 500,000 jobs) with a radial mass transit network and limited road accessibility to the centre ▪ Ring roads complement and interact with mass transit to provide centre access ▪ Development outside the centre is focussed around mass transit infrastructure ▪ Transport investment to centre is equal between road and mass transit ▪ Mass transit is cheaper than car in generalised cost of travel to centres	▪ Paris ▪ Tokyo ▪ New York ▪ Athens ▪ Toronto ▪ Sydney ▪ Hamburg
Low Cost Strategy	▪ Large number of radial routes ▪ Bus rapid transit (BRT); buses and trams carry the majority of passengers, with limited car use/capita ▪ Very dense development at centre serviced by buses	▪ Bogota ▪ Lagos ▪ Calcutta ▪ Istanbul ▪ Karachi ▪ Manilla ▪ Tehran
Traffic-Limiting Strategy	▪ City centre hierarchical structure in place to minimise the need for travel: city centre, sector centres, suburban centres, neighbourhood centres ▪ Radial rail and ring rail systems put in place, such that all centres accessible by rapid transit, bus, cycling or walking, as well as by car ▪ Limited access to the centre by car ▪ High cost of car travel compared to mass transit (parking, congestion charging)	▪ London ▪ Singapore ▪ Stockholm ▪ Vienna ▪ Bremen ▪ Goteborg

Based on Thomson's city archetypes, McIntosh et al. (2014) researched further, using and enhancing the global city database of Newman and Kenworthy (1989) by extending the database into an additional decade, from 1960 to 2000. McIntosh's (2014) work was the first to econometrically model the Global Cities database over a four-decade period and it introduces the use of city archetypes to explain VKT/capita in relation to car use. The general findings of the VKT/capita of the different archetypes is summarised below:

- In terms of VKT/capita of the different archetypes, very predictably, the *Full Motorisation Strategy* cities have the most extensive car use, followed by the *Weak Centre Strategy* cities and then the *Strong Centre Strategy* and *Traffic-Limiting Strategy* cities.
- The traffic-limiting archetypal cities' car use is half that of the full motorisation strategy cities and, density–wise, the traffic-limiting archetypal cities are 1.2 times denser than fully motorised cities.

- Though there is a marked difference in density, both the strong centre and weak centre strategies had the same car use, which was 34% less than the full motorisation strategy cities.
- Regarding the use of mass transit options, strong centre strategy cities had the highest passenger-kilometres per capita, which was 51% higher than in fully motorised cities. Being not far behind, the traffic-limiting and weak centre strategies use of mass transit was 30% higher than the full motorisation strategy cities.

McIntosh concluded that the strong relationships between city archetypes and their underlying frameworks explain the values of VKT/capita through human behaviour. Additionally, urban density and mass transit service provision have a causal relationship with private vehicle usage that influences the region and typology of cities.

2.5 Defining middle suburbs

A concrete definition of middle suburbs is still obscure. However, they are described by many scholars with a confusing array of contextual terminology, including old suburbs (Persky & Kurban, 2001), inner suburbs (Bollens, 1988; Jackson, 1987; National Association of Home Builders, 2002; Orfield Jr, Puentes, & Orfield, 2002), inner ring suburbs (Downs, 2010; Drier, 1996), older inner ring suburbs (Bier & Post, 2003), sitcom suburbs (Hayden, 2000), post–World War II suburbs (Design Center for American Urban Landscape, 1999; Lucy & Phillips, 2000; Seaver, Morris, & Rapson, 1998), first suburbs (Orfield Jr, Puentes, & Orfield, 2002; Schwarz, 2003), first ring suburbs (Fishman, 2000; Rokakis & Katz, 2001), first tier suburbs (Hudnut & Hudnut, 2003) and middle suburbs (Newton & Glackin, 2013; Newton, 2012). Irrespective of the terminologies used by the scholars, they differ only slightly and mostly on the timing of development, geographical location concerning the central city, age of population and quality of living. Table 2.2 lists the scholars and their definitions of middle or inner ring suburbs.

Table 2.2 Definition and terminology of middle suburbs identified in the literature, adapted from Leigh and Lee (2005)

Author	Terminology	Description
Hudnut (2003)	First tier suburbs	▪ Occupy 25% of metropolitan areas ▪ A term considered to be relatively precise and neutral, and one that takes into account the timing of development as well as geographic location beyond the central city

Author	Terminology	Description
The Ohio First Suburbs Consortium (2004)	First suburbs	▪ Generally, suburbs that were built, or mostly built, adjacent to or near central cities before 1960
Seaver, Morrish and Rapson (1998); Design Center for American Urban Landscape (1999)	Inner or first ring suburbs	▪ 'Post–WWII communities' constructed between 1945 and 1965
Lucy and Phillips (2000)	Inner ring suburbs	▪ "Middle-aged neighbourhoods" that were built from 1945 to 1970 (p. 57) ▪ "…ordinary single-use residential-only subdivisions of the type constructed in every metropolitan area from the end of WWII through 1970" (p. 55)
Schwarz (2003)	Inner ring suburbs (pre-war and post-war)	▪ Pre-war suburbs: developed in the mid-19th to early 20th centuries, tending to have distinctive architecture, tree-lined streets, walkable commercial areas and good accessibility to public transport ▪ Post-war suburbs: constructed rapidly to provide housing for the baby boom generation, tending to have homogeneous architecture and automobile-dependent neighbourhoods
Hayden (2000)	Post-war suburbs	▪ Mass-produced housing developments, built at great speed after World War II
Newton (2012)	Middle ring suburbs; middle suburbs	▪ Laid out originally as residential domiciles, now constituting a contiguous, built-up region between 10 and 30 km from the CBD

Taking the various scholarly definitions into account, middle suburbs can be explained as suburbs that are generally post-World War II, constructed between 1950 and 1970 (Newton, 2010), for which the primary mode of transportation has been the automobile, especially personally-owned cars. Initially laid out as residential domiciles, the middle suburbs now constitute a contiguous, built-up region that has expanded to a distance of approximately 10-30 km from the CBD and is now showing aspects of physical decline.

2.6 Structure of middle suburbs

Metropolitan regions around cities all over the world have experienced a dramatic increase in suburbanisation over the last couple of decades, and there are many alternative explanations as to the causes behind this phenomenon. Mieszkowski and Mills (1993) mentioned two theories: the natural evolution theory and the flight-from-blight theory. Natural evaluation theory describes suburbanisation as the result of rising incomes that lead to relocation of higher income people at the periphery of the metropolitan area in larger and newer houses, leaving behind the older houses for lower income households. In subtle contrast, the flight-from-blight theory describes suburbanisation as being the result of the continual flight of middle- and higher-income groups to suburban areas to avoid the problems of central cities, such as racial tension, crime, higher taxes and lower environmental quality (Lee, 2004). Many other scholars explain the growth of suburbanisation with diversified causes that include, *"rising real income, greater use of cars and trucks, widespread desire for living in relatively new and low-density settlements, economic advantages of home ownership, and strongly entrenched tendencies for people to segregate themselves socio-economically and racially by neighbourhoods"* (Bradbury, Downs, & Small, 1982, p. 136). Another causal factor is lenient government policies associated with land use controls, housing and transportation (Bergstrom, Dorfman, & Ihlandfeldt, 1999; Duany, Plater-Zyberk, & Speck, 2000; Katz, 2002).

The diversity of suburban areas and the emergence of suburban rings can be attributed to the evolution of transportation systems. Adams (1970) and Lee (2004) found private automobiles to be the specific mode of transportation that is associated with developing inner ring and middle suburbs. Before World War II, trolleys and electric rails were the dominant factors that created public mass transit cities, with inner ring suburbs established around train stations and relatively close to the core city. After the war, automobile dependence, due to the perceived convenience and mobility of cars, increasingly took inhabitants out to the middle suburbs. The accelerated dominance of automobiles over time has taken control of city planning from the planners and introduced automobile-dependent cities into our lives in a more extensive manner. City extensions have developed, transforming the metropolitan region into diverse sub-areas of the central city, with inner-ring suburbs, outer-ring suburbs, suburban sub-centres and even exurbs at the fringes.

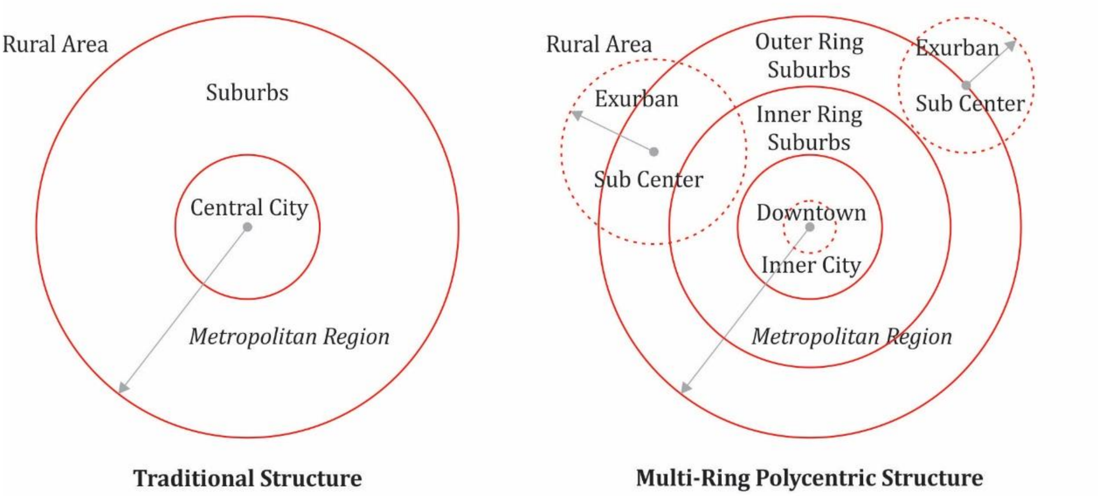


Figure 2.1 The emergence of suburban rings and sub-centres within metropolitan areas, adapted from Leigh & Lee (2004)

The traditional suburban environment has come to be seen as a compromise in quality of life since being challenged by the outer suburban sprawl. In consideration of a metropolitan smart growth strategy, planners and policy-makers have placed significant emphasis on revitalising the middle suburbs, since the traditional model of redevelopment via city brownfield sites is no longer working (Newman, Matan, & McIntosh, 2015; Newton, 2012). As an alternative approach, the smart growth movement emphasises the reuse of existing resources in already urbanised areas within a metropolitan area. Fishman (2000), with his survey of US metropolitan areas, concluded that the strategic location of the middle suburbs between the metropolitan centre and urban fringe is vital and has the potential to provide a new model of development to achieve the objectives of the smart growth movement. This movement seeks to redirect public investment into urbanised areas, thereby stemming urban sprawl at the edge of metropolitan areas (Lee, 2004). Furthermore, in their book "Economic Revitalization: Cases and Strategies for City and Suburb", Leigh and Fitzgerald (2002) suggested that economic development strategies that seek to promote equity and sustainability should emphasise middle suburbs.

Characterising middle suburbs in greater detail, Newton et al. (2012) described a few attributes that are present in low-density Australian suburbs, using Melbourne as a case study:

- Unlike inner suburbs, the buildings and infrastructures of middle suburbs show signs of physical and technological obsolescence because their urban character and demography vary substantially with disparities in housing affordability and diversity.

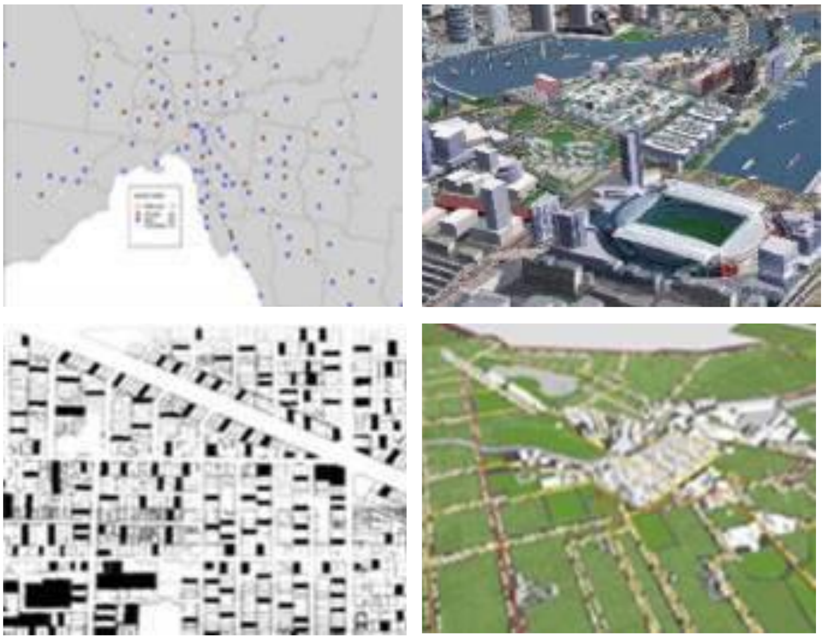
- In comparison with outer suburbs, middle suburbs have rich transport services and amenities. However, to contribute to the inward movement of people and the economy, densification with new housing and population is still lagging due to the factors listed below.
    - Accessibility to the city centre through public transport is better in middle suburbs than outer suburbs, but less well-serviced precincts need to be identified and serviced with an appropriate mode of transport.
    - Dwelling units are lower in number in the middle suburbs than both outer and inner suburbs, which reveals the potential to increase capacity.
    - Both net population density and population growth are low in middle suburbs, compared to outer suburbs, again revealing an opportunity for redistribution.
    - Middle suburbs are geographically well-placed to access jobs located in both the inner suburbs and central city, which carries the highest concentration of jobs.

2.7 Regeneration typologies of middle suburbs

Urban regeneration, renewal, redevelopment, rebuilding, renovation, restoration and retrofit are all terms that have been used somewhat interchangeably in the literature to describe the processes aimed at revitalizing the existing built environment, local communities and local economies (Newton, 2013). Newton et al. (2012) distinguished three scales of operation and transformation that take place in middle suburbs, with specific reference to housing and their precincts. Firstly, retrofit involves the modification of any structure that is already in use, using new materials or technologies that were developed after the period of construction of the original structure. It could be the addition of insulation or installation of a new heating system. Secondly, renovation can range from a single item of building renovation, such as refurbishment of a kitchen or bathroom, to a completely new extension. Thirdly, regeneration implies the complete reproduction of new housing in place of obsolete housing using new construction materials and contemporary design. Regeneration is a process of a higher order that recreates the form and condition of the environment, extending beyond the individual dwelling to neighbouring properties and infrastructure (Couch, Sykes, & Börstinghaus, 2011; Lawless, 2010; Newton et al., 2012; Newton, 2012; Roberts & Sykes, 1999).

2.8 Redevelopment arenas of middle suburbs

There are mainly two prospective arenas for housing intensification and precinct regeneration through strategic planning and development in middle suburbs: brownfields and greyfields[5].Such regeneration occurs in different forms that include: extensions and alterations to existing property, piecemeal infill and precinct-scale redevelopment incorporating activity centres, transit-oriented development (TOD) and transport corridors (Murray, Newton, Wakefield, & Khor, 2011).



Top left:
Activity Centres
Top Right:
Brownfield Precincts
Bottom Left:
Piecemeal Infill
Bottom Right:
Transport Corridors

Figure 2.2 Existing regeneration approaches of middle suburbs, adapted from Newton et al. (2011)

The report, "Towards a new development model for housing regeneration in greyfield residential precincts" by the Australian Housing and Urban Research Institute (AHURI) described brownfield regeneration as a process of transforming parts of cities that have outlived their original functions. Generally, the brownfields are the abandoned or under-utilised docklands that occupy prime waterfront sites in all coastal cities (Kirkwood, 2003). Factories, scrap yards, railroad corridors, vacant commercial sites like decommissioned petrol stations and thousands of industrial sites are the principal

[5] Greyfields, in the Australian context, have been defined as ageing but occupied tracts of inner and middle ring suburbia that are physically, technologically and environmentally failing and which represent under-capitalised real estate assets (Newton, 2010).

examples, typically owned by a single party, and perhaps contaminated to some extent but remediable, depending upon the nature of prior use. Greyfields, on the other hand, have no requirement for remediation and predominantly lie between the more vibrant inner-city housing market and the more recently developed greenfield suburbs. They generally provide greater access to employment, public transport and services than the outer suburbs.

The report by Newton et al. (2011) also noted that greyfield regeneration requires a new and critical focus for strategic planning with a new framework model that is proactive in dealing with precinct-scale development rather than piecemeal. The model should offer new options such as low-rise, high-density developments and should involve community participation. Additionally, it should encompass the existing public sector interventions relating to housing in deprived neighbourhoods and act beyond the fragmented, piecemeal process of development that has characterised the past twenty years due to being centred on individual residential properties. The identified three major pathways are:

- Activity centres and transit-oriented development (TOD);
- Public transport corridors; and
- Greyfield residential precincts.

The principles of TOD are well established and it acts as a stimulus for urban renewal. The activity centre is configured as the heart of the enlarged community, with a better mixture of land uses and higher-density housing clustered around high-quality transport services (Dunn, 2009). Activity centres have been a focus for intensification of greyfield sites, pre-dating Melbourne’s 2030 Strategic Plan. However, their rate of progress has been much slower than anticipated, due to local reactions directed principally against the scale of proposed high-rise developments that are expected to change the neighbourhood character.

There are many different types of TOD that have been described by scholars based on evaluations of their walkability (Schlossberg & Brown, 2004), vehicle miles travelled (Austin et al., 2010), connectivity of the public transportation node (Bertolini, 1999; Zemp, Stauffacher, Lang, & Scholz, 2011), evolution of cities toward becoming transportation-oriented (Cervero, 1998), and potential to develop as a TOD using density and diversity indicators (Kamruzzaman, Baker, Washington, & Turrell, 2014; Singh, Fard, Zuidgeest, Brussel, & van Maarseveen, 2014). In order to assess how attitudes and residential self-selection can affect the success rates of TODs, De Vos and Witlox (2013) subdivided TODs into three types, based on the initial stage of development. Similar to Cervero's (1998) adaptive cities, new TODs can be classified as new neighbourhoods developed around new public transportation services. They are compact and of mixed-use in nature. High-density TODs are comparable to strong-core cities, where high-quality public transportation is provided in, and between, existing neighbourhoods with both high density and diversity. A lot of North American and Australian cities are characterised by the development of low-density neighbourhoods with low diversity and a car-oriented design (Brueckner, 2000; Dittmar, Belzer, & Autler, 2004; Glaeser & Kahn, 2004; Newman & Kenworthy, 1996).

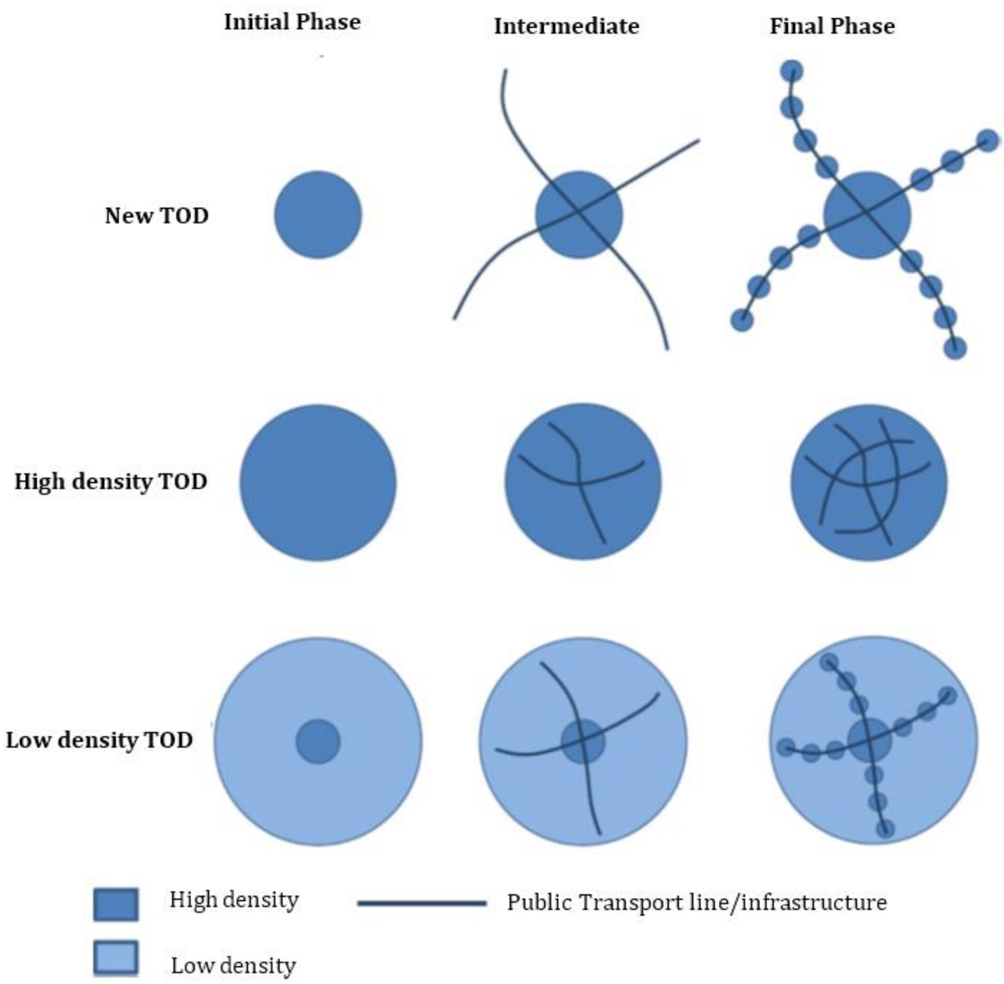


Figure 2.3 Types of TOD, adapted from De Vos, Acker and Witlox (2012)

A low-density TOD is a suburban-style neighbourhood that combines improved public transportation services and developments of increased density and diversity with existing low-density housing. However, the transformation of low-density neighbourhoods around these public transportation lines is essential to be of mixed-use and higher density. Otherwise, there is a risk of creating transit adjacent developments (TADs) instead of TODs (Curtis, 2008; Curtis & Olaru, 2010; Olaru, Smith, & Taplin, 2011; Renne, 2009). The Hong Kong Special Administrative Region (HKSAR) is an example of combining different types of development. Having a successful railway system operating in and around the city centre, they developed high-density TODs around transportation services and expanded their railway system outside the core urban area to guide development in new towns with new TODs (Loo, 2009).

Public transport corridors act as an additional locus for medium–rise, high-density development in a linear fashion. This type of development is expected to deliver a significant volume of net new housing in greyfield areas, while also relieving development pressure from the existing interstitial suburbs, enabling them to act as the 'green lungs' (enhanced water, energy, food production, etc.) of our cities and remain at their existing levels of low density. In response to the existing sub-optimal situation, the two options discussed above are necessary but not sufficient to tackle the remaining, significantly high proportion of greyfield sites (Newton et al., 2012). A precinct-scale regeneration (in consolidated[6], dispersed[7] and hybrid[8] precincts) can offer a dwelling mix of higher density that is also mixed-use (Murray et al., 2015), is energy efficient, with carbon neutrality or zero carbon status (Newton & Tucker, 2010), and uses an integrated water system involving water-sensitive urban design (Diaper, Sharma, & Tjandraatmadja, 2008; Kenway & Tjandraatmadja, 2009; Maheepala & Blackmore, 2008;

[6] This precinct type consists of a large parcel of assembled land enabling high-density built outcomes suitable to large-scale development. Development sites of this type can produce high yield and construction efficiencies, and have the potential to achieve high quality design input and provide precinct-based infrastructure (Murray et al., 2015).

[7] This type consists of small suburban parcels dispersed over a 400 square metres area. Based on current infill development patterns, this model is based on a single developer working over a number of non-contiguous sites. It can provide high quality, diverse housing types ranging from low- to medium-densities. Opportunities for intensive infrastructural efficiencies are limited but the scope for improved landscape and street amenity is enhanced (Murray et al., 2015).

[8] This type of precinct consists of a mixture of stand-alone and aggregated lots, potentially connected by infrastructure and landscaped elements. Assuming a single developer working over the precinct sites, certain economies of scale may be possible including prefabrication and a common design strategy. In addition, the mix of lot sizes means that different types of land use can be developed and higher densities are achievable (Murray et al., 2015).

Novotny, 2013). It also can offer optimal reuse and minimisation of waste during construction (Lehmann & Crocker, 2013), with improved walkability and cycling paths (Foster, Giles-Corti, & Knuiman, 2011) and a sense of place to enable the creation of an attractive physical neighbourhood with sociable community settings (Gehl, 2013).

2.9 Urban regeneration

The term 'urban regeneration' was developed from a similar concept in the field of public policy, also known as urban revitalisation, urban renewal and urban renaissance. It addresses urban issues such as economic decline, environmental decay, community dereliction, growing unemployment and the associated social problems caused by these urban issues. According to Roberts (2000),p.40, urban regeneration is defined as *"comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change*." He charts the evolution of urban regeneration policy over the past five decades in an alliterative sequence running from 'reconstruction' through 'revitalisation', 'renewal' and 'redevelopment' to 'regeneration'. Regeneration is concerned with the regrowth of economic activity where it has been lost; the restoration of social functions where there has been dysfunction, or social inclusion where there has been exclusion; and the restoration of environmental quality or ecological balance where it has been disturbed. Thus, urban regeneration is an aspect of the management and planning of existing urban areas rather than the planning and development of completely new ones (Couch, Fraser, & Percy, 2003). It requires an integrated vision and action, which leads to the resolution of urban problems and seeks to bring about a lasting improvement in the economic, physical, social and environmental conditions of an area that has been subject to change (Roberts, 2000; Roberts & Sykes, 1999). However, when urban regeneration is mentioned, it usually refers to the revitalisation of the central city and its immediate surroundings, which is generally an older and more densely populated urban core surrounded by a metropolitan area of lower density and larger land area (Barnett, 1986). The varied contexts include physical conditions, economic systems, the political situation and global trends attributed to different urban problems. Notwithstanding how diverse the problems are, the definition supports the fact that there is a common desire to prevent cities from declining and there is a need to attract inward investment by introducing catalysts to make it happen.

2.9.1 History of cities

Urban regeneration is an enduring theme throughout world history, from very early human settlements to a modern metropolis. At the early stage of human settlements, ancient cities used to be rebuilt in response to warring invaders and destruction from natural calamities like volcanic eruptions, hurricanes and earthquakes. Day by day, the forces of urban decline become more predictive and less dramatic. For example, during the Renaissance, the medieval sections of several European cities were re-planned.

"The clergy or nobility demolished ancient walls, straightened and widened streets, removed aged buildings and added parks, monuments and aesthetically pleasing visual features. The rebuilding of Rome under a sixteenth-century plan prepared by Pope Sixtus and his assistant Domenico Fontana is a most notable example" (Barnett, 1986, p. 167).

Along with population and land use changes, transportation became an intrinsic part of urban planning in dealing with urban decay at the beginning of the last century. The issues related to make cities liveable, such as addressing the problem of horse-drawn traffic in much the same way we now worry about pollution from mechanical transport. The offered solutions to such problems were for people to live in the suburbs, leaving the city, or to beautify that which was ugly within the city, bringing order to chaos and planning for the future. In response to such problems, in Europe, the garden city movement supported by the mass housing industry consumed the land released by agricultural decline, eventually producing today's suburbia (Latham & Swenarton, 1999). In America, such a movement created plans to revitalise cities like San Francisco, Chicago, Denver, Cleveland, Indianapolis, Minneapolis, Washington DC and some other central cities, overlooking the effort to establish a consensus between government and business sectors. Such measures transformed cities but made them the victims of ever-growing demands by the automotive manufacturers for roads to service their vehicles. Whatever was achieved in the first half of the last century merely scratched the surface of urban development and, certainly, had less effect than the bombing campaigns of the Second World War (Latham & Swenarton, 1999).

While the details varied from nation to nation and city to city, urban renewal usually involved financing and rules that were provided by the national government, with programmes being implemented by the municipal and state governments (Gale, 1984). Many scholars have identified the phases of urban regeneration over the last five to six decades and roughly ended up segregating them into three phases, depending on the level of intervention by governments to control the private sectors. Since WWII, the state-led, wholesale redevelopment that occurred up to the 1960s and a brief period of multi-dimensional redevelopment and rehabilitation efforts from the mid-1960s to 1970 can be considered as the first era of urban regeneration, and it is generally termed 'urban renewal.' For about two decades after WWII, there was a general belief that economic growth could eventually solve all development problems. As a result, urban regeneration was equated with state-led, physical redevelopment and remedial action within these declining cities, with planning that envisioned a better future. Such actions concentrated on physical renovation to erase the existing flaws and unify diverse elements of cities under city development programmes. In the 1960s, with the "*rediscovery of poverty and a large number of victims of 'multiple' deprivation*" (Carmon, 1997), it was recognised that massive bulldozing of dilapidated buildings was too expensive in both economic and social terms. During these years, urban residents began to be aware of the disruptive consequences of government-led urban renewal programmes that fell far short of expectations to generate a new era.

Eventually, in the 1970s, there was a growing awareness of the importance of economic and environmental regeneration in conjunction with social projects (Thornley, 1991). In many European cities, such programmes and projects initially were publicly funded. However, since 1979 the private sector has been brought much more to the fore and this promoted what Oakley (1995) described as an over-reliance on property-led regeneration. This mode of renewal was predicated upon the belief that "*the private sector [is] the only possible way of restoring lasting prosperity to the decaying areas of our towns and cities*" (Smith, 1989).

The economic growth-biased urban renewal strategy of the 1980s had produced 'divided cities' (Fainstein & Harloe, 1992; Marcuse, 1993) and 'islands of renewal in seas of decay' (Berry, 1985). It became increasingly evident that property-led urban renewal did not offer a reliable foundation for stable and sustainable economic regeneration (Healey, Davoudi, O'toole, Tavsanoglu, & Usher, 2002). The key task is to link property development investment to the real demands and needs of the developing local economy and the cultural environmental concerns of local citizens (Healey, 1992). In fact, increasing social problems in 'disadvantaged' neighbourhoods have led to the 'rediscovery of community' and new 'partnership' arrangements being initiated by governments, involving not only the public and private sectors but also voluntary organisations and the community (Ng, 2005).

2.9.2 Characteristics of urban regeneration

The relationship between urban economy and urban environment has been established through changing urban forms in the era of globalisation. As discussed, for centuries regeneration was an outcome of the economic growth of cities that affected people's quality of life. However, nowadays, quality of life itself has become the prerequisite for the economic development of cities and, to some extent, it is the main engine of regeneration. Loftman and Nevin (1995, p. 300) characterise urban regeneration as "*a pioneering or innovative, high profile, large-scale, self-contained development which is primarily justified in terms of its ability to attract inward investment, create and promote new urban images and act as the hub of a radiating renaissance – facilitating increases in land values and development activities to adjacent areas*". According to Bianchini, Dawson, and Evans (1992) and Loftman and Nevin (1995), these urban regeneration projects are characterised by the following features:

- They are important instruments for the transformation of entrepreneurial urban governance;
- They are the extension and reinforcement of property-led development;
- They are adjacent to flagship architecture, landmark buildings, major office complexes, pivotal transport hubs or leisure and sporting facilities;
- They involve the 'rhetoric of partnership' and elite-dominated urban policy formation (with some arguing that this is a biased observation in that 'real partnership' has also taken place);
- They are usually located in areas conducive to business opportunities that are equipped with a 'convenient' regulatory environment for attracting private-sector money, such as a central business district;
- The public sector provides initiatives to attract private-sector capital for the delivery of these projects by concessionary contracts;
- They marshal powerful vested interests, elite groups and politicians to form a project-led network;
- They involve massive investment and high financial risk; and
- They are financed by mechanisms including public-private partnerships and joint ventures or through the extensive provision of public grants or subsidies.

2.9.3 The interrelationship of regeneration and transport investment

The available literature frames urban regeneration in many ways. According to Colantonio and Dixon (2010), it differs in meaning to different people, ranging from large-scale activities to neighbourhood interventions to improve the quality of life. Roberts (2000) highlighted the importance of a comprehensive vision and integrated actions to bring about both the resolution of problems and lasting improvements in the economic, physical, social and environmental conditions. Regeneration used to be dominated by physical regeneration until Barcelona inspired neighbourhood-based regeneration projects that included local job creation programmes (Elkington & Rowlands, 1999; Franke, Strauss, Reimann, & Beckmann, 2007; Hediger, 2000; Roberts, 2000). Hemphill, Berry, and McGreal (2004) examined the measurement process for sustainable urban regeneration performance with an indicator-based approach. In their study, they ranked transport and mobility (the travelling habits of the working population and residents in terms of their journeys to work and leisure activities), economy and work (reflecting the economic and industrial characteristics of the urban regeneration process) and community benefit (incorporating the social aspects of regeneration and sustainability) as influential components of urban regeneration, among others.

Table 2.3 Variables selected to measure the effects of new transport infrastructure, adapted from Dabinett and Lawless (1994)

		Area of Study		
Effects	**Land & Property**	**Business opportunities and locations**	**Employment patterns**	**Image**
Direct	Perception of transport-induced change in property values	Perception of transport development, use and value to businesses	Perceptions of transport developments and use	Perceptions of transport-induced change in Sheffield's image
Intermediate	Change in property values	Change in level of business operations	Scale and structure of labour market	
Process	Decisions to develop property	Business moves	Journey to work (JTW) patterns	
Final (outcome)	Physical development	Jobs		

2.9.3.1 Perception of urban regeneration

In the United Kingdom, regeneration through the production of new urban spaces by attracting investors and visitors has been at the forefront since the 1980s and 1990s. Deindustrialisation and loss of manufacturing jobs in urban areas led to property- and consumption-based developments that provided a focus for economic regeneration and the construction of new place attachments for local people. The transformed town centres, docklands and old industrial sites became an example of particular forms of market-driven regeneration (Smith, 2001). Competition between places for investment has become the norm, with regeneration agencies focused on identifying and satisfying the 'needs' of potential investors, rather than those of local communities (Harvey, 2000).

Raco (2003) argued that the success of such regeneration projects depends on the perceptions of people around them and that the actual level of security is one of the major components that drives the mindset of all stakeholders. An area characterised by dereliction, petty crime or something generating that negative perception of crime often triggers urgency for urban regeneration. Assurance of those urban areas as being safe is a main priority for regeneration agencies when creating spaces or facilities that will attract investors, but this can be challenging. Ensuring safety involves high visibility, mobility and accessibility to the places for people of the larger catchment area.

2.9.3.2 Transport infrastructure, accessibility and mobility

Mobility and accessibility are the two central concepts required to understand transportation. Accessibility refers to opportunities being available within a certain distance or travel time, while mobility refers to the ability to move between different activities (Hanson & Giuliano, 2004). Accessibility includes the attractiveness of a place as both an origin (What opportunities are there to reach other destinations?) and as a destination (How easy is it to get there from all other origins?) (May et al., 2004).

Transportation systems influence land development by increasing both accessibility and mobility (Hanson & Giuliano, 2004) whereby transport infrastructure provides alternatives to the travellers (regarding cost, travel time and level of spatial interaction) to facilitate accessibility and competitive options to travel between destinations. As the distances between activity sites become longer, accessibility becomes more and more dependent on mobility, particularly in the private-car era. American cities, for example, have experienced growth in mobility related to the construction of a national highway system, which also links cities to such an extent that accessibility has become automobile dependent.

Land use and transportation are also interlinked. Transport infrastructure affects accessibility and mobility between destinations, which eventually reflects in the generation of more activity and urban growth. In the short term, the existing land use helps to shape travel patterns; however, in the long term, transportation systems shape land use patterns. Land use and transportation influence each other and come to a balance after any of these two issues change. The distribution of both jobs and residences is in response to changes in the transportation network but the distribution of population and employment also results in changes to transportation performance. In the short term, travel demands change in response to the increase in transportation facilities and capacity. In the long term, changes in the locations of activities result in change in travel demands and a further change in system performance (Hanson & Giuliano, 2004; May et al., 2004).

2.9.4 Actors of regeneration and the process of involvement

There is an apparent absence of a rigorous framework to assess the impacts of transport infrastructure on urban regeneration. In 1992, researchers at Sheffield Hallam University were commissioned to monitor the economic and physical impacts of the South Yorkshire Supertram (SYS) system, a light rail project instigated by the South Yorkshire Passenger Transport Executive (SYPYE) and the Department of Transport (DoT). Later on, the scope of the research was widened by a grant from the Economic and Social Research Council (ESRC). The new scope included a number of infrastructure investments that were suggested by the city council in order to develop a more rigorous methodology to ascertain the impacts. It was also expected that this would provide a fuller understanding of the effects of investment on intra-urban economic and physical changes and their impacts on regeneration, as well as the benefits to non-users of SYS (Dabinett & Lawless, 1994). The study examined the complicated relationship of output (new roads, an airport and light rail) and outcomes (physical development and jobs) of the LRT project. Apart from the conventional cost-benefit analysis of the impacts of LRT, evaluation of the study was complemented by the investigation of three secondary impacts to provide additional justification for the investment: local employment; land and property development; and business investment (Crocker, Dabinett, Henneberry, Lawless, & Townroe, 1993). To outline the measuring mechanism for the urban regeneration impacts of the SYS project, the conceptual framework of the study hypothesised that LRT, as a new transport infrastructure service, creates effects regarding changes in accessibility and costs, and in the perceptions of decision-makers. Four sets of actors, listed below, were found to be potentially influenced by these effects (Lawless & Gore, 1999).

a) Households and individuals: Shopping habits and participation in the local labour market are altered by new transport investment.
b) Companies: Along with the influences on the labour market, the road system is used to bring supplies, to offer access to customers and to transport manufactured goods. Companies also feel the effects of transport investment.
c) Investors: Particularly non-local property companies and their agents, investors are also potential receivers of the investment; and
d) Enablers and regulators: In promoting new investment and in operating the local land-use planning system, they must be mindful of the outcomes.

The effects include physical developments, changing property prices, additional new jobs and changes to retained jobs, and changes in the distribution of business activity in the form of outcomes articulated through the property market, labour market and markets for goods and services. The next sub-section describes the interrelationship of the above actors with the effects on land and property, business opportunities and locations, employment patterns and changes in image due to transport investment to facilitate urban regeneration.

2.9.4.1 Effects of regeneration over the actors

There is a growing body of literature that investigates the relationship between transport investment and business performance at the intra-urban scale. Studies at the inter-regional scale suggest that companies may relocate operations if the impacts of new transport opportunities result in the reduction of production costs by avoiding congestion, realising latent demand, improving accessibility to business and enhancing customer accessibility (Diamond & Spence, 1989). Similarly, at the intra-urban scale, cost-effective sectors within retailing, distribution and manufacturing will tend to benefit from new investment in transport.

"*Another major area of interest is that of the local labour market, which is not only crucial in understanding patterns of employment expressed in the demand and supply of labour* *but is also a central mechanism in efforts to achieve distributional effects inherent to urban regeneration objectives. It is conceivable that both firms and individuals could benefit from enhanced intra-urban transport investment. New or improved networks, especially in the way of public transport, should widen job opportunities*" (Dabinett & Lawless, 1994).

2.9.4.2 Regeneration outcomes and economic growth

The general consensus about transport investment is that, alone, it is not capable of significantly assisting urban regeneration or having a decisive influence (Banister & Berechman, 2002; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Gospodini, 2005; Transport and Tourism Division & Asian Institute of Transport Development, 2007). However, strategic investment in transport infrastructure has the ability to boost the economy when confronting uncertainties, which was demonstrated in the US as part of a response to the challenges of the recession in 1930. A similar initiative boosted France's international economic competitiveness via a high-speed railway network, and Hong Kong's economic vitality and sustainability were ensured via the economic certainty and optimism infused by the building of a massive port and airport immediately before its handover to China in 1995 (Dimitriou, 2010). Rietveld, Bruinsma, Van Delft, and Ubbels (2001) emphasised the interdependence between transport infrastructure and economic growth. They contend that transport infrastructure is a necessity for the functioning of an economy through its vital support of the production and consumption processes.

To create a supportive business environment, the size of the regeneration project is a foremost factor to consider. However, a study of twelve European cities by Gospodini (2005) suggests that, apart from the size of the investment, there are other influencing factors involved that regulate the scale of the effects of urban development, redevelopment and regeneration. These include the type of transport infrastructure project, the condition of the built environment in the greater corridor area, existing local market demands for the new proposed facilities and land use, and the local institutional framework available to undertake the project, along with the existing political milieu. In addition to these, Flyvbjerg, Bruzelius, and Rothengatter (2003), emphasised the importance of some conditions that embrace:

- whether serious capacity problems exist;
- whether a relocation of households and companies will be triggered by new capacity and significant transport savings; and

- whether there is a combination of various types of investment in both infrastructure and social capital, attracted by proactive development policies.

2.9.4.3 The interrelationships of jobs and retail outlets with urban regeneration

A successful urban regeneration project incorporates investors, developers and, more importantly, retailers with high-quality retail space in order to create a customer base. According to Davies and Ward (2002), the physical environment for retailing is multi-layered, and they identified two in particular. The 'upper level' consists of shopping centres, precincts or malls where people are attracted by the concentration of many choices within a single compound, and the 'lower level' is concerned with the specifics of the retail unit itself as being important in creating an appropriate space for retail consumption. In regeneration, the vibrancy of the shopping environment should be seen in the light of changes in retail hierarchies, whether it is a city centre regeneration or a mass transit corridor that bifurcates a low-density neighbourhood.

The concept of a link between retailing and local economic regeneration is, of course, not new. To describe this interrelationship from the perspective of the UK, Lowe (2005) mentioned "*since 1980s onwards, and prompted by the severe decline in the nation's manufacturing base in the recession of 1979–82 (Massey & Meegan, 1979), the role of services as alternative sources of employment and as catalysts for future economic development came increasingly into focus (Daniels, 2002). Many local authorities previously opposed to retail expansion and shifts in the retail structure of their local areas, began actively to promote such changes alongside strategies for economic regeneration centred on the development of a new and different image for their city (Kearns & Philo, 1993; Lowe, 1993; Paddison, 1993; Shields, 1991) ….. from the 1990s onwards, however, the links between retailing and urban regeneration became increasingly more prominent. Retail planning regulation was progressively tightened. Given this progressive regulatory tightening, a retail-led urban regeneration agenda came to dominate in the late 1990s".* The long-term trend towards a service-sector economy, along with a decline in the manufacturing sectors within the UK, led retailing to became a potential creator of jobs and economic vitality, not only nationally but primarily in local regeneration projects, especially in disadvantaged inner-city areas since they retain strategic advantages like location, untapped local market demand and nearby availability of human resources (Porter, 1995).

Table 2.4 Benefits of retail developments to urban regeneration, adapted from Mitchell and Kirkup (2003)

Personal	Community
▪ Employment	▪ Pride
▪ Income	▪ Identity
▪ Training	▪ Environment - quality of space
▪ Involvement	▪ Use of public art
▪ Safety	▪ Business contributions
▪ Health/diet	▪ Retail viability and vitality
▪ Choice of products	▪ Retail synergy
▪ Choice of services	
▪ Shopping services	
▪ Lower cost travel	

In recent times, issues associated with retail change, regeneration and exclusion have received increasing attention within the literature (Williams & Windebank, 2000; Williams & Hubbard, 2001). Mitchell and Kirkup (2003) made a few critical points about the contribution of retail businesses to urban regeneration. In response to tackling inequalities in access, choice, quality and price for some low-income consumers and consumers with impaired mobility within communities, retail developments can offer substantial support to urban regeneration (Wrigley, Warm, Margetts, & Whelan, 2002). The link between retail and regeneration is becoming recognised as one of the dominant mechanisms for renewal of deprived areas and communities (Walker, 2002). A strong retail sector offers support to regeneration by providing jobs, services, investment and a focal point for community activities (Moyes, 2002). Being a retail chain Tesco contributed significantly in urban regeneration with experience in building 12 significant new stores within deprived areas of the UK. Tesco claims to have created 1,245 new full- and part-time jobs in under three years (TESCO, 2002). Such retail projects provide the genesis for further regeneration with even broader commercial benefits that include entry-level jobs to fight unemployment, new social networks, safer streets, lower crime rates, better housing, a focal point for the community, and easier shopping access without a car. Additionally, a quality redevelopment can bring improvements to landscaping, which can contribute to an area being perceived differently.

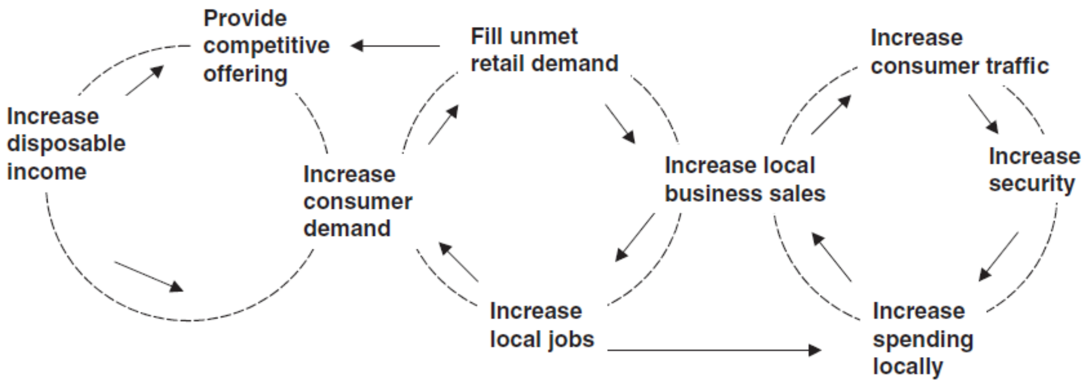


Figure 2.4 The virtuous cycle of consumer spending in areas of urban regeneration (adapted from BGC & ICIC, 1998)

Apart from the criticism that retail businesses do not offer high-paid jobs and result in the transfer of wealth outside of the community via non-local businesses, a survey by the Boston Consulting Group (BCG) and Initiative for the Competitive Inner City (ICIC) (1998) found that retail demand per inner city square mile is often 2–6 times more than each metro square mile in the United States, which remains unmet by the local retailers. Despite being low-paid, retail jobs provide an entry into the job market, an opportunity to learn basic work skills and access to training. In short, the study suggested (Figure 2.4) that "*Providing a competitive offering and filling unmet retail demand in the inner city creates a virtuous cycle that leads to increased disposable income, consumer demand, local jobs, business sales, consumer traffic, security and local spending*" (Boston Consulting Group (BCG) and Initiative for the Competitive Inner City (ICIC), 1998).

However, crime, insufficient demand and potential shrinkage are considered as factors that present the most significant obstacles for retail investment in the United States (International Council of Shopping Centers (ICSC) and Business for Social Responsibility, 2002).

2.9.4.4 Land Value Capture (LVC) and urban redevelopment

Land value capture (LVC) is defined as a public financing method by which governments –

(a) trigger an increase in land values via regulatory decisions (e.g., change in land use or FAR) and/or infrastructure investments (e.g., transit);

(b) institute a process to share this land value increment by capturing part or all of the change; and

(c) use LVC proceeds to finance infrastructure investments (e.g., investments in transit and TOD), any other improvements required to offset impacts related to the changes (e.g., densification), and/or implement public policies to promote equity (e.g., provision of affordable housing to alleviate shortages and offset potential gentrification).

There are two main categories of LVC: development-based LVC and tax- or fee-based LVC. Development-based LVC can be facilitated through direct transaction of properties whose values have been increased by public regulatory decisions or infrastructure investment. Tax- or fee-based LVC is facilitated through indirect methods, such as extracting surplus from property owners, through various tax or fee instruments (e.g., property taxes, betterment charges, special assessments, etc.).

As for example, Hong Kong SAR, China, is one of few global cities whose rail transit sustains the world's densest urban form productively. The 218-kilometer Mass Transit Railway (MTR) network consists of 10 railway lines with 84 stations serving Hong Kong Island, Kowloon, and the New Territories, with more than 4 million passenger trips a day. Due to the high ridership, MTR generated a net operating profit of HK$6.694 billion (US$869 million) from its transit operation and achieved farebox recovery of 185.5 percent for 2012. This financial success is thanks to the Rail Plus Property program implemented by the MTR Corporation.

In Tokyo, a 3,500-kilometer extended railway network with about 2,000 stations operated by 48 transit agencies serves the world's largest metropolis with 37 million inhabitants. Tokyo provides one of the best experiences in applying development-based LVC to finance railway investments with the revenues from real estate development (Suzuki, Murakami, Hong, & Tamayose, 2015).

2.9.4.5 Property and urban regeneration

Investors need to have confidence in the maturity of the property market regarding transparency of returns. Investing in property in areas of regeneration is evidently risky, and success is more meagre and fragmented, unlike the prime property market (Adair, Berry, Deddis, McGreal, & Hirst, 1998). Healey et al. (2002) drew attention to this interrelationship by defining urban regeneration as a concept that encapsulates the decline in inner-city economies along with the process of renewal to establish a basis for economic growth and social well-being, while Adair et al. (1998) added that it occurs when it has reached the stage that market forces alone will not suffice. However, property development and successful urban regeneration are not synonymous; rather there is only a tangible outcome in the form of real estate development when the private sector stimulates the property market along with the public sector, either in partnership or as mutual facilitators (Parkinson, 1999).

Land value uplift of the surroundings, and the land actually involved in the project itself, works as a source of energy for regeneration; otherwise, the process will not be self-sustaining. Regeneration initiatives that facilitate the property markets by raising land values are essential to the urban renewal process (Simons, 1998). The property market is comprised of users, investors and the development market, and that is why the characteristics and behaviours of the local economy are reflected in the movements of rent, demand and supply of accommodation. Yields are determined in the investment market and the macroeconomy, with changes reflecting investors' perceptions of rental growth and demand for property investment (Keogh, 1994).

Many studies (Chua, 1999; Graeme & James, 1996; Lee, Byrne, & French, 1996; MacGregor & Nanthakumaran, 1992; Souza, 2003) have mentioned key criteria in the investment decision-making process and determination of allocations across asset classes by investors who expect returns, a risk-free environment and diversification of benefits. Adair et al. (2003) summarise the factors influencing investment decisions for regeneration as follows:

- Apparently, the perceived total return is the primary factor influencing investment decisions in regeneration locations, with the expectation of achieving above-average returns, while the principal barriers to investment in regeneration are perceptions of negative returns. However, target rates of return are different for each investor and risk premiums differ across projects (Adair et al., 1998).
- Rental growth, arising from occupier demand and capital appreciation reflecting investor demand, is the principal factor by which new regeneration projects are evaluated (Adair et al., 1998).
- Geographic location appears to have a stronger influence on investment flows than economic performance (Callender & Key, 1996).
- Unlike the prime property market, lack of data and information about regeneration areas creates added conditions of uncertainty, perpetuating

misconceptions regarding the risk-return profile of regeneration areas. This may be sufficient to discourage major institutional investors.

Analysing the developed total returns index of property investments over 20 years (1980 to 2001) within eight major UK urban areas of regeneration, Adair et al. (2003) suggested that urban regeneration properties can meet national and local benchmarks in long-term performance and that perceptions of weak performance have developed from a lack of information. Institutional investors and policy-makers can change their strategies to overcome the information gap and attract private investment for urban regeneration.

The 'urban fabric' (or urban structure) of a city is formed through the city's transportation infrastructure and, more specifically, through the mode of travel to work. The study of Sheffield, in the UK, by Lawless and Gore (1999) identified infrastructure as a key element in improving a city's image. Gospodini (2005), in her study on the encouraging effects of transport infrastructure in 12 European cities, noted that transport infrastructure projects, such as metro systems, regional rail, trams and trolley-buses, have an impact on the development, redevelopment and regeneration processes of urban areas, which are summarised below:

- They may support the creation of peripheral new centres and possess the capability to transform existing urban and suburban cores into high-quality residential areas, as in case of Stuttgart, as well as the cases of Herrenberg, Stuttgart and Kingston, and Park, Tyne and Wear.
- They may support new housing developments with quality characteristics, as in the case of Zurich-Wetzikon, and attract desirable economic activities (new services and industries) to residential areas, as in the case of Schwarzenbach, Zurich.
- They may promote urban reconstruction to enhance the quality of space in declining and segregated areas, as in the case of Valencia, and in deteriorated central areas with old buildings, as in Brussels.
- They may work as a catalyst to accelerate and reinforce existing trends in urban reconstruction and renewal, as in the cases of Omonia, Athens and Inner Stadt, Vienna.

According to Batty (2012), regeneration is part of the process of enabling the city's various networks to keep functioning, and in parallel with this thought, declining areas that might be considered problematic are the key to the processes of natural regeneration. If we interfere with them, without understanding all the possible ramifications, such planned regeneration can be disastrous, leading to exactly the opposite effects than those intended. The key is to find the right mix of activities, and to plant seeds that lead to the regeneration attracting related activities because of their obvious synergy. Therefore, local contextual factors should be considered carefully before selecting any mass transit corridor or deciding on the appropriateness of a particular transport mode. The next sub-section discusses the contextual factors that aid property and land value appreciation, and their relationship with the physical developments and jobs that are outcomes of regeneration activity, and which influence the market conditions.

2.10 Contextual factors and value appreciation

It can be said that enhanced accessibility brought about by new transport infrastructure may attract new development, appreciate land values, encourage densification, bring changes in land use, raise rents, and more (Brown & Whelan, 1991). However, in practice, it is far more complicated than coming to a simple conclusion, especially when it comes to the question of setting up a public transit option (Cervero, 1984; Davoudi et al., 1993; GRIECO, 1988). This sub-section articulates the findings of a range of cases, worldwide, to provide a discussion of the influential contextual factors that encourage the establishment of a mass transit corridor. There are a variety of factors that can be grouped into four major types. Housing factors include types and sizes of land parcels, internal space articulation, and the age and density of properties, while factors relating to location deal with the distances of necessary amenities from the redevelopment site. Both of those contextual factors control the morphology of physical development to facilitate regeneration by acting through the property market. Transport and economic factors control the distribution of businesses (goods and services) and their employees, with any new transit facilities resulting in improved means of journeying to work, proximity to stations, reduction in car ownership and, more importantly, realisation of redevelopment potential in the surroundings.

2.10.1 Housing factors

Dziauddin, Powe, and Alvanides (2015) used the Geographically Weighted Regression (GWR) technique to estimate the increased value of land (in the form of residential property) due to improved accessibility instigated by the construction of LRT systems, in Kuala Lumpur, Malaysia. In their research, they reveal that, along with added premiums on residential property value as a positive effect, there are also some adverse effects of varying magnitudes. Reviewing a number of other examples, it can be found that proximity to rail stations has induced a premium of up to 25% (Debrezion, Pels, & Rietveld, 2007), while Chen, Rufolo, and Dueker (1998) experienced the opposite due to the nuisance effects of noise, safety issues, aesthetics and additional traffic.

It is not easy to state the capitalised value of a rail transit system. Bowes and Ihlanfeldt (2001) identified some of the influential factors as being access to alternative transportation by commuters, distance between residential properties and rail transit stations, positive effects such as improved commercial services, nuisance effects such as insufficiency of parking spaces causing parking congestion within adjacent neighbourhoods, and the generation of crimes adjacent to stations. Similarly, Billings (2011) argued that price gradients alone are not capable of quantifying the impacts of rail transit, particularly regarding accessibility. Neighbourhood property values coupled with price gradients result in a more acceptable way to estimate the accessibility impacts of rail transit. In his experiment, it became evident that positive impacts (such as 10% higher appreciation rates in repeat sales) are greater in condominium properties compared to single house residential properties when closer to rail transit stations. He explained that, as condominiums represent a higher proportion of single households and non-family households, safety and parking are less costly to them, which helps to decrease travel costs that in turn supports the price appreciation of the condominiums.

Debrezion, Pels, and Rietveld (2007) identified variable factors regarding the impact of a railway station on property values. Railway stations, with different levels of service, frequency, connectivity and service coverage, impact differently upon their surroundings. This differential value continues in regard to property types, e.g., residential or commercial. Considering the range of affected areas, residential properties are most affected according to their large number mostly while commercial property impacted by railway stations only to its adjacent vicinity. However, the individual impact is greater on commercial properties than residential properties when they are situated within a short distance of a station (Cervero & Duncan, 2002a; Weinstein & Clower, 1999). Moreover, proximity to a railway station was found to add higher value to low-income residential neighbourhoods than to high-income residential neighbourhoods (Bowes & Ihlanfeldt, 2001; Nelson & McCleskey, 1989) because low-income residents rely more on public transport so are willing to spend more to live close to the stations. Additionally, Nelson (1998), Bowes and Ihlanfeldt (2001) added more on this to support the argument that the impact of railway station on property value depends on demographic factors. Income and social (racial) divisions are common. Proximity to a railway station is of higher value to low-income residential neighbourhoods than to high-income residential neighbourhoods. The reason is that low-income residents tend to rely on public transit and thus attach higher value to living close to the station. Because of the fact that reaching the railway station mostly depends on slow modes (waking and bicycle) the immediate locations are expected to have higher effects than locations further away.

2.10.2 Locational factors

There is a consensus among some researchers that the effects of a rail transit system vary among neighbourhood types, differentiated by income and social divisions. According to Nelson (1992) and Redman, Friman, Gärling, and Hartig (2013), property values gained positive momentum in low-income neighbourhoods in Atlanta, while Gatzlaff and Smith (1993) found the opposite in Miami, where only high-income areas experienced the increases. The reason for such inconsistencies lies in the local and locational factors. Dziauddin, Powe, and Alvanides (2015) surveyed Greater Kuala Lumpur and found that for every metre away from the nearest LRT station property prices in Petaling Jaya reduced by up to USD14.652. That was because Petaling Jaya used to suffer from severe traffic congestion and inefficient public transport but the introduction of the Kelana Jaya line significantly improved travel time between Petaling Jaya and Kuala Lumpur by locating its stations strategically at major financial and commercial centres and densely populated areas of Greater Kuala Lumpur. Conversely, in the Wangsa Maju area, the selling price of properties increased in value by up to USD19.158 for every metre away from the nearest LRT station. The locational and local factors that decreased residential property values close to the stations included traffic congestion problems around the stations that were aggravated by a lack of 'park and ride' facilities causing commuters to leave their vehicles, inappropriately, in the nearby local neighbourhood. The authors identified several areas such as Wangsa Maju that were located within 5 km of the CBD and were already well connected through good main roads and served by efficient bus services, to which the introduction of the LRT system added little value.

Similarly, the physical existence of infrastructure and its accessibility can directly influence land and property values. Kilpatrick, Throupe, Carruthers, and Krause (2007) revealed that proximity to the mass transit corridor alone, without any direct access, delivers negative impacts on housing values nearby. Rosy estimates were modelled on the basis of 668 sales of single-family houses for a period of 15 years (1990-2005) in the Mount Baker neighbourhood of Seattle, but they found a negative impact of the nearby interstate 90 tunnel, when compared to identical homes located at different distances, because the public transit corridor was buried in the tunnel with no easy on-ramp access for local positive public benefit.

According to Song, Cao, Han, and Hickman (2019) public transport infrastructure is essential to city development, improving accessibility and allowing people to engage in activities, allowing travel by environmentally friendly modes, and also creating economic benefits. The study investigates the impacts of public transport accessibility on development, examining changes in housing prices, and applying hedonic modelling. London's Docklands Light Railway (DLR) is selected as a case study and found that residential properties in station catchment areas of the south-eastern and northern branches of the DLR have a premium respectively of 0.352% and 0.093% per 100m proximity to a station. They concluded, by assessing inclusive variables, it is found that housing value is also determined by the property's own features and the neighbourhood, particularly the property tenure. The detected housing value uplift implies that the provision of good public transport is crucial in policy making, especially in areas with poor public transport accessibility.

There is a scarcity of literature that focuses directly on the 'park and ride' (PNR) facility compared to other transit-related topics, and most of them are in Europe and the USA (Duncan & Christensen, 2013). Furthermore, none of them puts forward direct empirical evidence on the decision-making process that led to the provision of PNR facilities, although there is a growing body of literature to characterise the optimal location for PNR facilities (Farhan & Murray, 2005, 2008; Horner & Groves, 2007; Wang, Yang, & Lindsey, 2004). Usually, PNR facilitates mass transit as a feasible travel option for people who do not live in the immediate vicinity of a station and adds significant value to the car-based cities (Rye & Stephen, 2008; Transit Cooperative Research Program, 2004), functioning as an attractive agent to the riders of rail (Duncan, 2010; Kuby, Barranda, & Upchurch, 2004). Duncan and Christensen (2013) investigated light rail stations based on some vital factors. The investigation included the characteristics of immediate surroundings, regionally essential features (e.g., the CBD), characteristics of municipalities in which the stations were located, and characteristics of the rail system and transit agencies that operated the relevant rail system in several US cities. They came to the conclusion that PNR tends to be built in less urbanised places with cheaper land and lower densities. Especially, transit agencies prefer to set up PNR facilities at terminal stations because they cover a geographically larger catchment area and they are less likely to be in non-residential areas like airports, universities and the CBD. If the government places less emphasis on long-term strategic goals in planning to support mass transit-oriented developments, then the municipal environments that are more politicised become more reluctant to invite PNR in their stations.

2.10.3 Transport factors

Pledging a favourable and competitive mode of transport for its users proves to be a challenging matter to deliver. This goal is never achieved unless the right mode is provided at the right places, considering all possible locational and contextual choices. Bollinger, Ihlanfeldt, and Bowes (1998) argued that office rents were reduced within a quarter of a mile of railway stations in Atlanta, USA, due to concerns about lack of safety, but part of their study also explored the positive relationship between accessibility to the highway and office rents. Similarly, if a newly introduced rail transit system is limited in its ability to provide accessibility to the majority of commuters' required destinations, there is a risk of having little or no impact at all on the scenario. Du and Mulley (2007) demonstrated that the Tyne and Wear railway stations (Newcastle, England) had negative impacts on dwelling values by around 40% due to their failure to provide a favourable transport mode for users, in that the car was a much more useful option to reach the CBD.

Several recent studies investigating influences on property values (Cervero & Duncan, 2002b; Diaz & Mclean, 1999; Smith, Gihring, & Litman, 2009; Smith & Gihring, 2006) have been carried out, with some examples where they found heavy rail to be producing more significant effects than light rail due to its faster speed, greater frequency and wider geographical coverage. Whereas commuter rail, known as suburban rail, added even higher value than heavy rail, generating greater premiums for the properties located near to the stations when they were at the centre, or at least within walking distance, of a commercial core. (See for example, Armstrong Jr, 1994; Cervero & Duncan, 2002a; Mohammad, Graham, Melo, & Anderson, 2013).

Apart from accessibility, permanent and fixed structures also play a part, as Hess and Almeida (2007) pointed out, because a lack of such features reduces the uplift in property values to only the modest level accorded by their proximity to bus routes and stations. Mohammad et al. (2013) conducted an investigation that contributed to the research of Debrezion, Pels, and Rietveld (2007) by exploring a large dataset made up of 102 observations obtained from 23 European and Asian studies over the period between 1980 and 2007. The results indicated that the investments in rail had created variable impacts in changing the values of land or property across both continents. There were many factors to consider, including the type of land use, type of rail service, life cycle maturity of the rail system, distance to stations, geographical location and accessibility to roads. Even data specification and methodological characteristics can be responsible for such significant variations.

The impacts of any introduced rail transit system on property and land values are not constant. They change over time due to the emergence of new policies that, for example, increase transportation costs of another available mode of transportation. The cost of transportation eventually leads to changes in land and property values, which implies that the maturity of any transit option can create a variable impact over time. An example is the Metropolitan Atlanta Rapid Transit rail system in the USA, which was reported to produce little impact in a 1989 study by Nelson and McClesky soon after it had started its operation in 1979. However, a study of the same example by Bowes and Ihlanfeldt (2001) found both positive and negative impacts, then a later study by Mohammad et al. (2013) added more to this argument, reporting the degree of impact being related to the maturity of the rail system. They stated that, on average, the appraised benefit of any rail transit system is always higher compared to its actual benefit after the system has stabilised, and that values differ after the announcement, during construction and immediately after opening. It is also important that the radius of impact and pattern of increase or decrease in value is not linear (Al-Mosaind, 2001).

According to the RICS Policy Unit (2002), the extent of influence may extend up to 1,000 m for residential areas and 400 m for commercial areas but, in rare cases, it can rise to 2,000 m and 1,200 m for each zone, respectively.

Wagner, Komarek, and Martin (2017) added value to the available literature, estimating the effect of the Norfolk Tide light rail on three residential real estate market outcomes: the real sale price, sale-list price spread, and time-on-market. Their identification strategy exploits a proposed, but not constructed rail line in neighboring Virginia Beach, Virginia as the control group. The estimates show that the Tide light rail system had a negative effect on homes within 1,500 meters of constructed stations and on an average, the sale price declined in actual light rail neighborhoods relative to the control group by 7.8% following the start of the construction phase and including the operational phase. Thus, using the preferred hedonic pricing estimate, the aggregate decline in housing values due to the light rail was approximately $75 million, which is more than 20% of the original construction costs. Furthermore, homes within 1500 meters of a station sold for approximately 2% less than the original listing price compared to homes in the control group.

2.10.4 Economic factors

Historically, research investigating the factors associated with transport infrastructure like a modern rail system, whether heavy or light rail, has established that it improves connectivity between residences and workplaces, presumably in the Central Business District (CBD) where employment and economic activity is concentrated. Based on the classical urban land economic theories proposed by Alonso (1964), both Muth (1969) and Mills (1972) pointed out that the cost of transport is an influential determinate of land value because decreasing transport costs lead to positive impacts. Traditionally, it has been argued that any proliferation in transportation systems can be assessed regarding increased accessibility and reduced transportation costs of travel to the CBD, and this is reflected in property values.

There are a considerable number of research studies that have attempted to identify the reasons for variations in land and property values due to certain characteristics of the properties, neighbourhoods and accessibility. Access to transport services such as stations and highways is perceived to add benefits to its users, commuters and surrounding residents because an attraction zone is formed that eventually enhances land or property prices of the surroundings. It is quite evident that, due to the availability of data sources for analysis, the impacts of rail on housing properties has been investigated more than other types of land use (Diaz & Mclean, 1999; Duncan, 2008). Summarising an ample number of studies, Mohammad et al. (2013) revealed that rental values of commercial properties experience greater increases than residential properties. Additionally, they found that land value increases were higher than property value increases due to investment in rail. Though there are likely to be many differences, the favourable changes in land and property values due to proximity to stations were greater in East Asian and European cities than in North American cities. An acceptable reason may be that Europe and East Asia are, predominantly, less dependent on cars than North America. Though no particular pattern has been found, the literature establishes that congested zones experience greater value increases by adding more value via mass transit options (Clower & Weinstein, 2002). However, a small number of studies have found that location within walking distance to stations or rail lines acts negatively on property and land values where it was noted that noise, pollution and an increase in the level of crime acted as negative catalysts (e.g. Bollinger, Ihlanfeldt, & Bowes, 1998; Chi-Man Hui, Sze-Mun Ho, & Kim-Hin Ho, 2004; Diaz & Mclean, 1999; NEORail, 2001). Additionally, the location of land or property within a CBD is not affected much by a rail transit system, and land value changes tend to be higher than property value changes.

There is not enough empirical evidence in the literature to decide how much influence a rail transit project can exert in the planning process of a development. Knaap, Hopkins, and Donaghy (1997), in an article, presented a formal model to measure the influence of plans over the process of urban development where they observed that the initiation of a light rail transit project created impacts on community development that resulted in appreciating land values. They also observed that such capitalisation exerted pressure to develop high-density projects because the high appreciation in land value discouraged low-density developments. Additionally, dense development controls the necessity to develop on the urban fringes and ensures increased ridership and transit revenues for the future as well.

Though rental rates are far more elastic and responsive than sale prices in relation to the market conditions, surprisingly, there is not much empirical evidence on how accessibility to transit stations is capitalised in rental rates. One reason may be that, in most cases, researchers were dealing with small data sets that covered only a short period of time, for specific cases in a small geographic area. Weinberger (2001) examined information from over 4,600 lease transactions over a 16 year period (1984-2000) in Santa Clara County, California, and found similar results over residential and commercial properties. The results indicated that the properties within half a mile of a light rail station experienced higher lease rates than other properties in the county, using length and type of lease, building improvements, regional and local economic cycles and location as controlling factors. It seems apparent that commercial properties appreciated in value more than residential properties, outweighing any nuisance effects like noise, pollution, traffic and intrusion.

Different views can be found on the effects of over-population and employment around station areas. Bollinger and Ihlanfeldt (1997) found no significant impacts on either population or employment in station areas for the heavy rail of Atlanta provided by the Metropolitan Atlanta Rapid Transit Authority, but they admit it has changed the composition of employment in favour of public-sector jobs. Conversely, the opposite scenario was observed in Washington DC's Metro heavy rail service areas. They experienced significant differences in employment levels between the station and non-station areas (Green & James, 1993). Supporting both the arguments, Pan (2013) examined the Houston MetroRail Transit Line in Texas and discovered that neighbourhood and locational factors, such as population density, have significant impacts on property values. He found that job density and job accessibility have diverse effects on property values. It was evident that there were positive effects of job density in construction, retail and other services, but significant adverse effects in the information sector.

2.11 Multiple-Criteria Evaluation tool selection processes

Planning practitioners have been using numerous methods and tools over many years to support their various activities in different contexts, with the argument that they never fully grasp the necessity and embrace the diversity of methods, techniques and models developed in the laboratory to analyse spatial problems, to evaluate alternative options or to project future scenarios. The inadequacies of most geo-information tools that have been documented by a number of scholars (Bishop, 1998; Couclelis, 1989; Geertman, 1999; Klosterman, 1994; Nedović-Budić, 1998; Ottens, 1990; Scholten & Stillwell, 1990; Worrall, 1994) include their unresponsiveness to the needs of the planning profession, complexity, non-specificity, incompatibility with real-life planning tasks, inflexibility and strict rationality. This continuing mismatch between the demands of practitioners and the supply of methods and techniques has created a new generation of redeveloped tools, materialised under a generic term: Planning Support System (PSS). It consists of a wide diversity of geo-information tools that are dedicated to supporting both public and private planning processes (or parts thereof) at any particular spatial scale and within a specific planning context (Geertman & Stillwell, 2003). In any context, urban growth and infill is often very emotional for people and creates anxiety about the future, but a PSS has the capability to help planners to navigate the growing complexities of planning (Vonk, Geertman, & Schot, 2005). Newman (2016) suggests that the use of a PSS in each new development can ease this anxiety, and multiple benefits can be fashioned from the planned changes. More precisely, Harris and Batty (1993) depicted the concept of a PSS as a combination of a range of computer-based methods and models in an integrated system that supports particular planning functions. A single PSS forms a framework that combines:

- identification of the planning challenge;
- a methodology to guide planning through 'analysis, prediction and prescription'; and
- the application of data to inform modelling and design.

In their opinion, a single PSS forms the framework in which three sets of components are combined: the specification of the planning tasks and problems at hand, including the assembly of data; the system models and methods that inform the planning process through analysis, prediction and prescription; and the transformation of basic data into information that, in turn, provides the driving force for modelling and design (through a cyclic process) (Geertman, Allan, Pettit, & Stillwell, 2017).

Academics are the primary agents for research and development of PSSs and bring them into the planning arena, while private sector and government involvement remains relatively low, with limited commercial off-the-shelf (COTS) software available for use. However, some PSSs, such as 'What If?' (Pettit et al., 2013), UrbanSim (Waddell, 2002) and UrbanFootprint (Schmiedcke, 2016), have been growing in use and some have academic prototypes. There are some PSS tools in the market, however, within the scope of this research, and those that have applicability to the research objectives will be discussed.

Since 1990, 'What if?' has evolved from a desktop application to an updated and re-engineered online application, making it accessible to a broader community within the last twenty years (Geertman et al., 2017). This is an open source GIS-based PSS that is capable of conducting land suitability analyses, projecting future land use demand and allocating the projected demand to suitable locations, based on a range of planning criteria, through three different modules.

I. Land suitability module: Spatial data layers that create opportunity and constraint layers
II. Land demand module: Demographic, housing and employment project information

III. Land use allocation module: Existing zoning, transport and other infrastructure plans.

What if? has been used to assist planning in cities and regions across Australia. In Melbourne, Victoria, (Pettit, Keysers, Bishop, & Klosterman, 2008) and Hervey Bay, Queensland, (Pettit, 2005) it has been utilised to understand land use supply and demand, and likely future land use scenarios. In Perth, Western Australia, 'What If?' was used as a tool to 'test' scenarios, specifically to balance seemingly competing goals within Perth's strategic plan, Directions 2031[9]: ecosystem protection and economic growth focusing on the generation of two scenarios for the Metro North West region – an employment-generating scenario and an environmental conservation scenario (Pettit et al., 2015).

UrbanSim is a simulation platform for supporting planning and analysis of urban developments, incorporating the interactions between land use, transportation, the economy and the environment. It was developed after a 1995 conference hosted by the Travel Model Improvement Project (TMIP) to address the limitations of land-use modelling (Waddell, 2002). According to UrbanSim Inc (2017), prebuilt models at census block detail for the United States have already been released, and models at zone or parcel level will shortly be released for other parts of the world. UrbanSim has been applied in the context of Australia, specifically in South-East Queensland (Biermann, Pettit, & Brits, 2015).

UrbanFootprint is a modelling framework for data development and organisation, as well as land-use planning, modelling and analysis. UrbanFootprint, designed by Calthorpe Associates in Berkeley, California, has been widely used in North America; for instance, it has recently been used to assist Madison, Wisconsin, in guiding its 10-year land use, infrastructure and finance strategies (Pettit et al., 2017; Schmiedcke, 2016).

According to CitiLabs (2017), the Cube suites provide six modules that seemingly work together to answer specific 'what if' type questions regarding changes to the

[9] Directions 2031 is the most recent, high-level, spatial framework and strategic plan to outline a vision for metropolitan Perth (the Perth and Peel region) that guides the strategic direction of major planning elements including housing, infrastructure and services. Its goals emphasise long-term affordable housing provision, ecosystem protection and economic growth, planned alongside a sustainable transport network (WA Government, 2010).

transportation networks, land use and population. It can assist to evaluate public transit alternatives, road pricing strategies, land use developments, freight terminal locations, updated signal plans and alternative geometric designs, for example. Each module carries distinctive capabilities that are listed below.

- Cube Voyager: builds macroscopic regional models to understand large scale personal travel demands.
- Cube Avenue: offers mesoscopic simulation solutions to model the dynamics of congestion throughout a day.
- Cube Dynamism: is a microscopic traffic simulation solution model for all aspects of traffic operations and parking.
- Cube Land: provides economic land-use forecasting software that can be used in conjunction with a transport demand model to look at the interaction of real estate markets and transport systems.
- Cube Cargo: models freight movement throughout a city or region to understand the impacts of commodity flows.
- Cube Analyst: directly estimates trip matrices from available roadway and public transport counts and other survey data.

The Australian Urban Research Infrastructure Network (AURIN) is a federally-funded e-infrastructure initiative *"to establish an infrastructure network to support the urban research, policy and decision-making community"* (Pettit, Glackin, & Trubka, 2014) that has been tasked with providing a unified space for built environment research. This platform provides a centralised location for access to data from different agencies, as well as access to a range of PSSs (Sinnott et al., 2015). Instead of creating future city plans, the AURIN workbench helps to analyse and benchmark current urban performance with the help of 1,800 datasets from more than 30 providers (Pettit et al., 2017). Sydney's state government released "A Plan for Growing Sydney" (Government of NSW, 2014) to guide land use and planning decisions for an increasing population over the next 20 years with an implementation challenge of the growing housing affordability crisis. The AURIN portal was used to produce data-driven evidence to inform professionals with information like locations of the hotspots for housing affordability within the city, the relationship between rent increases and income-to-rent ratios, the typology of affordable housing properties, etc.

Table 2.5 A comparison of PSS uses and features, modified from Pettit et al. (2017)

Digital Planning Tool	Scale of Analysis/Predominant Use/City analysed	Open source?	Visual Capabilities	Challenge addressed
AURIN Portal	Regional/ Supports research and policy with a platform for a precinct-level PSS and federal datasets/Sydney, NSW	Partial	2D maps, brushing	Understanding regional affordability issues at a fine-grain scale
What if?	Metropolitan/ Municipal and city level to test growth scenarios/Perth, WA	Yes	2D maps	Scenario-testing to evaluate land-use supply vs. ecology
Envision	Precinct/ Precinct and subdivision level to identify areas for infill/Melbourne, Victoria	No	2D maps	Identifying areas for infill in middle suburbs
CommunityViz®	Subdivision/ City, precinct and subdivision level to develop preferred growth scenarios/Brisbane, QLD	No	2D maps, 3D maps, brushing	Reviewing impact analyses with community organisations to assess development scenarios

The tool 'Envision' is similar in some respects to What if? because it uses a multiple-criteria evaluation (MCE) approach to determine suitable land for urban growth. Envision and the related Envision Scenario Planner (ESP) were developed as research-driven PSS tools through the Co-operative Research Centre for Spatial Information (CRCSI). Its primary focus is to determine where a developer might be targeting future land acquisition through the calculation of a residential potentiality index. It has been designed to assist government regarding smart subdivision solutions over conventional sub-optimal piecemeal development and to predict precinct-level redevelopment opportunities by identifying greyfield sites for redevelopment (Pettit, Glackin, & Trubka, 2014). Currently, it has road and limited transport data, with the capacity to add new transport and land use layers. Outputs are limited to finding precincts close to specific forms of transport, and analyses are completed only in 2D (Newton et al., 2012). ESP is being supported by Envision to identify potential sites for development. It allows users to understand the impacts of a redevelopment solution, considering small-scale design features such as setback, materials used in construction, etc. It assesses redevelopment scenarios with 3D analyses and performance assessments (Trubka, Glackin, Lade, & Pettit, 2015). “Plan Melbourne 2017-2050” was released to guide Melbourne’s population growth, estimated to swell from 4.5 million to 8 million in 2050. Newton et al. (2012) identified the under-utilisation of Melbourne's middle suburbs, areas that are10–30 km from the CBD, where Envision was used to assist planning efforts in one of the middle suburbs, the City of Manningham. The research revealed zones to consider for redevelopment, and new locations not previously identified in planning documents.

CommunityViz®, a commercial off-the-shelf (COTS) software program (Klosterman, 2005), is one of the earliest PSSs developed and compares scenarios against user-defined benchmarks (Trubka et al., 2015). The latest version of CommunityViz® is an extension of Esri's ArcGIS platform, consisting of two components: Scenario 360 for analysis and communication, and Scenario 3D for 3D visualisation. The tool has been applied at the subdivision, precinct and city levels. CommunityViz® has been used in some North American communities in scenario planning and to develop preferred growth scenarios (Placeways, 2016). In Brisbane, Australia, CommunityViz® was used (Pettit et al., 2015) to develop a scenario-based impact analysis of the structure plan proposed by local government authorities that operate in Queensland to uphold objectives regarding the preservation and enhancement of ecological sustainability being enforced by the Planning Act 2016 (Queensland Government, 2016). The structure plan was not well-documented (a 2D map with proposed building heights and land use) to inform community members about the assessed impacts of the proposed density changes, which eventually raised concerns. The tool facilitated dialogues between the community and local government around issues regarding a proposal for high-rise mixed-use buildings to be placed in a historically low-density area.

The spreadsheet-driven tool, Land Use and Transport Integration (LUTI) model, was developed by Cole Hendrigan during his doctoral research under the supervision of Professor Peter Newman. It can calculate real estate yields by investigating the correlation between the ridership generated by a proposed density volume (through attuned floor area ratio) of the area to be redeveloped and suggesting a density for the proposed transport provision. The model is far more complex than the capacity in which it is used for this particular research. The basis of this method was adopted from the “Guide to Traffic Generating Development” (Roads and Traffic Authority NSW, 2002, 2013) that was developed by the Road Transport Authority (RTA) of New South Wales.

It provides guidance on some matters related to the traffic impacts of land use developments, most notably on matters relating to traffic generation and parking. Its audience extends beyond that of traffic authorities (Roads and Maritime Services and Councils) and is widely used throughout Australia.

Based on the different modes of transport, real estate yields deal with the capacity of a public transport mode to convey passengers (per hour) and the associated reduction in parking that frees up surface area and capital to accommodate real estate. Each mode of transport employed has different potential to reduce the space to be reserved for roads and parking spaces for cars. Such action adds corresponding opportunities to build denser mixed-use walkable communities (Hendrigan, 2015).

According to Vonk, Geertman, and Schot (2005), there are 34 available PSSs and research is required to expand the territory of their real-world applications. The Spatial Decision Support (SDS) Knowledge Portal is continuously helping the literature to grow and case studies are guiding PSS use (Spatial Decision Support Consortium, 2017). Trubka et al. (2015) identified some modelling and visualisation PSS tools that include Urban Canvas, CityEngine, Precincts, Envision Tomorrow, NASA World Wind and Google Earth. Papa, Silva, Te Brömmelstroet, and Hull (2016) reviewed the widespread availability of Accessibility Instruments (AIs), which investigate the integration of land use and transport through a lens of accessibility, listing 21 different tools developed in Europe and Australia.

This study preferred to use the GIS-based PSS, Envision, which is a multi-criteria evaluation software program that has been built to address the specific problems of middle suburbs but can be applied in all Australian cities for various reasons with a successful outcome. It is equipped with a contextual dataset to explore the potentiality of land parcels, which in this research has been used to identify potential sites around proposed mass transit corridors. It also offered software attributes that are well matched with the factors identified through the literature study. Like What If? and CommunityViz®, Envision follows a co-design approach, which is an iterative design process that adapts and edits the tool's software, based on feedback from the users. The development team held workshops to increase its transparency with stakeholders and to identify the 'key variables' to be tested. Both the inputs and outputs of each PSS were modified based on workshop feedback, which eventually made the tool more contextual and responsive to the bottom-up approach of decision-making. The spreadsheet-driven tool, LUTI, was selected because it is simple and easy to use, within the context of this research, to determine an appropriate transport mode regarding trips generation by the anticipated population densities of different land uses.

2.12 Overview of the persistent worldwide problems and Perth as a study area

The world of contemporary urban development is torn between two paradigms: Post-war suburbanisation and ex-urbanisation. Both are facilitated by increasing automobile use and expanded highway systems backed by planning policies on the one hand and, on the other, a surge of interest in sustainable urban growth, featuring concepts such as smart growth, new urbanism, growth management, affordable housing, infill and transit-oriented development, and urban growth boundaries. Suburbanisation continues to be the dominant paradigm, as measured by increasing urban land cover, vehicle miles travelled and new edge-of-city developments on the urban fringes (Goetz, 2013). This sub-section discusses a worldwide perspective of the problem that persists in low-density middle suburbs that were developed in the 1950s and how present cities are tackling such decline by making smart choices in transportation.

A development cycle is defined as a time period for a specific spatial unit that covers its emergence and decline in development. A cycle is based upon the fact that a system, once in place, works according to the relative stability of its parameters and their dynamics in time and space (Rodrigue, Comtois, & Slack, 1997). In advanced countries, the level of urbanisation stopped increasing between 1965 and 1990 since suburbanisation had taken over due to many factors, with car dependency being the most influential one of them. This phenomenon is now acknowledged to indicate a process of population redistribution at the regional scale. Klaassen, Molle, and Paelinck (1981) introduced the Theory of Spatial Cycle (SCT), to explain the different stages of urban development from a regional-wide perspective. According to Rontos, Mavroudis, and Salvati (2011), in SCT, the development of an urban region may be described using four phases:

I. the urbanisation phase, when certain settlements grow at the cost of their surrounding countryside;
II. the suburbanisation (or ex-urbanisation) phase, when the urban ring (commuter belt) grows at the cost of the urban core;
III. the dis-urbanisation (or counter-urbanisation) phase, when the population loss in the urban core exceeds the population gain in the ring, resulting in overall population decline; and

IV. the re-urbanisation phase, when the core city starts re-attracting population while the suburbs still experience a demographic decline.

The theory exemplifies the changes in direction and rate of population movement between core and ring, where the urbanisation stage represents the intense outward movement of population and economic activities to rural areas. Middle- to high-income households are self-selected for outward movement due to better environmental qualities, continued deconcentration of employment opportunities out into the suburbs, new transport technology and policies favouring decentralisation of population, which represents the suburbanisation (or ex-urbanisation) phase. With the re-establishment of companies and the over-concentration of the population into the suburbs, the previous stage is completed, and then the dis-urbanisation stage begins. Population growth, changes in household structure, income growth and the higher demand for housing resulting from it, increase the demand for settlement areas progressively further away from the core cities. The last phase, re-urbanisation, re-attracts people and economic activities inwards, towards the core of the cities for the promotion of new life-style patterns, the increased financial and institutional power of a metropolis, and the infrastructural developments.

The sign of a population reversal in rural areas was first identified in the United States, while a similar trend was soon detected in other advanced nations that included Canada, Australia, Western Europe and Britain. This suburbanisation commenced in the United Kingdom from the early 1960s when areas further away from urban influences started to grow faster than the main conurbation and their dependent regions, with net outward migration averaging 90,000 people per year (Pacione, 2005). The transport system, more specifically ownership of private vehicles, triggered this process to spread faster. Transport can be described as both the 'maker and breaker' of cities (Clark, 1958; Herbert, 2002). Decentralisation of people and capital, facilitated by the rise of a more flexible transport system and private cars, initiated the decline of inner and middle suburbs of cities. In the mid-twentieth century, the dominant flows were towards the periphery of city centres in the UK. From early 1960, this process began to facilitate the areas that were situated at a greater distance from metropolitan influence, at a much faster rate when compared to the main conurbation and their dependent regions. This process of counter-urbanisation continued to occur in subsequent decades and accompanied shifts in population and economic activity from north and west of the UK, which were increasingly affected by the de-industrialisation process and deterioration of inner suburbs that needed to undergo regeneration (Pacione, 2005).

Similarly, in the United States, the model of low-density suburban sprawl became the dominant paradigm for urban growth, throughout the private vehicle-dependent post-war era. Since then, growth has been concentrated in dense urban areas and suburbia's far-flung peripheries. Population growth occurred in the furthest reaches of suburbs because it was far less expensive to build on the wide-open, undeveloped land in outlying areas than anywhere else. Being no different from the rest of the car-dependent cities of the world, after decades of development, suburbia in the USA has evolved into a new reality where continued growth and the prosperity of the fringes clashes with the poverty and decline of the inner suburbs. As dense urban places attracted people and jobs because of their convenience and improved productivity, growth bypassed the older suburban areas that lie between the two poles of an urban centre and outlying new developments. The middle suburbs hollowed out and were squeezed economically, resulting in physical deterioration and population loss (Florida, 2017). The inner suburbs of the USA currently represent 20% of the population, whereas in the 1950s they represented 40%. They have since gained population but not at a faster rate than central cities and outer suburbs. Shrinkage in these locales is mainly related to poverty, coupled with dilapidated built spaces and, in some instance, abandonment.

The emergence of academic and policy-making interest in the phenomenon of the declining inner and middle suburbs in the USA has led to the discovery of parallel processes in the larger Australian cities (Randolph, 2002). Australia is a nation of suburbs (Davison G, Dingle T, & O'Hanlon S, 1995; Forster, 1999) where, traditionally, cities have expanded through low-density, single house lot subdivisions on the urban fringes, predominantly for home ownership (Troy, 2004). According to the Australian Bureau of Statistics (2006), 75% of the population still reside in the suburbs, especially in the detached house, because such owner-occupied dwellings have been the principal housing form in Australia, apart from medium-density infill around town centres. After decades of developments since the post-war period, the picture is now changing, with an emerging band of ageing 'middle ring' suburbs that were built in the 1950s (Randolph, 2002). Forster (2004) notes these locations as being a belt that is 'strongly affected by ageing in place' and suffering significant population loss in some areas. However, Australian cities have not suffered from the extensive 'blighted zones', manifesting in abandoned housing and social dysfunction, that have appeared in many USA and UK cities. The 'white flight' phenomenon has been evident in some cases but has not resulted in the large-scale abandonment of inner or middle ring areas that has greatly damaged many USA cities (Gwyther, 2005).

Being the closest neighbour of the United States, Canada differs in many aspects even though they share a common culture. There is a general perception that cities in the USA and Canada are more or less the same in respect of sprawling, eating up valuable farmland, developing into monotonous subdivisions, malls and business parks, and supporting the ubiquitous car and truck traffic that guzzles gas, fouls the air and water, and degrades urban public spaces. However, along with other scholars, Raad and Kenworthy (1998) have presented contrasts in the liveability of the urban environments in the two countries. They found that Canadian cities usually have attractive residential precincts, a strong pedestrian presence in the streets and a vital mixture of shopping, commercial and other activities, often along thriving, dense corridors with frequent, well-utilised transit services that are less fragmented by freeways and parking lots than the average USA inner city, where transit services in suburban areas are poor to non-existent (Raad & Kenworthy, 1998).

In Europe, the old integrated system of European cities is being eroded by technical change along with wholesale suburbanisation that is aided by globalisation. The historical durability of the medieval system of cities survived because of the value of town centres to the upper- and middle-classes. Additionally, the European public sector has a more dominant ability to control the growth regimes, compared to the USA (Audirac, 2007). The strength and vitality of central European cities, amalgamated with the de-concentration of population and employment, resulted in a new settlement pattern that was crafted with a proliferation of urban nodes, composed of commercial strips and swaths of single-family homes. Urban agglomeration in these old traditional cities was highly integrated within the broader surroundings. However, the traditional contrasts between city, suburb and countryside has become increasingly blurred, with an elusive definitional ambiguity (Bontje, 2001).

It is evident from the above discussion that cities around the world have continued to be challenged by rapid urbanisation, ageing infrastructure and population growth. Population density cannot be increased without a competitive transport network. Mobility systems are key to the everyday functioning of a city. The cities that have chosen to make bold and diversified moves in advancing their transport systems have gained a competitive edge, with enhancements to productivity, attractiveness and overall quality of life. Arcadis' 2017 Sustainable Cities Mobility Index compiled the overall performances of the mobility systems in 100 cities around the world, based on 23 individual indicators, where each one reflected a component of urban mobility; from infrastructure spending commitment to the affordability of public transport (ARCADIS, 2017). Hong Kong secured the top ranking because of its innovative and well-connected metro network and the high share of trips taken by public transport. As discussed before, the agglomerative strength of European cities most consistently ranks them the highest, occupying seven of the top ten spots because of well-used metro networks such as London's Underground, strong bicycle infrastructure in cities like Amsterdam and Copenhagen, and high shares of commuters using public rather than private transport. American cities are spread throughout the index. New York is the highest-ranked American city, securing the 23rd position due to its expansive and heavily-used metro system operating around the clock. Many cities in the USA and Canada have well-funded, comprehensive transport systems but they are undermined by under-developed public transport systems and heavy reliance on private vehicles, congested roads and a relatively low commitment to infrastructure spending. According to the "Infrastructure Report Card" released in 2017 by the American Society of Engineers (ASCE), USA infrastructure rates very poorly, which signifies that the nation has not made enough progress since 2013 with its ageing infrastructure, public financing and congestion issues (American Society of Civil Engineers, 2017). Australian cities are dotted throughout the index as well, due to their low uptake of public transport and metro networks. However, it is encouraging that Sydney and Melbourne both are building underground metros (ARCADIS, 2017).

No two cities are the same, and their social, economic and geographical challenges are unique. Cities around the world are facing the reality of excessive dis-urbanisation and dependence on private vehicles and automobiles. It is understood that people and goods have to be moved but, if cities do not sustainably adapt to their mobility needs, it will impede their success. Even with a very stringent policy and its strict application, development at the urban fringes may not be halted. Populations and economic activities need to be channelled inward with better transport infrastructure to overcome the mobility challenges. In Europe, the proportion of urban cores gaining population between 1981 and 1991 reached 47%, compared with only 22% over the previous period of 1975-81 (Rontos, Mavroudis, & Salvati, 2011). USA and Canadian cities developed in an age of rapid suburban growth and motorised transport. Both countries have provided significant government incentives for suburban home ownership. However, all levels of government in Canada have managed to curtail the flight of middle-class families to the suburbs by deliberately ensuring investments in mass transit systems, public housing and parks, 'nodal' distribution of populations, jobs and amenities throughout urban regions, and the preservation of social services and quality education, maintaining the social and racial diversity and liveability of its cities (Raad & Kenworthy, 1998).

The low-density suburban sprawl that developed during post-war years in the United States is now recognised for the economic, social and environmental cost of that sprawl[10]. According to Florida (2017), people should spend 30% of their income for housing, but that can reach up to 45% including transportation costs. Owning multiple cars and keeping them insured, repaired and fuelled is an expensive proposition. A pricier apartment in an urban core or a duplex house in the inner or middle suburbs that is along transit lines can be a more affordable option when compared to living in a cheaper house in a car-dependent suburb on the fringe. For example, a smart growth paradigm of higher density, mixed-use and transit-oriented urban centres has emerged in many metropolitan areas in Denver, Colorado, with new urban projects and aggressive transit-oriented development programs that offer something different to the sprawl of the past (Goetz, 2013).

Efficient urban mobility allows the movement of people to various places, connects workers to workplaces from their premises without spending valuable time in congested traffic and provides a foundation for economic growth. Developing mass transit routes or corridors demands future-planning to realise the untapped economic, social and environmental potential that the surroundings can offer. According to Johnson (2007), the planning solution to the many ills of the late 20th century Australian suburbs has become urban containment, with activity centres and urban consolidation as an answer to the depopulation of the inner city, the decay of the middle ring suburbs, and the higher living costs involved in the outer suburbs. Containment has been added to the planning

[10] "Sprawl (n.) is a pattern of land use in an urbanised area that exhibits low levels of some combination of eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses and proximity" (Galster et al., 2001).

agenda in the strategic planning documents of all states. An efficient urban transport network is an inseparable part of making this planning agenda successful and running any city to its full potential. The keys to implementing changes that will deliver improved mobility are public perceptions of public transport and alternative modes of commuting, other than cars, together with the technological advancements of transit modes, a streamlined user experience, and collaboration between government agencies and private sectors.

Perth was ranked the lowest among other Australian cities in ARCADIS (2017) Sustainable Cities Mobility Index, having no major cities from the USA, Canada or the UK ranked below it. Perth secured 87th place in the overall ranking index, while 73rd in the people sub-index[11], 82nd in the planet sub-index[12] and 81st in the profit sub-index[13]. Additionally, in the sustainable cities index published in 2018, Perth could not even manage to secure a position within the top hundred global cities around the world, while the neighbouring cities of other states ranked between 34th and 56th in the same index (ARCADIS, 2018). The car dependence of cities is an established global phenomenon. Since the end of the Second World War, much of the growth in the level of personal affluence of the average Australian has been channelled into the possession of at least one family car. Perth, Adelaide and Brisbane are rated among the most car-dependent cities in the world, with Sydney and Melbourne close behind (Commonwealth Scientific and Industrial Research Organisation, 1992). Therefore, Perth, and more specifically the biggest local government area by population in Perth, the City of Stirling, is a perfect choice for investigation as a case study. The following sub-sections justify the reasons for this choice and explain the related background.

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[11] The People sub-index measures the social and human impacts of the city's mobility system, such as coverage of the transport network and wheelchair accessibility, efficiency and upkeep of a metro system, and digital capabilities of the city's trains and buses.

[12] The Planet sub-index measures the environmental implications of the city's mobility system, including metrics such as air pollution, greenhouse gas emissions, electric vehicle incentives and green space.

[13] The Profit sub-index assesses the economic aspects of a city's mobility system. This encompasses key metrics for commuters, such as time taken to get to work and affordability of the public transport network, as well as the city's financial commitment to their transport infrastructure.

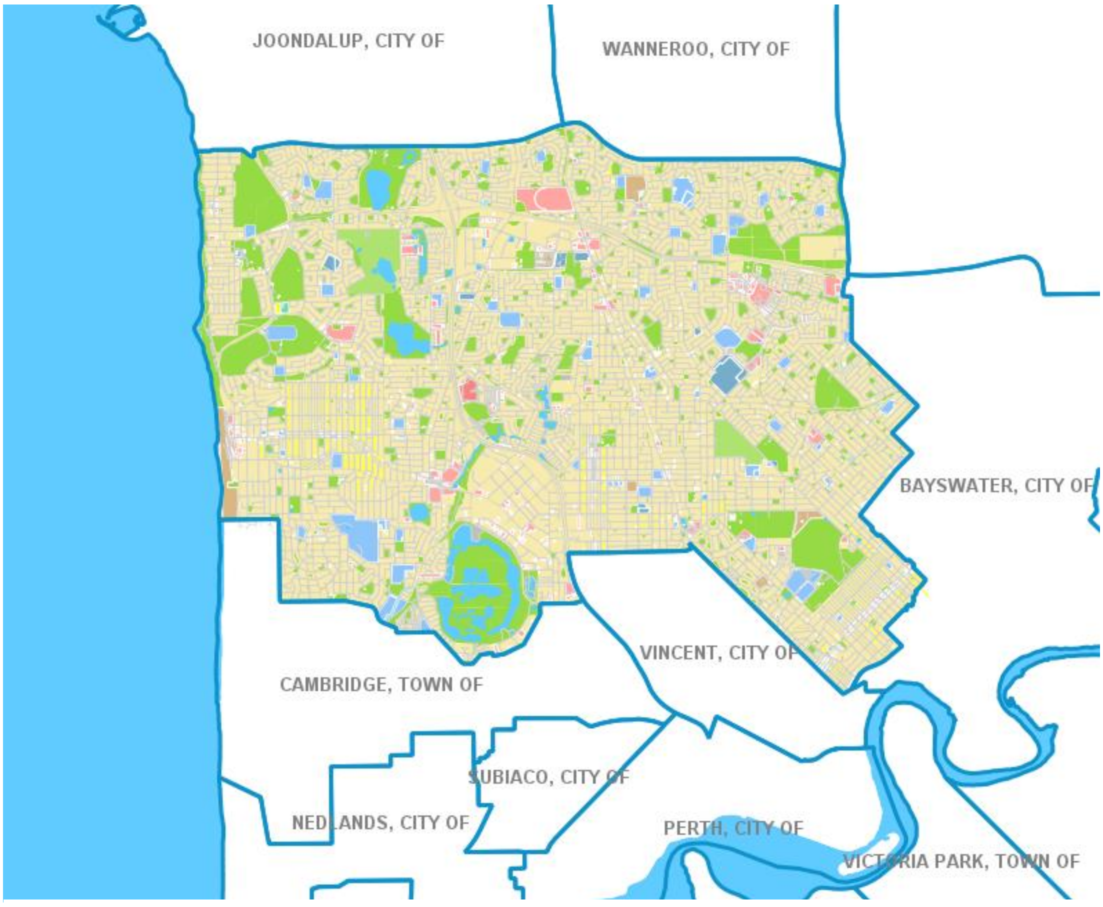


Figure 2.5 Statutory boundaries of the City of Stirling, Western Australia, retrieved from https://maps.stirling.wa.gov.au/intramaps80/ explored on June 2018

The City of Stirling is located in the northern suburbs, about 8km from the Perth CBD, with a population of over 215,000. The size of this population is expected to reach 230,000 by 2030. The City encompasses a total land area of about 100 square kilometres and incorporates 30 suburbs. Key employment sectors include retail, manufacturing, health and education. Stirling's major retail centres include Westfield Innaloo, Karrinyup, Mirrabooka Square and Dianella Plaza. Currently, only 8% of all trips in the Perth Metropolitan Area are by public transport (City of Stirling, 2009). Like many other cities of the world, the urban fabric of Perth is also characterised by cars that have led to the growth of low-density suburbs. The City of Stirling exhibits no difference in this character, with cars being the frequent mode of transport used by most of its dwellers.

2.12.1 Planning Context

The dependence on motor vehicles is very noteworthy in the case of the City of Stirling because more than 70% of trips to work are made by private motor vehicles, and a very low proportion of people walk, cycle or telecommute. There has been a significant increase in the total number of trips to work made by a single occupant driver and it is also evident that there has been a decrease in trip sharing over recent years (Australian Bureau of Statistics, 2006).

The City of Stirling has approximately eight job opportunities for every ten people who wish to work, yet only 30% of the City's workforce work within Stirling. These facts and figures suggest that opportunities exist for greater employment of city residents within the Stirling's boundaries to reduce travel demands in the future. Significant increases in patronage on all train lines has occurred over the last two to three years, caused by rising fuel costs and the doubling of the railcar fleet. This suggests a growing demand for alternative transport modes like light rail (City of Stirling, 2009).

2.12.2 Constraints Analysis

The primary constraints identified in policy papers produced by the Local Government have addressed some critical issues, including a lack of integration among activity centres, low-density suburbs with under-utilised land, built forms that are non-responsive to the surroundings and, most importantly, unsustainable modes of transport that have worked as a catalyst to drive all the other issues.

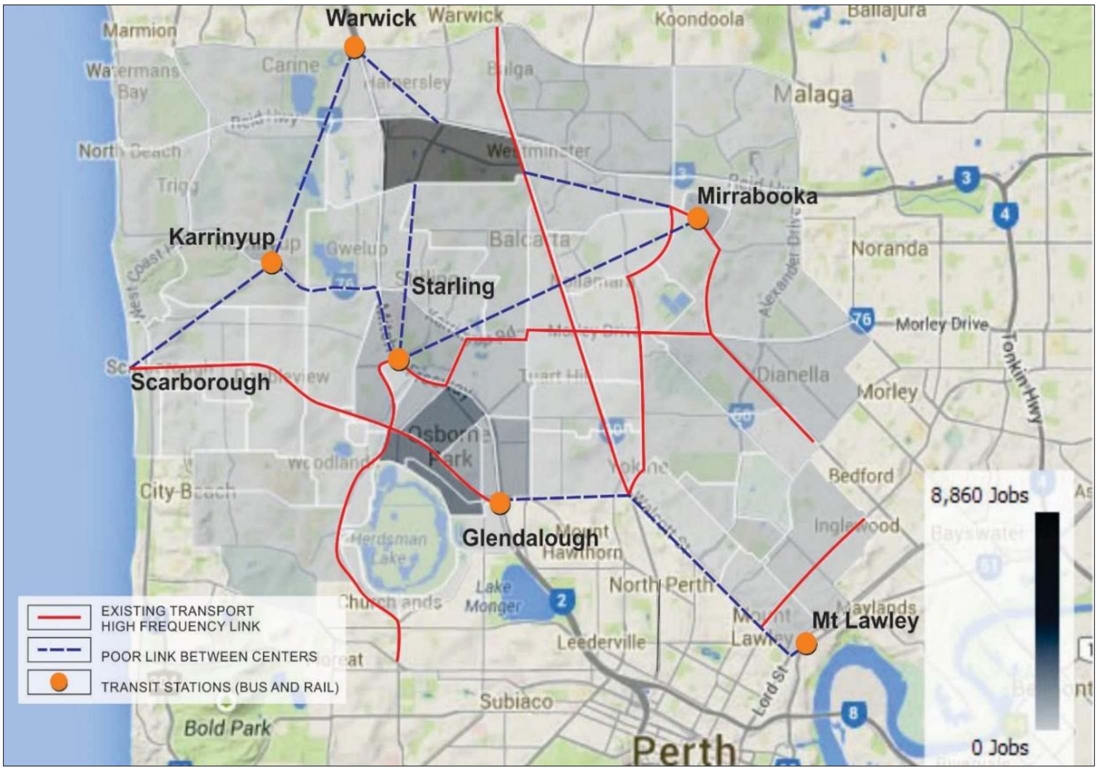


Figure 2.6 Transit integration of the City of Stirling, WA, adapted from COS (2009)

2.12.2.1 Lack of integration among activity centres

The City of Stirling has a few particular locations where the major job opportunities are concentrated. Areas such as the Balcatta Industrial Area, Innaloo, Osborne Park, Herdsman, and the areas adjacent to Mitchell Freeway are considered to be more economically vibrant compared to other parts of the city. There are significant shortfalls that exist between the following destinations:

- Balcatta Industrial Area and Warwick Station;
- Karrinyup and Scarborough;
- Mirrabooka and Balcatta Industrial Area;
- Mirrabooka and Stirling Regional Centre;
- Glendalough Station and Mt Lawley (City of Stirling, 2009).

2.12.2.2 Land use

The area around Glendalough Station is dominated by land uses such as car yards and other industrial uses that attract very few people. The area around the Warwick Station is mostly characterised by (R20) low-density residential development, which also reduces the potential for the station's catchment to be extended because anything below R30 is very low density, as described by the Western Australian Planning Commission (Western Australian Planning Commission, 2013). Similarly, the Mt Lawley Station is surrounded by low-density (R12.5) residential activity and heritage-protected sites. Only the area adjacent to the Mitchell Freeway enjoys the benefit of being a walkable catchment for the stations.

2.12.2.3 Built form

The character of the built form in the City of Stirling, particularly within the commercial centres throughout the city, are not very permeable in nature, which limits the potential for walking or cycling for short trips due to the strong bifurcation of the surroundings and the inactive building frontages. The unattractive walls or fences of many premises reduce the passive surveillance and fail to contribute to achieving a sense of place in the area. Poorly located local centres are along roads that offer little passing trade. Connections between the local centres are characterised by the automobile-dominated travel network that hinders the development of inter- and intra-connectivity among them.

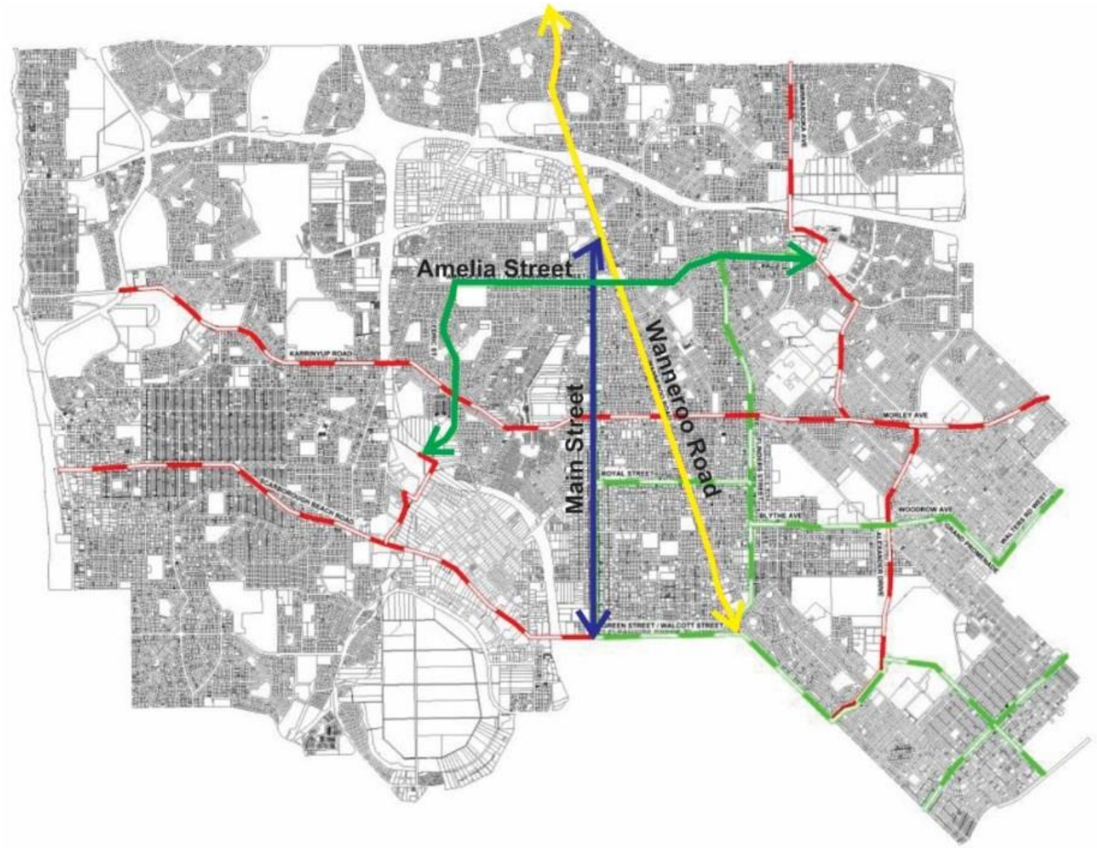


Figure 2.7 Potential transit routes of the City of Stirling, WA, which were investigated by this study

2.12.2.4 Possibilities for integration

The Integrated Transport Strategy paper published in 2009 (P.81) highlighted that the tram lines that used to operate in Perth until 1950 could be a prospective route of initial investigation for Stirling. These included the Beaufort Street, Walcott Street, Scarborough Beach Road and Main Street services. The built forms along these roads are the consequence of these tram lines and would still largely be conducive to the reintroduce of such services in a new format like LRT.

The City of Stirling council has already shown its keen interest to evaluate the potentiality of introducing light rail in the vicinity, producing some publications based on the strategic vision they have already endorsed. The council identified a couple of potential corridors, based on the findings of studies they have produced. The studies highlighted the potentialities of the possible routes based on physical properties like road reserve width, the requirement of widening some sites to establish an LRT, the need to relocate installed subterranean infrastructure, traffic patronage, responsible authorities, etc. Considering all these factors, Wanneroo Road, Main Street and Amelia Street have been prioritised most highly. This study examines these three transit routes to make a relative analysis of their potential to support urban regeneration in the middle suburbs of the City of Stirling.

2.13 Summary

The impacts of transport infrastructure on urban regeneration are always difficult to measure and it becomes more challenging for the low-density, middle suburbs of car-dependent cities, where people already have an affinity for a certain travel mode. There is a growing body of literature on how existing transit options make an impact on their surroundings, especially regarding land value uplift, but very few have pointed out the significant contextual factors that work as moderators, even before commencing any development, or explained their contribution to urban regeneration.

Factors that relate to car dependency and urban sprawl are interlinked, so does the existence of middle suburbs with potential lands to be redeveloped. It seems from the literature on urban design, land use and transport planning, and automobile dependence that there are plenty of commentators but their messages are not informing urban regeneration in the middle suburbs of car-dependent cities, through either the decision-makers or the wider population. Transport has a significant role to play in shaping future cities, even those that have already spread beyond the limit to meet the multiple demands of sustainable cities. Though every city is different, they fall into the categories of a walking city, a mass transit city or an automobile-dependent city. To transform them from an automobile-dependent to a transit-oriented city, development of a densely populated transit corridor is a widely accepted option, worldwide. However, it is still difficult to predict the success of a transit corridor with an appropriate transport mode because the context varies and there is not enough research that provides a firm basis on which to judge the future impacts of any transport mode, its required density, daily patronage required to run the project, etc. Therefore, it is crucial to identify the contextual factors that assist a mass transit corridor to gain its foreseeable success in contributing to urban regeneration since a widely applicable formula is required to explore the full potentiality of the middle suburbs of car-dependent cities. There should be an analytical framework that integrates all the critical factors of urban regeneration with attributes that are related to the contexts.

There are multiple PSS tools in the market, and some of them are quite relevant to this study. Envision and LUTI were found to be the most appropriate PSS tools because they deal with more of the contextual attributes of the problems and they have been used previously within the Australian context.

Based on the investigations of previous studies that have been explored in this chapter, a conceptual framework to determine an appropriate transport mode for a particular transit corridor as a potential option for urban regeneration in the middle suburbs of car-dependent cities will be presented in the next chapter.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The practices and challenges of measuring the effects of transport infrastructure on urban regeneration have been discussed in the previous chapter. Both academia and industry and government require a methodology to determine the appropriateness of a transit corridor, as well as its mode of transport, to facilitate urban regeneration in the middle suburbs of car-dependent cities.

The methodology proposed in this chapter provides a conceptual framework to assess the feasibilities of a potential transit corridor with an appropriate transit mode. It includes an overview of the research method and the process for its implementation in the form of a workflow. A brief synopsis of the study area and potential transit routes chosen for investigation in this study is also presented.

3.2 Research method

The research method is comprised of two major components that include the determination of an appropriate transit mode for any transit corridor and the evaluation of a chosen transit corridor regarding trips generation by the anticipated populations, with different land uses, that will support a suitable transit mode (Figure 3.1). The research methodology includes the following key stages:

- Conceptualisation of the interrelationships between urban regeneration and mass transit development initiatives (Chapter 2);
- Determination of contextual factors to assess potentialities of public transit corridors in contributing to urban regeneration (Chapter 2);
- Determination of individual weights of contextual factors and sub-factors to support the decision-making software, Envision, in its production of visual thematic maps (Chapter 4);
- Generation and integration of thematic maps, developed through Envision, to define the potentiality of particular transit corridors (Chapter 5); and
- Determination of an appropriate transit mode, regarding trips generation, to support a mass transit corridor in facilitating urban regeneration through the Land Use and Transport Integration (LUTI) model (Chapter 6).

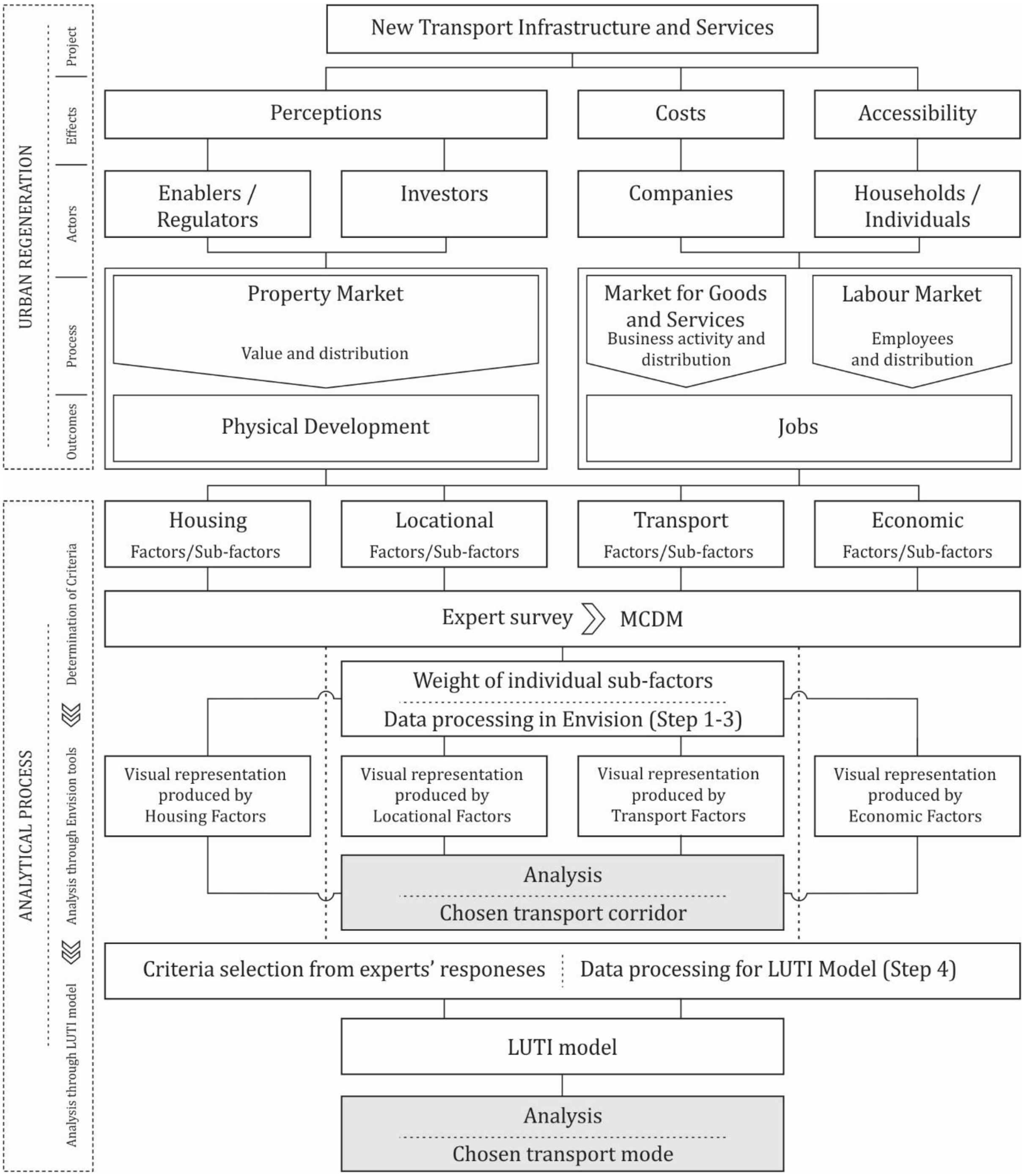


Figure 3.1 Research methodology workflow

3.2.1 Conceptualisation of interrelationships between urban regeneration and transit development initiatives

The literature study formed a foundation for outlining a measuring mechanism for the impacts of new transport infrastructure and services on urban regeneration, by investigating the interrelationships among them. It revealed, through a body of pragmatic, well-thought-out research, that transport infrastructure is capable of developing and adding new value to its surroundings, based on the actions of particular actors through processes that can deliver a positive outcome. In other words, a new transit option can create positive effects regarding changes in accessibility and costs, and in the perceptions of decision–makers. The set of actors listed below were found to potentially influence these effects as well as being influenced by them (Lawless & Gore, 1999).

a) *Households and individuals:* Shopping habits and participation in the local labour market can be modified through new transport investment, which also relies on their involvement.
b) *Companies:* Along with their influences on the labour market, use of the road system to bring supplies, to offer access to customers and transport manufactured goods provides companies with many positive outcomes from transit infrastructure investment.
c) *Investors:* Particularly non-local property companies and their agents also receive potential benefits from the investment; and
d) *Enablers and regulators:* By acting to promote new investment and in operating the local land-use planning system, their actions are critical in creating positive impacts.

The joint efforts from these actors can bring positive physical developments into the neighbourhood, creating favourable changes in property prices and accommodating both new, additional, and retained jobs. Changes in the distribution of business activity flow through the property market, labour market and markets for goods and services.

The next sub-section discusses the relationships among contextual factors that contribute to property and land value appreciation with the physical developments and jobs that are an outcome of regeneration activity to influence market conditions.

3.2.2 Determination of contextual factors

It can be said that the enhanced accessibility enabled by new transport infrastructure may attract new developments, appreciate land values, encourage densification, bring about changes in land use, raise rents, etc. (Brown & Whelan, 1991). However, in practice, it is far more complicated, especially in relation to making decisions about the most appropriate transport mode for a dedicated transit corridor (Cervero, 1984; Davoudi et al., 1993; GRIECO, 1988). Recognising the emphasis placed in the literature on the observed impacts of a mass transit corridor upon its surroundings, this study provides a discussion of which influential contextual factors encourage the establishment of a transit system, with an appropriate transit mode, by articulating the findings of a range of worldwide cases.

There are a variety of factors influenced by light rail to heavy rail transit, which can be grouped into four major types. Housing factors include types and sizes of land parcels, internal space articulation, age and density of the properties, while factors that relate to location deal with distances from necessary amenities. All of the contextual factors control the morphology of physical development to facilitate regeneration by acting through the property market. Transport and economic factors control the distribution of businesses (goods and services) and their employees, eventually being reflected as improvements brought about by any new transit facility in the forms of improved means of journeying to work, proximity to stations, reduced car ownership and, more importantly, realising the redevelopment potential of the surroundings. The background for categorising all of these factors into four major groups is detailed in Chapter 2.

3.2.3 Determination of individual weights of contextual factors and sub-factors

The detailed discussions in the literature review assisted with the articulation of the contextual factors that have been found to be influential in successful cases of urban regeneration via development of a mass transit corridor in car-dependent cities. The four major groups of contextual factors, along with their sub-factors, are not equally influential and play their parts differently. It is necessary to know the comparative standing of contextual factors and sub-factors in order to determine the optimum concentration of potential lots and precincts for redevelopment using the web-based decision support system tool, Envision. The individual weights of the factors are determined by pair-wise comparison using the Multi-Criteria Decision-Making (MCDM) method. The justification for using MCDM, the process of calculating individual sub-factor weights, and the method of preparing them for use with Envision as inputs are detailed in Chapter 4 of this thesis.

3.2.4 *Generation and integration of thematic maps produced through Envision*

Envision is a decision support system tool that can be used to create different planning scenarios. It was developed as an outcome of a research project named "Greening the Greyfields" (GtG) launched in 2011. As a partnership project between Curtin University, Swinburne University, the Co-operative Research Centre for Spatial Information (CRCSI) and several state and local government authorities in Australia, this PSS tool helped to develop strategies to address sub-optimal infill patterns in existing suburbs and curtail the effects of urban sprawl (Glackin, Trubka, & Dionisio, 2016). Through use of the software, it is possible to bring together the multiple layers of property, planning, utility and demographic data into a distributed (shared) urban spatial information system (Newton & Glackin, 2013). This web-based GIS platform, with dynamic, up-to-date information and real-time access, provides a basis for professionals like planners, property developers, design and construction professionals, investment organisations, local government and neighbourhood communities (in various combinations) to explore development opportunities. The attributes are grouped under detailed context, regional/demographic context, precinct identification and a few other categories that are not directly related to the scope of this research.

3.2.4.1 Detailed context

By being able to simultaneously access and query data from a variety of different areas of interest, this function uses a variety of land data sets to identify areas of strategic redevelopment within a municipality.

3.2.4.2 Regional/demographic context

This function allows users to identify areas of strategic interest based on aggregated (Statistical Area 1: SA1) census data from the Australian Bureau of Statistics (ABS) and also allows them to select and weigh a variety of variables, providing a choropleth (thematic map) as an output. This function is designed to be used in combination with the *Detailed Context* function to provide demographic information that may influence decisions regarding urban development.

3.2.4.3 Precinct identification

This function is designed to assist planning and development professionals in identifying dwellings that may be part of a precinct-scale regeneration plan. The tool allows users to select the indicators of redevelopment that are significant for a particular locality and/or strategy. By manipulating the cut-off values for these selected variables, the tool can identify dwellings that can potentially be amalgamated, or otherwise become part of a larger project, rather than using the typical lot-by-lot redevelopment approach (ENVISION Website, 2018).

This multi-criteria evaluation tool produces different thematic maps based on the criteria selected by users. The literature review helped to identify the theoretical basis for selecting evaluation criteria regarding significant groups of contextual factors that were identified. The produced maps provide an overview of the potentiality of particular routes (suggested by the local government authority, in this case) based on the selected attributes and their weights or magnitudes. The precinct identification tab of the Envision tool identifies the lots that are found to have potential for redevelopment as per the given values for the selected attributes. The map generation procedure was based on the survey input from the experts (described in Chapter 4) and it is detailed in Chapter 5, along with the justifications for determining the potentiality of routes to develop a public transit corridor by integrating all of the thematic maps produced through Envision.

3.2.5 Determination of appropriate transit mode via Land Use and Transportation Index (LUTI) model

The Envision scenario maps suggest comparable scenarios to set up transit options and identify the potential land parcels in the middle suburbs most suitable for redevelopment. However, the density threshold required to achieve the desired ridership is a pressure that is always felt by the policy-makers when attempting to secure economic benefits from any proposed transit corridor. The spreadsheet-driven tool, Land Use and Transport Integration (LUTI) model, can calculate real estate yields by investigating the correlation between ridership generated from different densities (through attuned floor area ratio) of an area which is proposed to be redeveloped. The tool also suggests different target densities required for different transport provisions (Hendrigan, 2015).

The basis of this method has been adopted from the "Guide to Traffic Generating Development" (Roads and Traffic Authority NSW, 2002, 2013) that was developed by the Road Transport Authority (RTA) of New South Wales. It provides guidance on a number of matters related to the traffic impacts of land use developments, most notably on matters relating to traffic generation and parking. Its audience extends beyond that of traffic authorities (Roads and Maritime Services and Councils) and is widely used throughout Australia.

The daily trips generated by various land uses are compared against the capacity of each transit mode, assuming 12 hours of service per day. The mode capacity of a transit option (e.g., rapid bus service or light rail) aims to accommodate the daily trips that would be generated by cars. The reduced parking ratio required for the summed volume of each land use type reveals the real estate yield, in other words, the floor space available for development, based on different transit modes. Mode capacity varies according to the car sizes and frequency of vehicles. As per the Stirling City Centre light rail feasibility study (Parsons Brinckerhoff Australia, 2010), peak hour capacity of buses reaches 6,600 passengers per direction while LRT is typically 9,000–32,000 per hour. 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.

Based on the different modes of transport, real estate yields deal with the capacity of a public transport mode to convey passengers per hour. The associated reduction in parking requirements frees up surface area and capital to build new real estate. Each increment in the mode of transport service has the potential to proportionately reduce the space required for roads and parking spaces for cars. Such action adds corresponding opportunities to build a denser, mixed-use, walkable community (Hendrigan, 2015). The density in this model was determined through three different scenarios – conservative, intermediate and ultimate whereby each type of land use is calibrated to its Floor Area Ratio[14] (plot ratio) and a mix of uses.

The precinct identification tool of Envision can identify the potentially redevelopable land and generate output of the potential lots in the format of a PDF according to the selected criteria and attributes (through its ‘precinct identification’ function), however,

[14] The floor area ratio is the principal bulk regulation controlling the size of buildings. FAR is the ratio of the total building floor area to the area of its zoning lot. Each zoning district has a FAR which, when multiplied by the 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

it is not capable of producing spreadsheet data to inform parcel size and land use type of the identified lots. A free and open-source geographic information system software package, QGIS (version 2.14.3-Essen) (QGIS, 2018) was used to extract these data from the Envision output file.

We do not claim that this method is entirely innovative in answering any definite question regarding a potential route for a proposed transit corridor with an appropriate transit mode. Instead, it enhances the current understanding of what positive externalities can be brought about by a mass transit corridor that has the potential to transform its surroundings in terms of encouraging new economic activity, especially when it is believed to be unlikely. This research will enable local policy-makers and stakeholders to find appropriate catalysts for local regeneration, which is the primary intention of this semi-structured framework development. However, the impacts of new transport investments may take a considerably long time to become apparent as the businesses, retail outlets and households take time to assimilate the potential benefits that emerge from any newly installed system.

3.3 Summary

This chapter has offered an overarching discussion of the methodology of this research and outlined the processes involved in determining the most appropriate location for a mass transit corridor in regard to the choice of a mode of transport that will facilitate urban regeneration in the middle suburbs of car-dependent cities. In Chapters 4, 5 and 6, respectively, the research components such as determination of individual weights of contextual factors and sub-factors, the use of individual weights as inputs for Envision to produce thematic maps and the process of determining the most appropriate transit mode for the chosen corridor will be described in more detail.

CHAPTER 4: DETERMINATION OF INDIVIDUAL WEIGHTS OF CONTEXTUAL FACTORS AND SUB-FACTORS

4.1 Introduction

Chapter 3 described the contextual sub-factors that were identified through the literature review in order to produce scenarios based on each context (e.g., housing, location, transport and economy) to identify their potentials in regenerating the middle suburbs of car-dependent cities. This chapter applies a Multi-Criteria Decision-Making (MCDM) model, specifically the Pair-wise Comparison Method (PCM), to determine the individual weight of each criterion, i.e., the contextual sub-factors to use in Envision when producing scenarios for each context.

4.2 Background

In Chapter 2, the importance of several factors in their abilities to facilitate urban regeneration were identified through the representation of how existing transit options make an impact on their surroundings, especially in uplifting land values. In addition, it is important to discover the significant contextual factors that work as moderators, and the possible areas in which they can contribute to the facilitation of urban regeneration, before initiating the development of a mass transit corridor. Apart from identification of the factors themselves, it is equally important to determine the individual weights of their potentialities, compared to each other. Therefore, MCDM can help to manage this problem by integrating dynamic information and judgements within a systematic framework (Levy, Hartmann, Li, An, & Asgary, 2007) and providing evaluation results for each sub-factor. The calculated weight of each contextual sub-factor can then be used as a variable value in the Envision tool. Envision produces a heat map as an output to locate the potential areas that satisfy the requirements of the set of chosen variables. In this research, Envision was used to find the inherent potential of redevelopment in the surroundings of proposed transit corridors.

MCDM is a tool that uses a chosen set of quantifiable and non-quantifiable criteria to develop a set of alternatives and then scrutinises them in a process of selection. To attain the optimal selection, the alternatives are compared against the selected criteria (Hickman, Saxena, Banister, & Ashiru, 2012; Singh & Malik, 2014).

Use of MCDM can be divided into two categories: Multi-Attribute Decision-Making (MADM) and Multi-Objective Decision-Making (MODM) (Mendoza & Martins, 2006).

MADM is used to select the 'best' alternative from pre-specified alternatives described regarding multiple attributes (Rao, 2007). It is used to generate a solution to problems that exhibit a finite number of alternatives. For problems of a continuous nature, MODM involves the design of alternatives that optimise the multiple objectives of decision-makers. The choices are usually infinite or very large, and the best one will be the one that most closely meets the decision maker's constraints and priorities.

A diversified range of MADM techniques can be seen in the literature, each with its own distinct points of advantage and disadvantage (Table 4.1). Such diversity offers flexibility in selecting the most appropriate technique from a wide range of options. However, the process is complicated because each option has its own strengths and weaknesses (Aruldoss, Lakshmi, & Venkatesan, 2013).

Table 4.1 Comparison of the most commonly used methods for MADM, adapted from Liu (2013)

Methods	Main features	Advantages	Disadvantages
Weighted-sum model (WSM)	This method is based on the assumption of additive utility (Martins, Coelho, Antunes, & Clímaco, 1996).	The most straightforward and practical method.	The additive utility assumption does not apply when combining different units of criteria (Triantaphyllou, Shu, Sanchez, & Ray, 1998).
Weighted-product model (WPM)	Any unit of measure is eliminated in the calculation (Triantaphyllou & Lin, 1996).	Dimensionless analysis (Triantaphyllou et al., 1998).	The final calculation does not provide absolute evaluation values for each alternative.
Analytic hierarchy process (AHP)	This method decomposes the decision problem into a hierarchical system of sub-problems, each of which is analysed in terms of each criterion (Mendoza & Sprouse, 1989; Phua & Minowa, 2005).	Hierarchical structure analysis of the criteria.	The potential of internal inconsistency may exist in the AHP (Hu, Wang, Li, & Zhang, 2010).
Preference-ranking organisation method for enrichment	This is one type of outranking method and requires the use of concordance and discordance indices	Flexible selection of preference functions and indifference thresholds (Silva,	The final calculation does not provide absolute evaluation values for each alternative.

Methods	Main features	Advantages	Disadvantages
evaluation (PROMETHEE)	(Kangas, Kangas, & Pykäläinen, 2001; Schmoldt, Kangas, Mendoza, & Pesonen, 2013).	Morais, & Almeida, 2010).	
Elimination and choice-translating reality (ELECTRE)	This is one type of outranking method, and each criterion is associated with a preference function (Kangas, Kangas, & Pykäläinen, 2001; Laukkanen, Kangas, & Kangas, 2002).	Good performance in the decision-making process with few criteria, but with a large number of alternatives (Goicoechea, Hansen, & Duckstein, 1982).	The ideal alternative sometimes cannot be identified (Triantaphyllou et al., 1998).
Multi-attribute utility theory (MAUT)	The utility function, which indicates the decision-maker's preferences, is defined over a number of attributes included in the method (Pukkala, 1998).	The transparent aggregation procedure can be easily understood by decision-makers (Von Winterfeldt & Fischer, 1975).	The decision-makers are required to have knowledge of probability theory (Tanadtang, Park, & Hanaoka, 2005).

Determining the weights of contextual sub-factors in order to choose the best alternative for a transit corridor is classified as a process of MADM. Eventually, the contextual sub-factors are considered as some alternatives, or sub-criteria, to be evaluated against a set of criteria. The best alternative needs to be determined to evaluate and compare the heat map scenarios developed from Envision, using the weights as an outcome of the Pair-wise Comparison Method (PCM) of the AHP.

4.3 Criteria weight determination by Pair-wise Comparison Method (PCM)

In this study, the criteria weights of contextual sub-factors were assessed by experts from industry and academia with diversified backgrounds. They included an urban strategic planner, an academician within planning management, a practising transport modeller, etc. The questionnaire was designed to collect information from the experts in the format of a pair-wise comparison matrix, as illustrated below, using an information sheet that contained a description of each criterion and the outcome of each matrix (see Equation 4.1).

$$C = [c_{ij}] = \begin{bmatrix} 1 & 1/c_{21} & 1/c_{31} & 1/c_{41} \\ c_{21} & 1 & 1/c_{32} & 1/c_{42} \\ c_{31} & c_{32} & 1 & 1/c_{43} \\ c_{41} & c_{42} & c_{43} & 1 \end{bmatrix} \quad \ldots (4.1)$$

where c_{ij} specifies the ratio of m_i/m_j, and m_i and m_j represent the importance of criteria i and j (respectively) in the views of the experts, in accordance with the AHP original scale (Table 4.2), ranging from 1 to 9.

Table 4.2 Scale of the AHP, adapted from Satty (1980)

Scale	
Degree of preference	**Value**
Extremely less important	1/9
Very strongly less important	1/7
Strongly less important	1/5
Moderately less important	1/3
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9

This value is selected by the experts by defining the relative value (importance) of one alternative when compared with the other, keeping one criterion fixed, i.e., prioritising the alternatives on the basis of individual criteria.

In the next step, a construct of the normalised matrix is made, whereby a normalised element r_{ij} is obtained using Equation 4.2,

$$r_{ij} = \frac{a_{ij}}{\sum_{i=j}^{N} e_{ij}} \quad \ldots (4.2)$$

where a_{ij} is an element of the initial matrix divided by the sum of all the elements of its respective column. The weight vector is then calculated using Equation 4.3, after the matrix for each criterion has been obtained, where N is the number of alternatives.

$$c = \frac{1}{N \sum_{i=1}^{N} r_{ij}} \quad \ldots (4.3)$$

Finally, the eigenvector is formed with a simple ranking of alternatives according to the particular criteria or comparable weights of the alternatives. Using the same set of steps, beginning with the same matrix C_{M*M} (containing the comparison criteria) one more set of eigenvectors is used to generate the weight values for the respective sub-criteria.

$$C = [c_{ij}] = \begin{bmatrix} 1 & \frac{1}{c_{21}} & \frac{1}{c_{31}} \\ c_{21} & 1 & \frac{1}{c_{32}} \\ c_{31} & c_{32} & 1 \end{bmatrix} \quad \ldots\ (4.4)$$

Aside from the relative weights, the consistency of answers given by the experts was also checked because it is highly unlikely to expect all the experts to provide consistent answers in their pair-wise comparison matrices. The answers can be random or illogical (Jaganathan, Erinjeri, & Ker, 2007; Kwiesielewicz & Van Uden, 2004). Therefore, a consistency check was performed using the following equation, as defined in Satty (1980):

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} \quad \ldots\ (4.5)$$

$$CI = \frac{\lambda_{max} - n}{(n-1)} \quad \ldots\ (4.6)$$

where CR is the Consistency Ratio, whose value defines consistency of the results, CI is the Consistency Index, and RI is the Random Index. The Random Index, RI, has been evaluated by a number of previous studies (Alonso & Lamata, 2006) and, in Equation 4.5, it indicates the sizes of the pair-wise matrices. In the ideal case, a perfectly consistent value for CR is 0, which is not practically feasible. A CR value that is equal to or less than 0.1 indicates an acceptable level in the pair-wise matrix, i.e., consistency in the expert's answers; otherwise, it is considered as an inconsistent judgement.

If there is any inconsistent judgement in the expert's opinion, the response is still valuable in determining the criteria weights. Ergu, Kou, Peng, and Shi (2011) introduced a method to improve the consistency of comparison matrices. It requires a series of transformations using matrix multiplication and vector dot products, which was also applied in this study. This method adjusts identified inconsistent elements with a slight change of the experts' logical interpretations of relationships among the criteria.

4.4 Transfer of criteria weights into input values for Envision

The objective of obtaining the weights of individual sub-criteria, i.e., contextual sub-factors derived from the pair-wise comparison matrices, was to prepare the variable-values for Envision to produce a separate thematic map based on the rounded up values of the percentages of priority vectors. Figure 4.1 shows the distribution hierarchy of the individual contextual sub-factors.

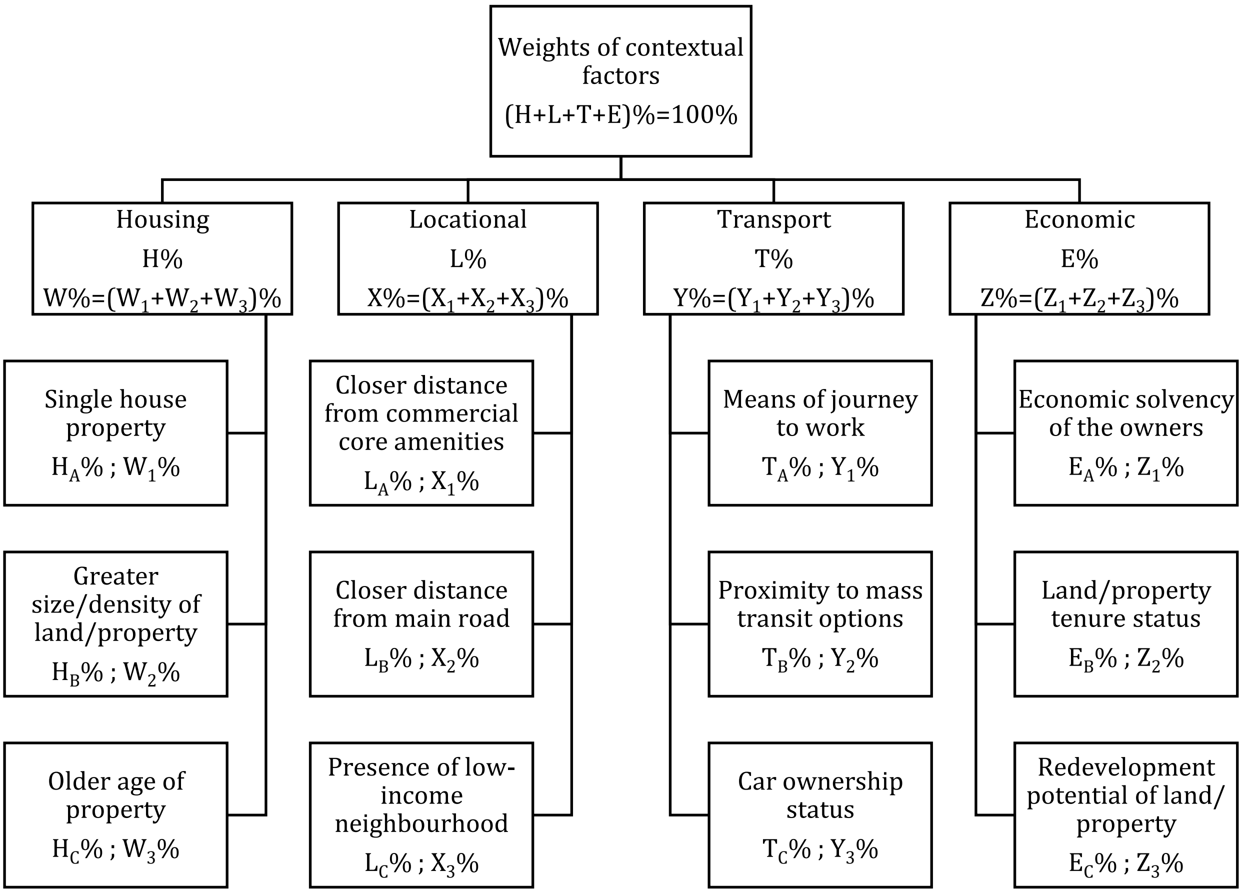


Figure 4.1 Hierarchy of achieved weights of contextual sub-factors

Equation 4.1 produced the individual weight (W%) of each contextual factor in relation to the other contextual factors while, following the same steps of pair-wise comparison, Equation 4.2 produced the value of each contextual sub-factor in relation to each other, i.e., H_A% for a single house property. To obtain the value of each sub-criterion, i.e., W_1 % or contextual sub-factors according to the weight of each factor, the following equation has been used:

$$W_1 = (H_A * H) \qquad \dots (4.7)$$

The thematic map produced by Envision requires input values (i.e., W_1, the rounded up value of each contextual sub-factor) for the number of variables that relate to the contextual sub-factors of housing, locational, transport and economic factors. Table 4.3 shows the relationships of the contextual sub-factors with the scrutinised attributes of Envision and their relative values acquired from PCM.

Table 4.3 Relationships of contextual sub-factors with attributes of Envision

Criteria: Housing Factors		
Contextual sub-factors	**Input for Envision (rounded up values)**	
Single house property (W_1%)	a) Single house	W_1
Greater size/density of land/property (W_2%)	b) 4 to 6 persons per household c) 3 to 5 bedrooms or more per house	W_2
Older age property (W_3%)	d) Older building	W_3
Criteria: Locational Factors		
Contextual sub-factors	**Input for Envision (rounded up values)**	
Closer distance from commercial core amenities (X_1%)	a) Near primary, secondary and tertiary schools b) Near district and strategic centre c) Near local centres d) Near medical facility e) Near park	X_1
Closer distance from main road (X_2%)	f) Near main road	X_2
Presence of a low-income neighbourhood (X_3%)	g) Socio-Economic Indexes For Areas (SEIFA) low	X_3
Criteria: Transport Factors		
Contextual sub-factors	**Input for Envision (rounded up values)**	
Means of journey to work (JTW) (Y_1%)	a) JTW via mass transit b) JTW via walking or cycling	Y_1
Proximity to mass transit options (Y_2%)	c) Near bus d) Near train station	Y_2
Car ownership status (Y_3%)	e) One vehicle per household	Y_3
Criteria: Economic Factors		
Contextual sub-factors	**Input for Envision (rounded up values)**	
Economic solvency of the owners (Z_1%)	a) Income $2k to $4k (per week per household)	Z_1
Land/property tenure status (Z_2%)	b) Mortgage paid off	Z_2
Redevelopment potential of land/ property (Z_3%)	c) Development efficiency d) Presence of extra land e) Dwelling capacity	Z_3

4.5 Responses of the experts

In this study, the author used an RI value equal to 0.58 and 0.90 (Satty, 1980), respectively, to compare three and four pairs of criteria. Eight respondent's opinions with five sets of pair-wise comparison matrices have been collected, where inconsistency of opinion was noticed in some cases. The Tables (4.4 – 4.8) list the criteria weights determined by pair-wise comparison from all respondents, with adjustment of the inconsistent responses that did not significantly change the logical relationships between criteria, ensuring that the CR values remained less than 0.1. The average of the weights for each criterion from the eight experts was calculated to determine the criteria weights of the contextual factors and sub-factors.

Table 4.4 Criteria weights determined by PCM and the CR values of contextual factors

		Housing	**Locational**	**Transport**	**Economic**	**CR**
Response 1	*original*	0.094	0.549	0.094	0.264	0.022<0.1
	improved	-	-	-	-	-
Response 2	*original*	0.061	0.149	0.261	0.529	0.154>0.1
	improved	0.066	0.124	0.271	0.538	0.091<0.1
Response 3	*original*	0.573	0.190	0.178	0.060	0.053<0.1
	improved	-	-	-	-	-
Response 4	*original*	0.114	0.479	0.286	0.120	0.058<0.1
	improved	-	-	-	-	-
Response 5	*original*	0.645	0.172	0.046	0.137	0.099<0.1
	improved	-	-	-	-	-
Response 6	*original*	0.068	0.529	0.242	0.161	0.145>0.1
	improved	0.067	0.547	0.188	0.198	0.086<0.1
Response 7	*original*	0.531	0.271	0.065	0.132	0.084<0.1
	improved	-	-	-	-	-
Response 8	*original*	0.303	0.455	0.157	0.085	0.129>0.1
	improved	0.399	0.357	0.161	0.083	0.043<0.1
Average	CR<0.1	**0.311**	**0.336**	**0.161**	**0.192**	

Table 4.5 Criteria weights determined by PCM and the CR values of housing factors

		Single house property	Greater size of land/property	Older age of property	CR
Response 1	*original*	0.084	0.666	0.250	0.011<0.1
	improved	-	-	-	-
Response 2	*original*	0.655	0.158	0.187	0.025<0.1
	improved	-	-		-
Response 3	*original*	0.102	0.254	0.641	0.062<0.1
	improved	-	-	-	-
Response 4	*original*	0.633	0.260	0.106	0.033<0.1
	improved	-	-	-	-
Response 5	*original*	0.658	0.253	0.089	0.265>0.1
	improved	0.633	0.260	0.106	0.033<0.1
Response 6	*original*	0.249	0.646	0.105	0.047<0.1
	improved	-	-	-	-
Response 7	*original*	0.211	0.488	0.301	1.462>0.1
	improved	0.179	0.685	0.136	0.070<0.1
Response 8	*original*	0.633	0.106	0.260	0.033<0.1
	improved	-	-	-	-
Average	CR<0.1	**0.396**	**0.379**	**0.224**	

Table 4.6 Criteria weights determined by PCM and the CR values of locational factors

		Closer distance from commercial core	Closer distance from main road	Presence of low-income neighbourhood	CR
Response 1	*original*	0.777	0.069	0.155	0.071<0.1
	improved	-	-	-	-
Response 2	*original*	0.760	0.068	0.172	0.063<0.1
	improved	-	-	-	-
Response 3	*original*	0.174	0.059	0.767	0.274>0.1
	improved	0.155	0.069	0.777	0.071<0.1
Response 4	*original*	0.105	0.097	0.798	0.006<0.1
	improved	-	-	-	-
Response 5	*original*	0.133	0.169	0.699	0.054<0.1
	improved	-	-	-	-
Response 6	*original*	0.765	0.106	0.129	0.034<0.1
	improved	-	-	-	-
Response 7	*original*	0.385	0.325	0.290	2.097>0.1
	improved	0.685	0.179	0.136	0.070<0.1
Response 8	*original*	0.655	0.158	0.187	0.025<0.1
	improved	-	-	-	-
Average	CR<0.1	**0.504**	**0.114**	**0.382**	

Table 4.7 Criteria weights determined by PCM and the CR values of transport factors

		Means of journey to work	Proximity to mass transit option(s)	Car ownership status	CR
Response 1	*original*	0.777	0.155	0.069	0.071<0.1
	improved	-	-	-	-
Response 2	*original*	0.211	0.686	0.102	0.120>0.1
	improved	0.193	0.724	0.083	0.057<0.1
Response 3	*original*	0.664	0.085	0.251	0.012<0.1
	improved	-	-	-	-
Response 4	*original*	0.621	0.258	0.120	0.665>0.1
	improved	0.685	0.136	0.179	0.070<0.1
Response 5	*original*	0.215	0.136	0.649	0.401>0.1
	improved	0.136	0.179	0.685	0.070<0.1
Response 6	*original*	0.193	0.724	0.083	0.057<0.1
	improved	-	-	-	-
Response 7	*original*	0.083	0.724	0.193	0.057
	improved	-	-	-	-
Response 8	*original*	0.333	0.333	0.333	1.149>0.1
	improved	0.655	0.158	0.187	0.025<0.1
Average	CR<0.1	**0.423**	**0.361**	**0.216**	

Table 4.8 Criteria weights determined by PCM and the CR values of economic factors

		Economic solvency of owner(s)	Land/property tenure status	Redevelopment potential of land/property	CR
Response 1	*original*	0.295	0.057	0.649	0.070<0.1
	improved	-	-	-	-
Response 2	*original*	0.155	0.177	0.669	0.016<0.1
	improved	-	-	-	-
Response 3	*original*	0.102	0.258	0.641	0.062<0.1
	improved	-	-	-	-
Response 4	*original*	0.649	0.295	0.057	0.070<0.1
	improved	-	-	-	-
Response 5	*original*	0.089	0.658	0.253	0.265>0.1
	improved	0.106	0.633	0.260	0.033<0.1
Response 6	*original*	0.574	0.286	0.140	0.118>0.1
	improved	0.633	0.260	0.106	0.033<0.1
Response 7	*original*	0.105	0.798	0.097	0.006<0.1
	improved	-	-	-	-
Response 8	*original*	0.368	0.299	0.333	1.600>0.1
	improved	0.480	0.115	0.405	0.025<0.1
Average	CR<0.1	**0.316**	**0.324**	**0.361**	

The respondents posted clear judgements on their views, comparing the identified contextual factors that they thought to be influential in setting up a mass transit corridor.

The results show that the location (33.6%) and housing factors (31.1%) were significantly more important to the respondents than transport and economic factors (Figure 4.2).

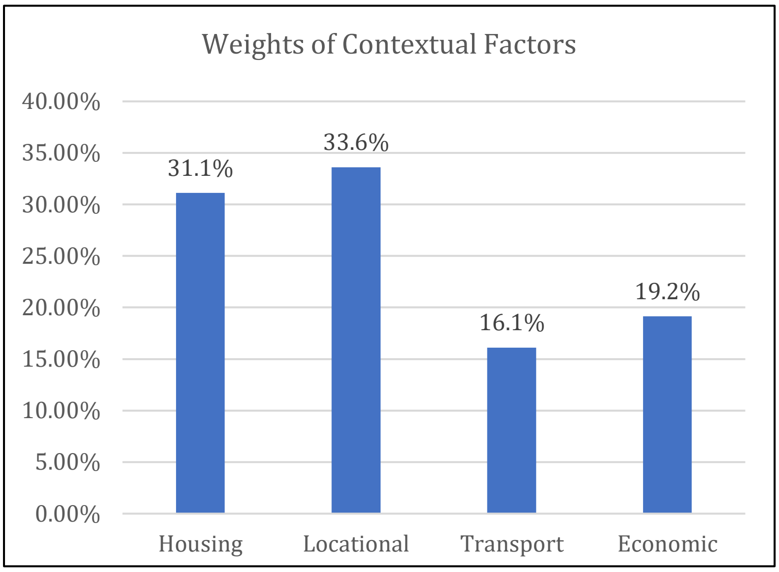


Figure 4.2 Weights of contextual factors

In relation to the housing factors, it is apparent that the single property houses and the larger lots of land are equally suitable for redevelopment (e.g., single house property and larger lots of land are 39.6% and 37.94%, respectively) while the age of property carries half of the importance compared to the other two criteria (Figure 4.3). This result may suggest that, if the other factors tick the boxes of a checklist of suitability for redevelopment, whether the property is close to the end of its physical life or not, the owners may still think of redevelopment as an option.

The location of a property and its distance from any amenities are important. A proposed transit corridor may play an important role to work as a catalyst in facilitating redevelopment; however, the location of the lots along a proposed transit route and its surrounding land use types are equally significant in making an impact on a redevelopment. The opinion from the experts suggests that the distance between the commercial core and property is approximately five times more important than its location close to a main road. Moreover, the presence of a low-income neighbourhood nearby the proposed transit route also carries significant importance. Results show that it is more than three times as important as being located close to a main road (Figure 4.4), which supports the findings of the research by Nelson (1992) and Redman et al.

(2013) in Atlanta, where the introduction of rail transit injected positive momentum into the low-income neighbourhoods.

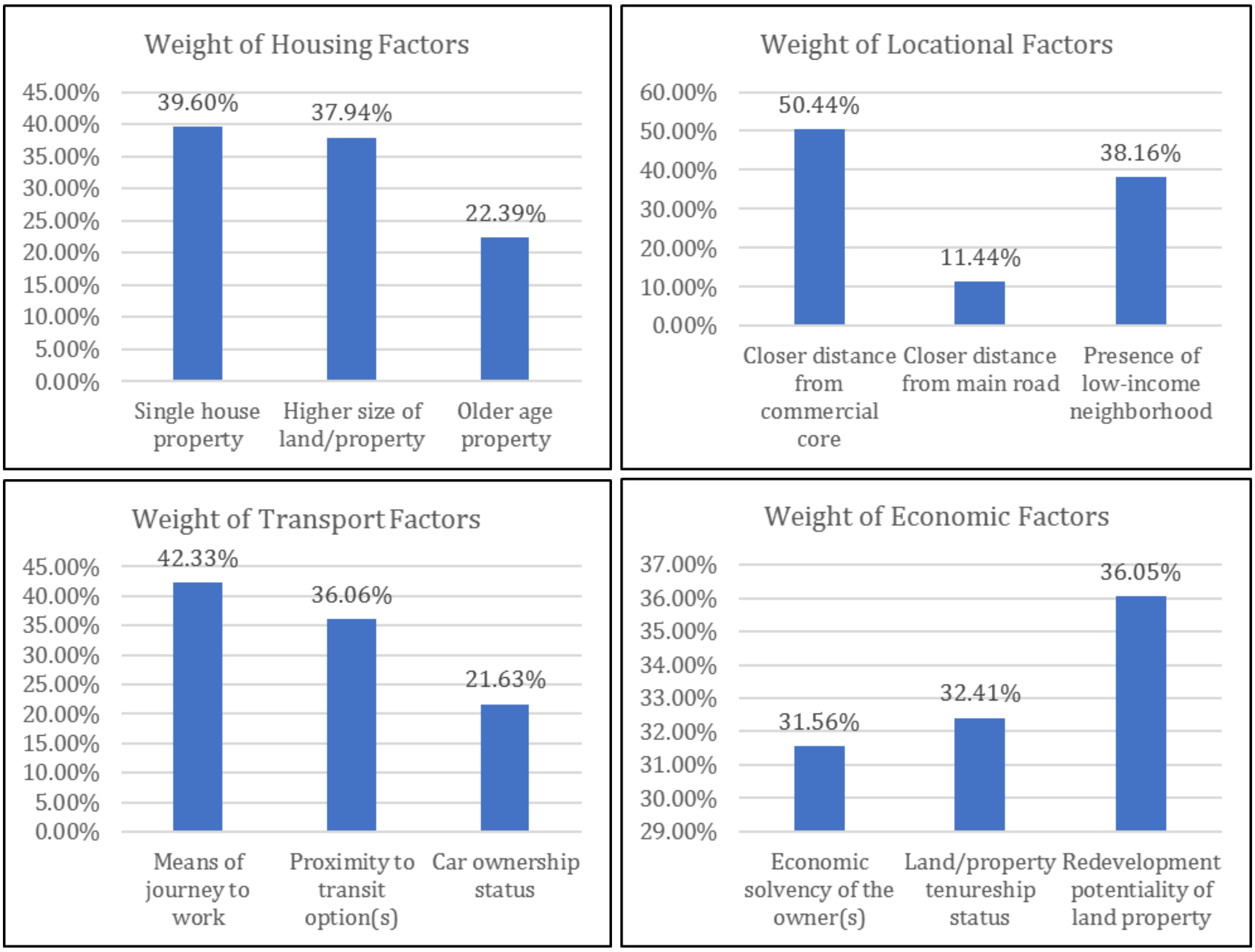


Figure 4.3 Individual weights of contextual sub-factors

Like the findings from the literature, car ownership was not found to be the primary factor among other transport factors for people to self-select a particular transport mode, such as a car. Alternatively, the presence of available mass transit options and their proximity were more important to people, no matter how many cars they owned.

According to Newton and Glackin (2014), economically, the ratio of land value to the total capital value of the residential property determines whether it is an under-performing asset or not. This is most probably the case, environmentally, and possibly socially too, leading to what has been termed a redevelopment potential index, or RPI. Based on the survey results from Maroondah, Melbourne, with 45,000 residential dwellings, it is suggested that, if the land value of an asset represents almost the total value of the asset (without any significant contribution from the present property on the land), it signifies that the asset is economically viable for redevelopment. The survey also found that the concentration of potentially redevelopable sites mostly were located in the middle ring suburbs of the city. The results from the experts surveyed within this current study indicated that the redevelopment potential of a property overrides other considerations, such as the owner's solvency or tenure status in regard to the property. The survey results signify that the redevelopment potential of an asset is more important than the status of its ownership. It seems to make no difference whether the property is owner-occupied or tenanted and, similarly, whether the owner has already paid out the mortgage for the property or is still paying it as it reflected in literature review.

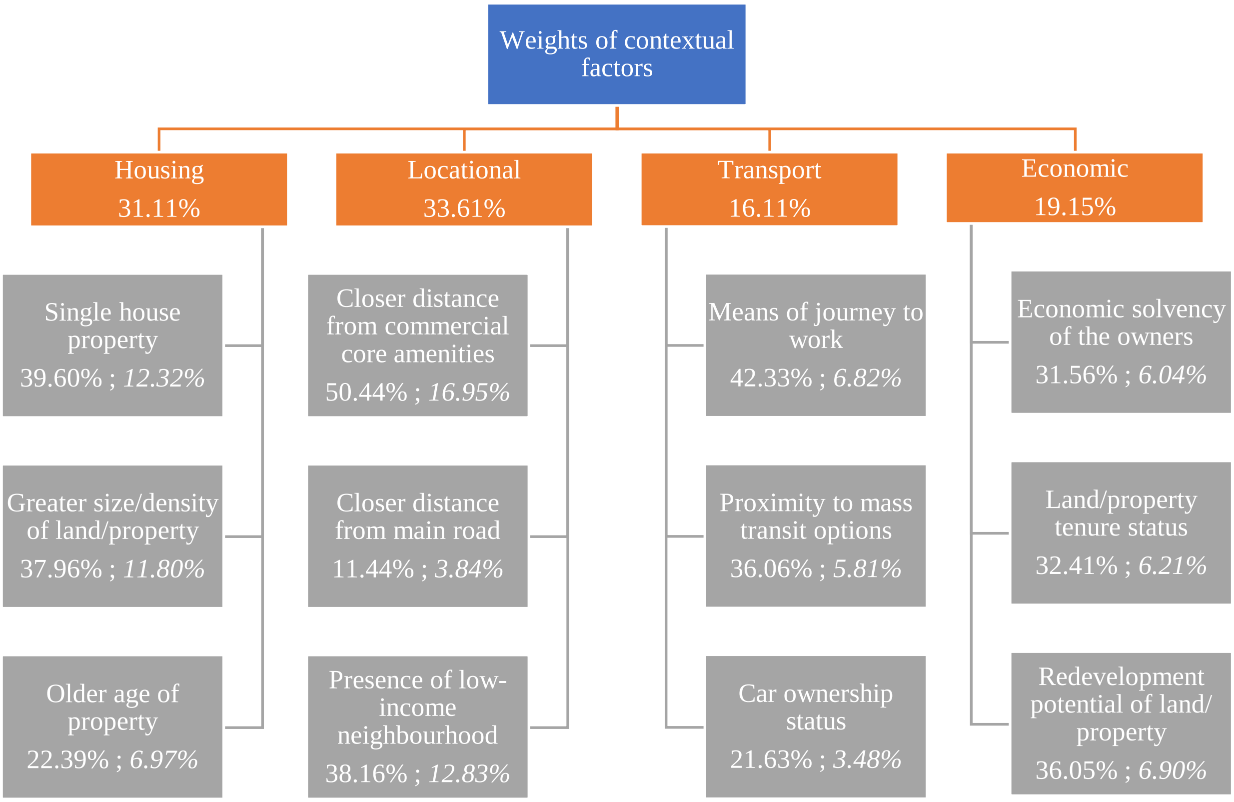


Figure 4.4 Achieved weights of contextual sub-factors from experts' survey responses

4.6 Input values for Envision

The PSS tool, Envision, receives input from the user by a numerical value for each variable that is selected. The tool allows users to select (and weight) a variety of variables, to produce a choropleth (thematic map) as an output. The input method in the tool for a variable is to select the checkbox next to a variable and slide the bar to choose a value between 0 and 10. When more than one variable is selected, it compares the values given for each variable to produce the thematic map. For example, if 10 is the value for variable A and 5 for variable B, it signifies that A carries double the weight or importance of B.

Table 4.9 Criteria weights of contextual sub-factors as inputs for the PSS tool, Envision

Contextual factors and sub-factors	**Input values for attributes in Envision**	
	Value of a variable by contextual sub-factors	Cumulative value, considering all subfactors
Housing		
a) Single house	4	1
b) 4 to 6 persons per household c) 3 to 5 bedrooms or more per house	4	1
d) Older building	2	1
Location		
a) Near primary, secondary and tertiary schools b) Near district and strategic centre c) Near local centres d) Near medical facility e) Near park	5	2
f) Near main road	1	0
g) Socio-Economic Indexes For Areas (SEIFA) low	4	1
Transport		
a) JTW via mass transit b) JTW via walking or cycling	4	1
c) Near bus d) Near train station	4	1
e) One vehicle per household	2	0
Economic		
a) Income $2k to $4k (per week per household)	3	1
b) Mortgage paid off	3	1
c) Development efficiency d) Presence of extra land e) Dwelling capacity	4	1

The survey of the experts collected data for comparison of the importance of contextual factors and sub-factors, i.e., criteria and sub-criteria in AHP theory. The weights of contextual sub-factors within a contextual factor are listed in the second column of Table 4.9, and the cumulative values of each sub-factors compared to all the contextual sub-factors are listed in the third column. The inputs from the second column can be used to produce thematic maps according to each contextual factor, such as housing, locational, transport and economic factors, while the third column values are the Envision inputs that produce the thematic maps developed according to the respective values of each variable compared to one another.

4.7 Summary

This chapter presented a method for determining the individual weights of the contextual sub-factors by pair-wise comparison of the multi-criteria decision-making process. The results of the survey of experts from the relevant fields indicated that the contextual factors related to housing and location are more influential than the transport and economic contextual factors. The results also showed that a single house property with a more significant land size is preferable for redevelopment because it can accommodate more dwellings. The lots close to the commercial core that are also located in the low-income neighbourhoods are more likely to receive a positive uplift in land value. The car ownership status of a community is not a hurdle if planners desire to change the mode of commuting to reduce car dependency. However, the value of land compared to the whole property itself is a significant determinant to push the owner to agree to redevelopment. The input data for the PSS tool, Envision, were also presented here, derived from the analysis of the experts' views using the Analytic Hierarchy Process.

CHAPTER 5: DETERMINATION OF THE POTENTIALITY OF PROPOSED TRANSIT CORRIDORS

5.1 Introduction

This chapter describes the concept and capabilities of the Envision tool, which is used to identify land parcels that are suitable for redevelopment to facilitate urban regeneration along a proposed transit corridor. This web-based PSS tool is proficient in combining layers of data relating to property, planning, utilities and demographics into a distributed (shared) urban spatial information system where users can assign a weight to each individual factor in order to generate a 'heat map' of a particular planning scenario. Chapter 4 described how the weight of each individual factor had been determined through use of the Multi-Criteria Decision-Making (MCDM) model. This chapter describes the method and workflow of using the Envision tool to prepare the data for use in the Land Use and Transport Integration (LUTI) model. The LUTI model was then used to determine the viability of the preferred transit corridor, which had been identified through Envision, regarding the suitability of a particular mode of transport.

5.2 Background

The software tool, Envision, is an outcome of a research project named "Greening the Greyfields" (GtG) that was launched in 2011 as a partnership project between Curtin University, Swinburne University, the CRCSI and several state and local government authorities in Australia. Its aim was to develop tools and strategies to address sub-optimal infill patterns in existing suburbs and curtail the effects of urban sprawl (Glackin, Trubka, & Dionisio, 2016). This research project attempted to develop a combination of geospatial tools that would be capable of addressing urban infill more strategically to promote sustainable outcomes for urban growth.

The GtG project covered many important aspects of urban regeneration of greyfields. The project was comprised of research that focused on:

- the benefits of urban agglomeration and avoidable costs provided by infill (Trubka, 2011), developing a software tool for stakeholders (primarily local governments) to determine the potential location of precincts for urban regeneration;
- development of a system for designing and visualising precinct redevelopment scenarios in 3D and assessing their performance; and finally

- to corresponds the project implementation, this project targeted the identification of statutory obstacles to precinct redevelopment in the greyfields to propose legal mechanisms to facilitate urban regeneration (Newton et al., 2012).

The Envision tool developed as an outcome of the GtG project, and was used to assist planning efforts in one of the middle suburb regions of Melbourne, the City of Manningham, to determine the potential location of precincts for urban redevelopment. The challenge was met to use this tool to determine the location of potential precincts along a few nominated transit corridors, which had been selected by the council based on an internal financial review in terms of relocation costs of subterranean services. Similarly, it is hoped that the outcomes of this current study will support the City of Stirling (CoS), the largest local council by population in Western Australia, in making the most strategic decision about the suitability of any proposed corridor for Light Rail Transit (LRT) in the coming future. It is anticipated that the development of a dependable framework that facilitates urban regeneration in the middle suburbs of car-dependent cities can be utilised, worldwide, if it can meet the similar challenges.

5.3 Envision

Envision is a useful greyfield precinct regeneration tool that has been designed as a web-based Planning Support System (PSS). It integrates multiple layers of property, planning, utility and geographic data into a shared spatial information system that will enable exploration for potential sites that can provide redevelopment opportunities to support strategic infill. The system is accessible through the Australian Urban Research Infrastructure Network (AURIN) (AURIN, 2018). The software is comprised of four geospatial tools. The first two facilitate site identification via multi-criteria evaluation (MCE). The third tool enables precinct identification and the fourth tool analyses the economic viability of redevelopment scenarios. In this research, the first three tools have been used extensively. The viability tool was not used because the economic viability analysis of a mass transit corridor does not only depend on the profit from redeveloping individual land parcels. Additionally, it is concerned with the land use mix, the desired Floor Area Ratio (FAR), expected patronage from the projected population density in regard to mode share, etc., which eventually bring economic vibrancy to a public transport corridor. The Land Use and Transport Integration (LUTI) model (described in Chapter 6) was used to assess the transport and real estate yields to determine the viability of a particular transit corridor, instead of calculating the mere profit of redeveloping individual land parcels with a proposed higher density.

5.3.1 Tools of Envision

The objective of the MCE technique is 'to investigate a number of possibilities in light of multiple criteria and conflicting objectives' (Voogd, 1983). This analysis technique integrates a set of variables (termed 'decision criteria') by normalising their values on a zero-to-one scale, weighting them regarding their relative importance, then combining them to form a composite index or summary score (Nyerges & Jankowski, 2009). The first two multi-criteria tools, *Detailed Context* and *Regional Context/Demographic Context,* deal with property level data, with indicators of characteristics from small census (SA1) zones that include tenure, age, income, car ownership, journey to work, etc.

> *"…The range of decision criteria is broad, incorporating indicators derived from property, planning, infrastructure and census datasets, necessitating users to select those that are most pertinent to specific regeneration strategies (in their local governments or institutional bodies) and weight them accordingly. Envision's MCE tools allow simultaneous analysis of ecological, geographical, infrastructural, and economic factors, and produces maps that illustrate the result of multiple interests. This is a powerful functionality to help LGAs in facilitating consensus in groups with potentially divergent perspectives, such as co-design sessions, charrette processes, workshops in local governments with officers from different departments, or discussions between state and local governments" (Glackin, Trubka, & Dionisio, 2016, p. 3).*

The author of this research was given access to the dataset of a local government authority of Western Australia, the City of Stirling (CoS), solely for academic purposes, especially for this research. The dataset used in this study was configured and updated to 10th August 2015 at the request of the council. Additionally, since the user interface for each analysis area is metadata driven, shortfalls in data can be overcome when new datasets become available by adding them to the system and updating the metadata.

The precinct identification tool allows users to refine their decisions by controlling the attributes and making a query to locate land parcels that show a high likelihood of being suitable for redevelopment. The tool selects cut-off values for a particular number of given indicators, which delivers the scenario by generating maps at the end of the process.

5.4 Workflow method of Envision

This sub-section describes the workflow method of Envision with a brief example to clarify the way of these tools are implemented. In general, the workflow includes:

- Step 1: Input the attributes from the MCE tool under the tabs of *Regional Context/Demographic Context* and *'Detailed Context* and weight them with the values attained through a justified method. In this study, they were acquired through a Multi-Criteria Decision Making procedure after conducting a survey of the experts in the related research field, as detailed in Chapter 4.
- Step 2: Step 1 produces a map in the default colour. The user can change the choropleth colour to a variation of a monochromatic colour set or a complementary colour set, as appropriate. The score class needs to be set to a suitable number (Envision allows a minimum of three variations to generate a heat map), which helps to produce maps with contrasting colours that can be read more easily.

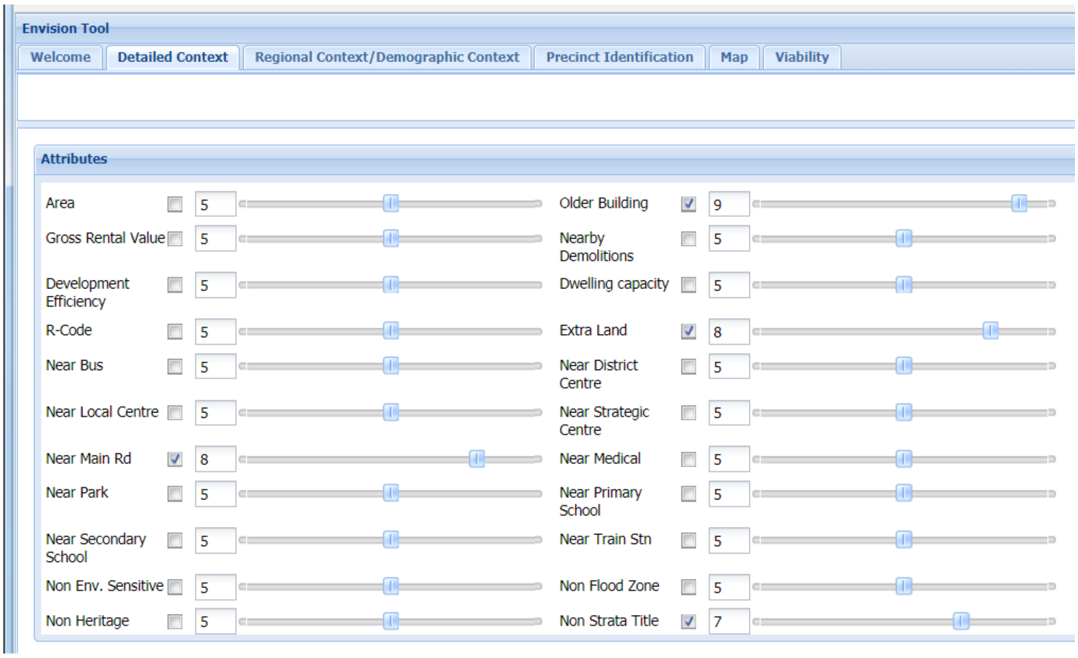


Figure 5.1 Envision 'Detailed Context' user interface, with proximity to a main road, older building, extra land and non-strata titled as the selected decision criteria

Figure 5.1 provides an example of the *Detailed Context* interface that can be used to identify the concentration of potentially redevelopable land with priority given to 'older building' (weighting of 9), those having 'extra land' in a cadastral lot (weighting of 8), 'near main road', the roads owned and operated by MRWA (weighting of 8; equal importance to extra land) and 'non-strata title' (weighting of 7). Here, the weighting of the variables was derived from logical assumptions based on the comparative importance of one over another, simply to produce an example output of the multi-criteria evaluation scenario, shown in Figure 5.2.

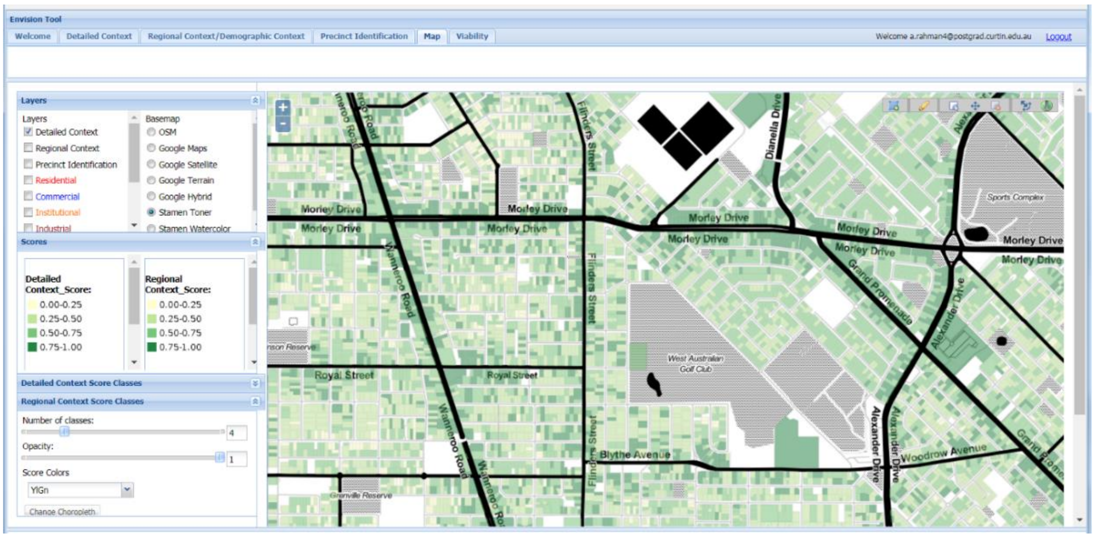


Figure 5.2 Example output from the decision criteria and weightings shown in Figure 5.1

- Step 3: The maps produced in the previous two steps, help to locate a zone of concentration of potentially redevelopable sites, based on the parameters selected with the aid of the experts' survey results. In this research, it helps to locate the prospective transit corridors suitable for mass transit or to produce a baseline to compare the alternatives by evaluating maps produced under different scenarios, e.g., housing, location, transportation and economic factors.

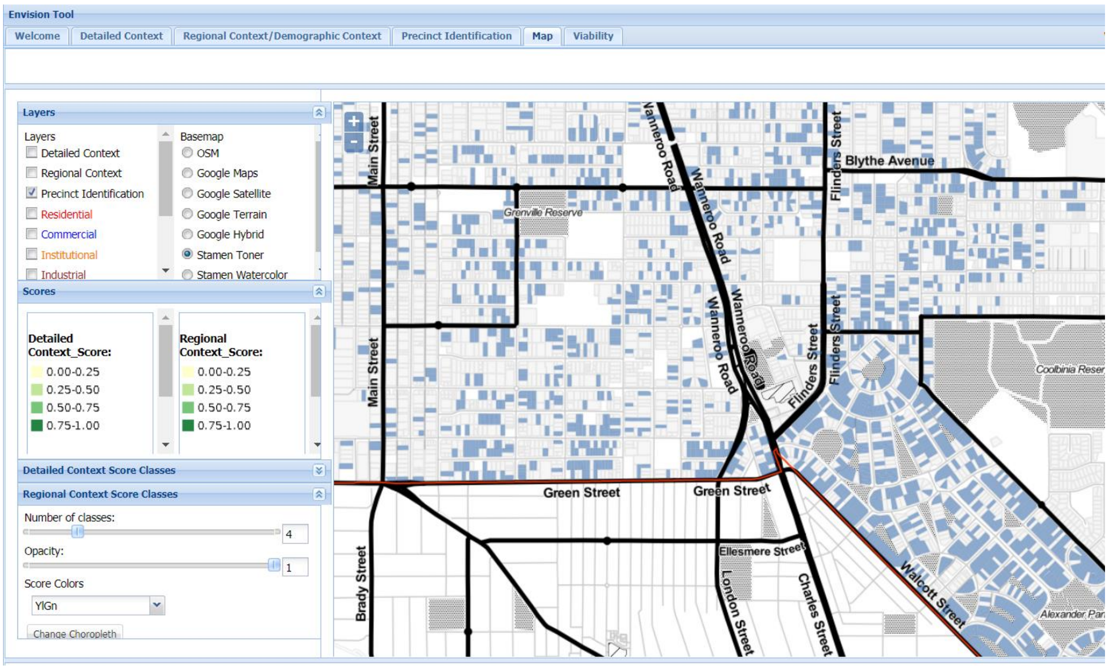


Figure 5.3 Example output of the Precinct Identification tool, showing dwellings with high redevelopment potential (index score 0.5), buildings greater than 50 years old with at least 350 square metres of extra land present within a land parcel that is not strata titled or in a flood zone

- Step 4: Once the corridor has been selected through the tools described, the third tool, *Precincts Identification*, is capable of designating the location of individual precincts or land parcels with potential for redevelopment. Again, the selection of parameters and essential attributes were derived from the responses received from the expert survey results. Qualitative judgment of the experts' opinions plays a supportive role to transform them into an appropriate scenario and to use them in the precincts identification tool. Thus, the attributes considered for the precincts identification tool were chosen based on the importance of contextual sub-factors emphasised by the opinions from the expert survey.

5.5 Export of data into LUTI Model

The land parcels identified through the precincts identification tool were exported and saved as shape files (*.shp and *.shx). All the shapes files were imported into a single file to combine all the lots that had been selected along a proposed transit corridor, using the freeware QGIS 2.14.3-Essen (QGIS, 2018).

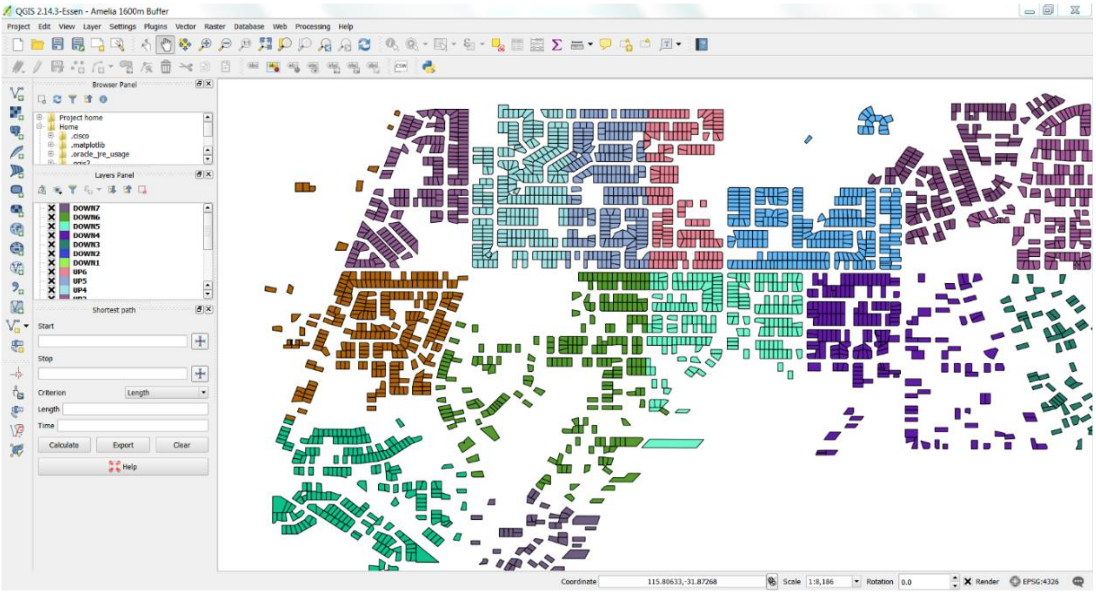
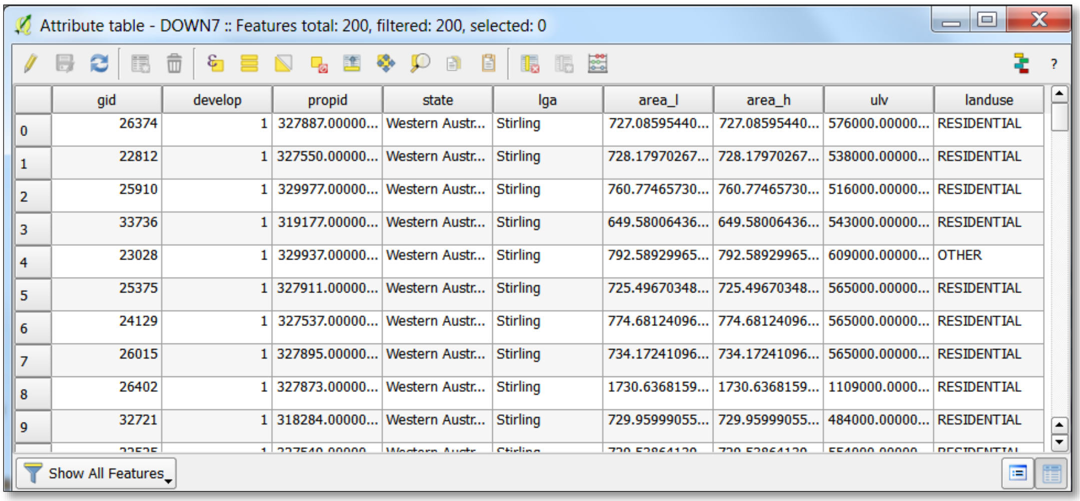


Figure 5.4 User interface of QGIS 2.14.3-Essen with a partial view of selected lots along an 800 m buffer to Amelia Street, Balcatta, WA, exported from Envision

This software is capable of exploring the embedded information associated with each land parcel that is attached to each shape file during the exporting of files from Envision. Figure 5.5 shows the list of information, such as area, land use type, etc. that is attached to shape files, available through the attribute table option of QGIS.



Attribute table - DOWN7 :: Features total: 200, filtered: 200, selected: 0

	gid	develop	propid	state	lga	area_l	area_h	ulv	landuse
0	26374	1	327887.00000...	Western Austr...	Stirling	727.08595440...	727.08595440...	576000.00000...	RESIDENTIAL
1	22812	1	327550.00000...	Western Austr...	Stirling	728.17970267...	728.17970267...	538000.00000...	RESIDENTIAL
2	25910	1	329977.00000...	Western Austr...	Stirling	760.77465730...	760.77465730...	516000.00000...	RESIDENTIAL
3	33736	1	319177.00000...	Western Austr...	Stirling	649.58006436...	649.58006436...	543000.00000...	RESIDENTIAL
4	23028	1	329937.00000...	Western Austr...	Stirling	792.58929965...	792.58929965...	609000.00000...	OTHER
5	25375	1	327911.00000...	Western Austr...	Stirling	725.49670348...	725.49670348...	565000.00000...	RESIDENTIAL
6	24129	1	327537.00000...	Western Austr...	Stirling	774.68124096...	774.68124096...	565000.00000...	RESIDENTIAL
7	26015	1	327895.00000...	Western Austr...	Stirling	734.17241096...	734.17241096...	565000.00000...	RESIDENTIAL
8	26402	1	327873.00000...	Western Austr...	Stirling	1730.6368159...	1730.6368159...	1109000.0000...	RESIDENTIAL
9	32721	1	318284.00000...	Western Austr...	Stirling	729.95999055...	729.95999055...	484000.00000...	RESIDENTIAL

Show All Features

Figure 5.5 Example of attribute table with a list of embedded information imported from Envision

The data accumulated through the QGIS attribute table was saved as a Microsoft Excel Worksheet to calculate the area (in square metres) of each land use type. This information is an essential requirement for the LUTI model. Chapter 6 describes, in detail, the process of the workflow method undertaken to speculate on the desired density scenario to establish a corridor that would be suitable for mass transit regarding trips generation by the anticipated population densities associated with different land uses.

5.6 Results

There are two types of value that were extracted from the opinions of the experts: the cumulative value of the sub-factors that reflects the weight of the variables in respect of other contextual sub-factors; and the weight value of the variables of individual sub-factors that consider the values within each contextual factor. The thematic map, produced using the cumulative value, does not express any focus in regard to the surroundings of the investigated proposed transit routes, so cannot be used to consider their potentialities with respect to each other.

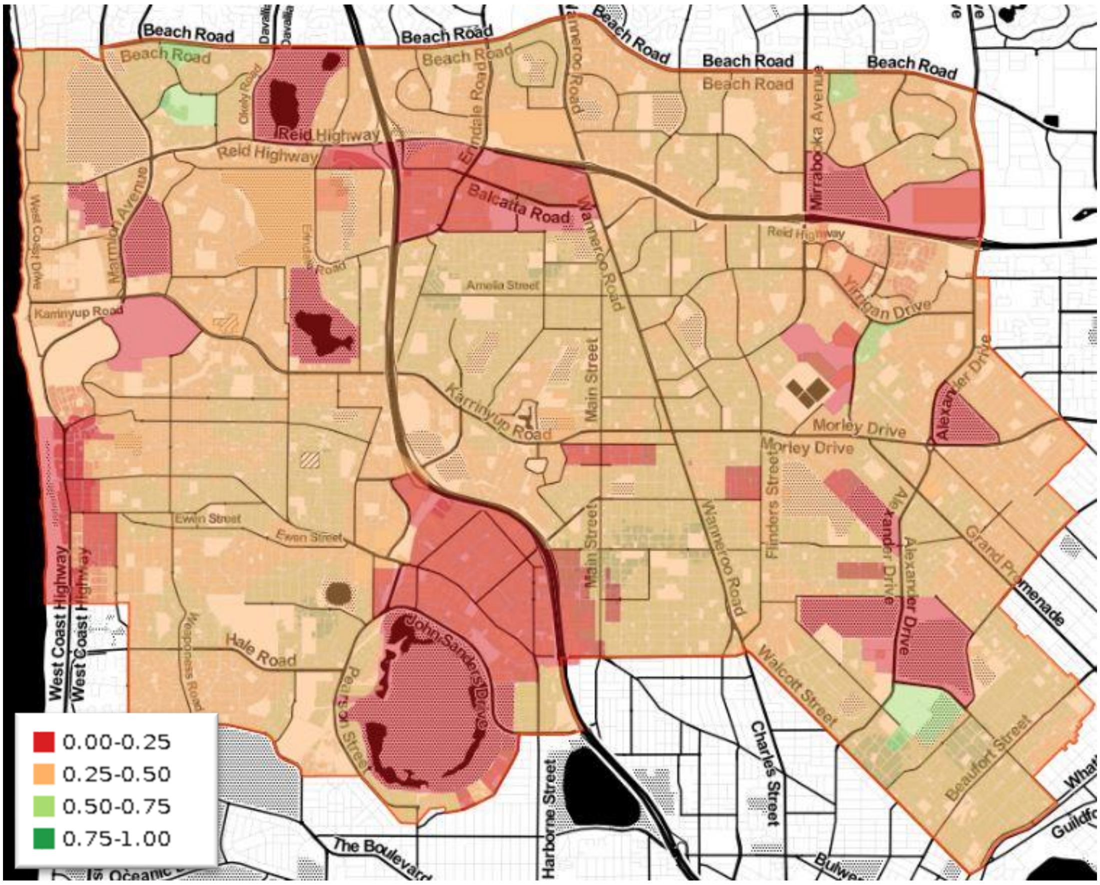


Figure 5.6 Thematic map based on the cumulative value of the contextual factors

Therefore, the context scenarios that are produced based on individual contextual sub-factors are the inevitable choice to explore the potential of each route. The individual context maps are more comprehensive tools to investigate potential areas in finer detail.

5.6.1 Housing Context

The values of the variables as inputs for the PSS tool, Envision, were acquired through the survey of experts' opinions (see Table 4.9 in Chapter 4), as described in the previous chapter. The values of the variables were set to the desired parameters to identify the concentration of lots containing older buildings, with more than two bedrooms, that were populated with greater than the average household population density of 2.6 persons per household(Australian Bureau of Statistics, 2016), while also being single house properties with no strata title. Those parameters were selected because they have more potential for redevelopment, being more prominent in lot size with close to the end of their physical lives.

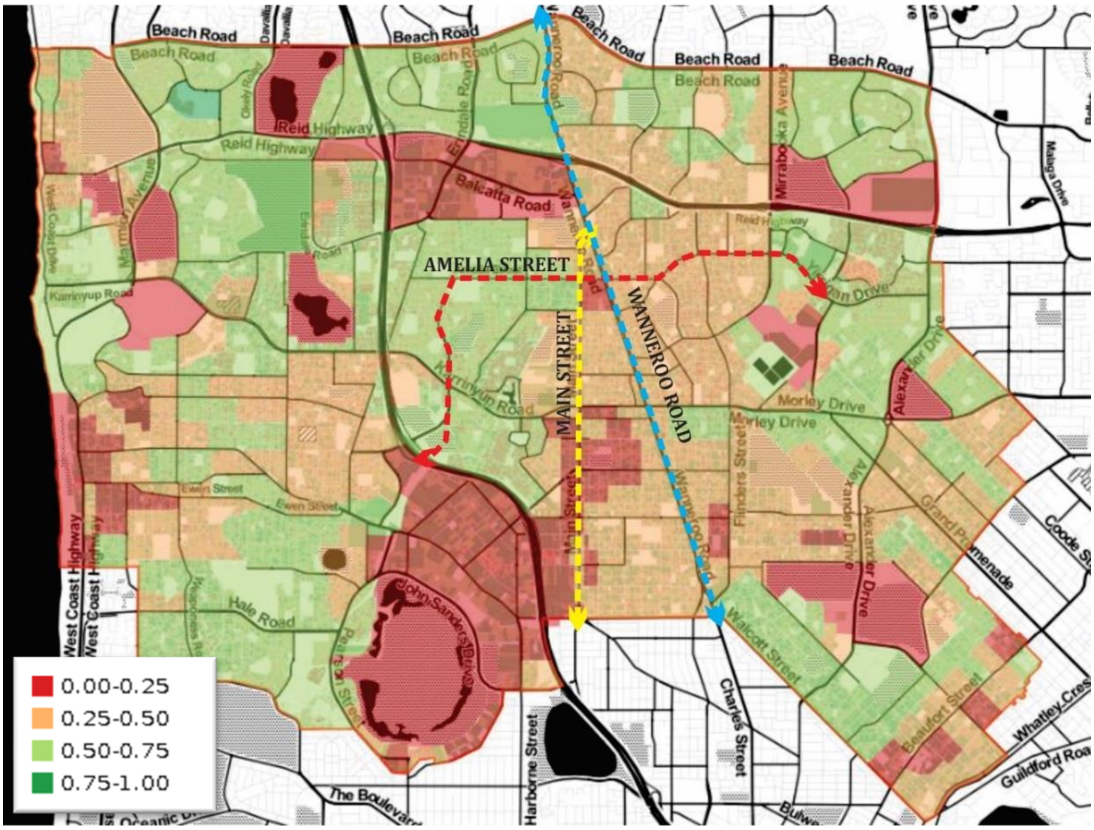


Figure 5.7 Thematic map based on housing factors

The Envision software produces a gradient map based on the parameters that have been set for contextual factors, where shades of green to red indicate highest to lowest concentration of lots as per the set values. The map in Figure 5.7 shows that the corridor along Amelia Street has a higher concentration of lots that meet all the selected criteria for housing, meaning it would provide better opportunities for redevelopment than the other two corridors, while the potentiality for Wanneroo Road is better than Main Street. So, based on the housing factor alone, the thematic map output ranks the choices as

Amelia Street, then Wanneroo Road, followed by Main Street. However, the housing factor is dominated by the physical characteristics of the lots; therefore, to fully investigate the redevelopment potential of the three routes, it is necessary to scrutinise the other major factors. The survey results indicated that the locational factor is of similar importance to the housing factor.

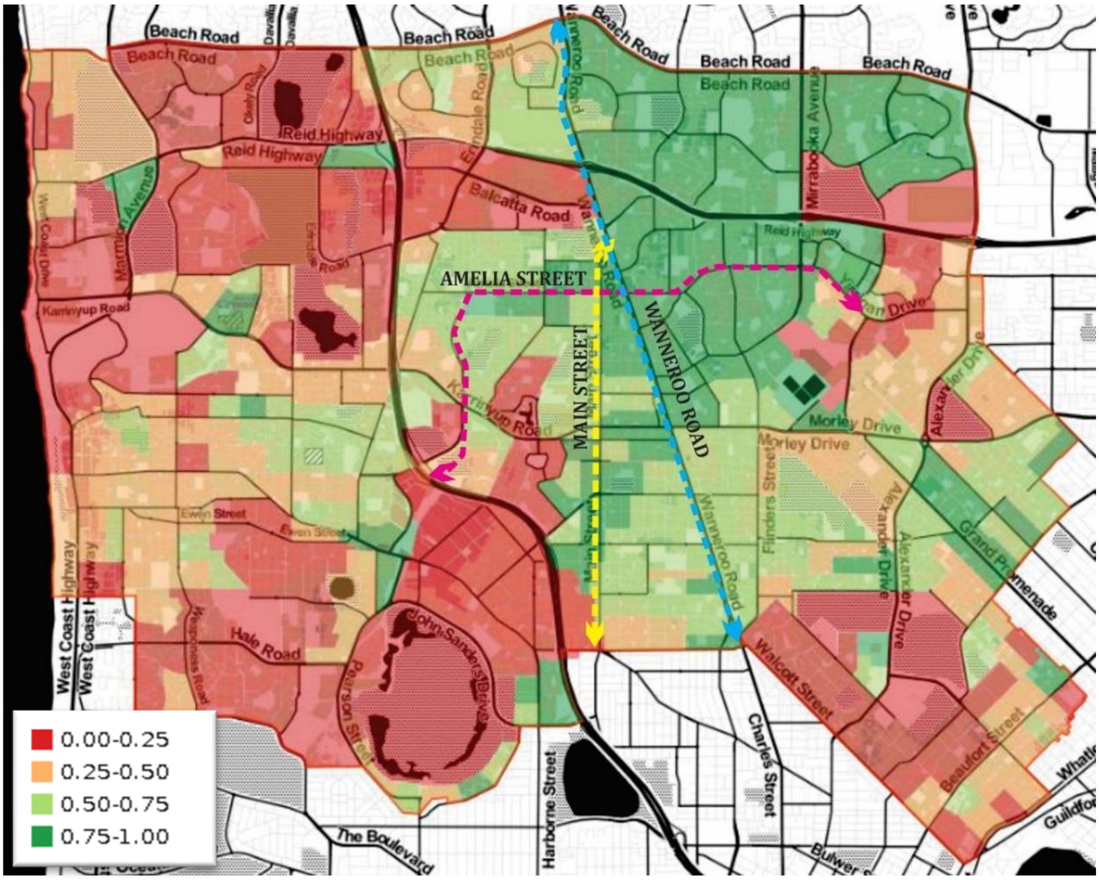


Figure 5.8 Thematic map based on locational factors

5.6.2 Locational Context

It is evident from the literature that a disadvantaged neighbourhood receives more value uplift for their land and property, when redeveloped, compared to a neighbourhood that is in an already advantageous position (Nelson, 1992; Redman et al., 2013). Apart from the advantages provided by being located close to main roads, district centres or amenities like schools, being located in a low Socio-Economic Indexes For Areas (SEIFA[15]) neighbourhood has been prioritised by the experts. So, that criterion was also

[15] SEIFA is a suite of four summary measures that have been created from 2006 Census information. The indexes can be used to explore different aspects of socio-economic conditions

used when inputting the values for the locational factor, in order to identify potential areas that might gain considerable value uplift from any proposed transit routes, thus promoting urban regeneration.

The gradient map rendered, based on the selected locational factors (Figure 5.8), shows that there are clear distinctions among the three different routes. Wanneroo Road provides the opportunity to connect a large, low-SEIFA area around Balga, Mirrabooka, Westminster and a portion of Nollamara. That ranks it highly as a potential transit route. Having the same advantage, Amelia Street is also surrounded by a greener gradient zone than Main Street, which places it higher in the rank as a potential route. Macedonia Park and the newly-developed Roselea Estate sit in the middle, between Cedric Street and Main Street, ranking Main Street lower, but not by a big margin.

5.6.3 Transport Context

People with an inclination towards a particular travel mode, such as private car, often enable themselves by selecting a neighbourhood in which to live that is favourable to that mode in particular. This is referred to as residential self-selection (e.g., Bhat & Guo, 2007; Cao, Mokhtarian, & Handy, 2007; Handy, Cao, & Mokhtarian, 2005; Van Wee, 2009). Most low-density suburbs were designed to be easily accessible by car, and car-loving persons will self-select themselves into those neighbourhoods (De Vos, Van Acker, & Witlox, 2014). Bearing that in mind, such travel–related, residential self-selection influences the travel mode choices of people, working in parallel with other actors like income, distance to work, neighbourhood type, etc., to realise their preferred travel behaviour (De Vos, Derudder, Van Acker, & Witlox, 2012; Schwanen & Mokhtarian, 2005; Schwarz, 2003). Therefore, it is always challenging to introduce a different transit mode into a car-oriented neighbourhood because it needs to have a specific density, with mixed land use. Conversely, it is equally challenging for the residents to adapt their low-density, car-oriented neighbourhood into a dense, mixed-use neighbourhood. The introduction of a new transit mode, such as LRT, is expected to welcome people who intentionally self-select themselves to live around the stations or in close proximity to the corridor. That,

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by geographic area. For each index, every geographic area in Australia is given a SEIFA number that shows how disadvantaged the area is, compared with other areas in Australia. Each index summarises a different aspect of the socio-economic conditions of people living in the area. They each summarise a different set of social and economic information. The indexes provide more general measures of socio-economic status than is given by measuring income or unemployment alone, for example. From Australian Bureau of Statistics (http://www.abs.gov.au/)

eventually, will increase the density of the surroundings, putting pressure on the mix of land uses to add more retail and commercial outlets.

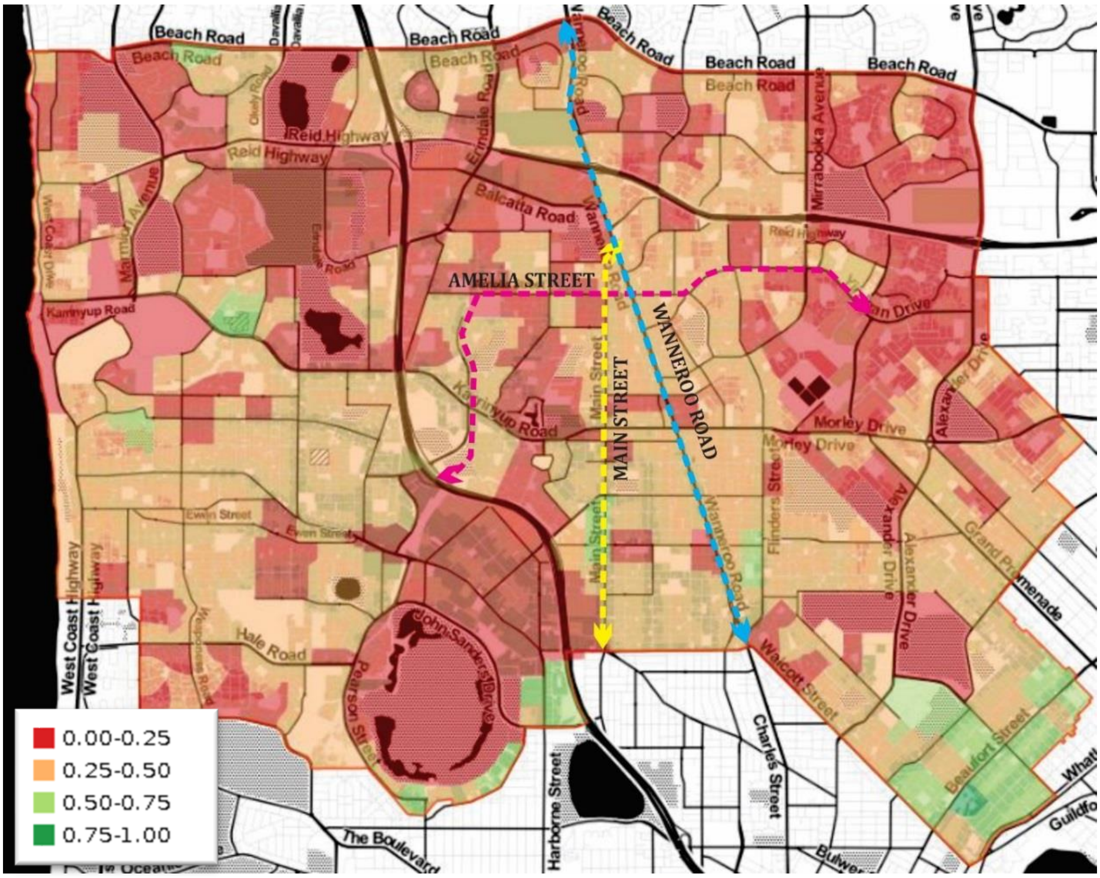


__Figure 5.9 Thematic map based on transport factors__

The localities sated with people who use mass transit and walk to a transit station for their journeys to work are the present sample of riders who potentially will be the customers of the proposed mass transit system. Conversely, the acquired value of transport factors also identifies the negative hotspots of localities who prefer to take a vehicle to work. They are the prospective consumer of a proposed transit mode and potential contributor to the reduction of traffic congestion. Strategically locating station could be useful to attract these consumers.

In the City of Stirling, 30% of the residents work within Stirling, yet 70% of trips for the journey to work are made by private vehicles (City of Stirling, 2009). According to the transport scenario map (Figure 5.9), a considerable portion of residents along Main Street and surrounding areas already walk and take mass transport to work, who can be counted upon as ready consumers for a new mass transit mode. Conversely, people living in the surroundings of the upper portion of Wanneroo Road (from Morley Drive to Beach

Road) are a comparably higher vehicle-reliant community who can benefit from a mass transit option such as LRT to reduce traffic congestion. However, taking account of all the surroundings, the circumstances of Main Street are fairly similar to Wanneroo Road, while people living around Amelia Street are most heavily reliant on private vehicles. Therefore, Main Street can be counted as having the most potential regarding readily available consumers for any proposed transit mode, putting Wanneroo Road in second place and Amelia Street last.

Cervero (1994), while examining ridership impacts on people, found that the share of switchers between transit modes sometimes exceeds 50%. People who prefer to take advantage of mass transit (to reduce daily commuting cost) may self-select themselves to live around mass transit routes that are currently active. Since Wanneroo Road already has established bus routes, it might be well-accepted by the current riders to share or switch modes if a new option is provided. Also, there are more commercial lots present on this road compared to the other two corridor options, so a change of land use along this route that attracts more riders could accommodate retailers who, in turn, would influence commuters' shopping habits, making a significant impact upon the vibrancy of the surroundings.

5.6.4 Economic Context

In response to the infill target of 47% that has been set for Perth (Western Australian Planning Commission, 2010), it is necessary to adopt a mechanism in any planning system that discourages development at the fringes. To identify a potential area for redevelopment around any prospective transit corridor from an economic perspective, attributes like dwelling capacity (number of dwellings the lot can accommodate) and development efficiency (ratio of existing dwellings to maximum dwelling capacity under current zoning), as well as being non-strata titled and/or having extra undeveloped land within the land parcel are definite pluses for planning professionals and land developers. It is assumed that, where the lot is occupied by the owner and the mortgage has already been paid off, the owner might respond more enthusiastically to any proposal for a development project.

Figure 5.10 Thematic map of mortgage payment scenario showing A: mortgage paid off; B: mortgage less than $1K per week and C: mortgage $1K-2K per week

Envision produces maps that use logic to count all the variables. It then renders the lots that satisfy all the conditions. The thematic maps in Figure 5.10 show the comparative scenarios for mortgages, ranging from 'paid off' to '$1K-2K per week', where it is evident that the 'paid off' scenario is more or less similar for all the routes and there are only meaningful changes when the other scenarios have been chosen. The map of the 'paid off' variable fails to reflect the actual situation by shading red almost the entire area of the map, leaving no meaningful information due to its rendering of lots that satisfy all the conditions together. Therefore, omitting the 'paid off' clause from the economic scenario building, or selecting a variable that more clearly identifies the lots with a low financial burden, makes the thematic map more useful. The map in Figure 5.11, therefore, also considers the location of the lots that would provide greater development efficiency, contain extra land inside the cadastral boundary and have greater capacity to accommodate additional density.

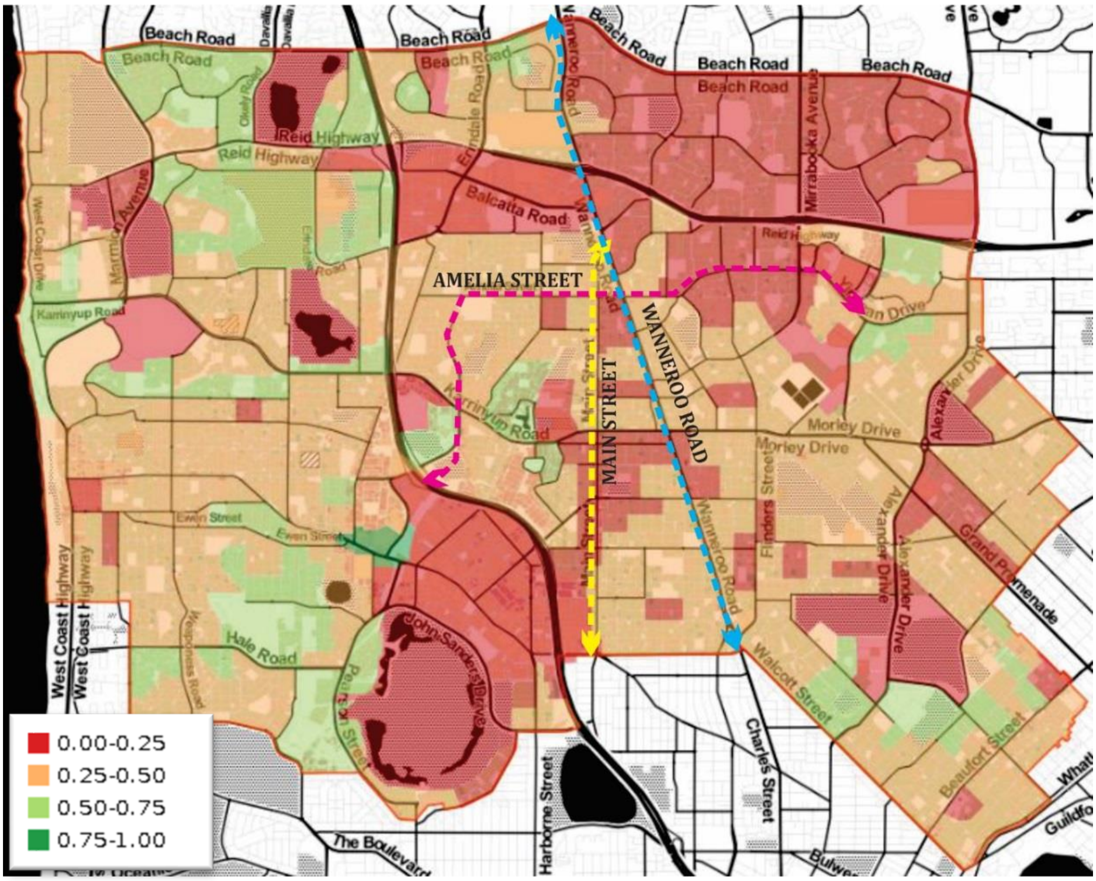


Figure 5.11 Thematic map based on economic factors

The economic factors weighted by the experts were chosen to make a concerted effort to recognise the zones with high development efficiency, parcels with extra lands to develop and where dwelling capacity is currently unused. The owner-occupied lots with low financial burden regarding mortgage repayment, with residents who have a higher weekly income than the average of $1,516 per week, (Australian Bureau of Statistics, 2016) are those where the owners are more likely to accept redevelopment when any transit development project is announced and initiated.

The scenario map rendered by economic factors (Figure 5.11) identifies Amelia Street as having more potential as a mass transit route than Wanneroo Road and Main Street, due to having greater development efficiency. The probable cause behind this would be the presence, around Amelia Street, of more owner-occupied, single houses with non-strata titles.

5.7 Comparing the potentiality of the routes

The visual representations of the maps make it much easier to judge the contexts than pages of data, but they can be prone to subjective judgemental error. However, with very few exceptions, the thematic maps are quite clear and distinctive, allowing the routes to be ranked in order. Assigning a 'scale of value' score (3: ranked first; 2: ranked second; and 1: ranked third, as in Table 5.1) to each context for each individual route, the combined results can be summarised graphically (Figure 5.12) where the potentiality of the routes can be immediately detected: the greater the area of the polygon, the higher the potentiality of the route for setting up a mass transit corridor.

Table 5.1 Ranking of contexts for each route

Routes/Context	*Housing*	*Location*	*Transport*	*Economic*
Amelia Street	3	2	1	3
Main Street	1	1	3	1
Wanneroo Road	2	3	2	2

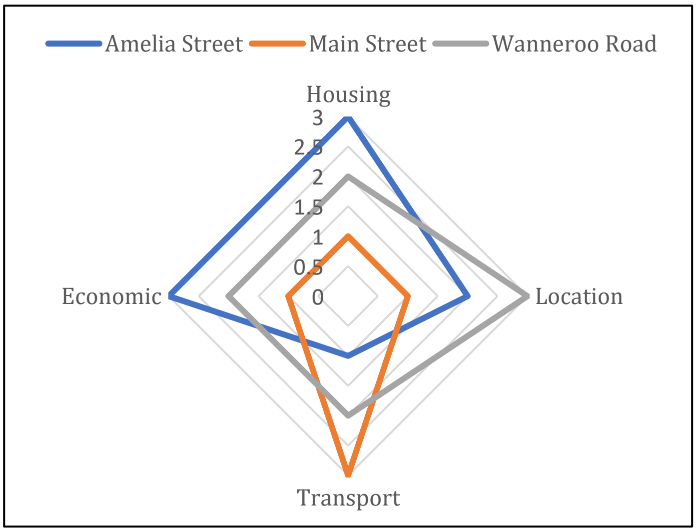


Figure 5.12 Ranking of routes by score for each context

Table 5.2 Ranking of routes in relation to the CR values expressed for contextual factors by the experts

Routes/Context	*Housing*	*Location*	*Transport*	*Economic*	*Total Score*
Amelia Street	0.933375	0.67225	0.161125	0.5745	2.34
Main Street	0.311125	0.336125	0.483375	0.1915	1.32
Wanneroo Road	0.62225	1.008375	0.32225	0.383	2.34

Finally, to differentiate between the proposed routes regarding redevelopment potential to facilitate urban regeneration, the scores have been multiplied by the ratio of importance expressed by the experts (for each contextual factor) to provide a composite total score. The result shows that Amelia Street and Wanneroo Road have equally high potential, and they are both ranked ahead of Main Street.

5.8 Land Parcel Identification

The *Precinct Identification* function of the PSS tool Envision uses variables that are related to the same kinds of variable that are listed in both the *Detailed Context* and *Regional Context/Demographic Context* functions. This function allows users to refine their decisions by making a new query that chooses different variables. However, the input values to this function differ from the other two because they need to be defined by specific parameters (e.g., square metres for land area, metres for distance from amenities and dwelling capacity ratio by any constant value) instead of a weighting for comparison with each other. The objective is to identify the land parcels that are likely to be redeveloped along any nominated route. The variables of the *Precincts Identification* function were selected in respect of the importance attached to the contextual sub-factors by the experts.

If we summarise the experts' opinions on the contextual sub-factors, it expresses their inclination towards the features that a land parcel should possess to best respond to any redevelopment initiative that is triggered by any transport infrastructure such as a mass transit corridor. The typical properties of the target land parcels would be the following, by contextual factors:

- Housing: lots with a single house where the building is old enough to be considered for redevelopment;
- Locational: close to the commercial core and amenities like schools, parks and medical facilities;

- Transport: within the proximity of transport facilities like bus stations;
- Economic: land that exhibits development efficiency, i.e., the presence of extra land to accommodate additional density with greater dwelling capacity.

The values of the selected variables are set through sound judgment in practical matters and reference to the available published literature. It was decided to identify the lots that are 45 years old or greater because it was assumed that their owners would be more likely to be interested in any redevelopment potential brought about by a transport infrastructure investment project. Considering these circumstances, it is worth mentioning that, according to the Building Commission (www.commerce.wa.gov.au/building-commission), residential building work contracts in Western Australia are governed by the Home Building Contracts Act 1991 (National Association of Home Builders, 2002). Practically, builders insure a home for six to seven years in the name of the initial owner as a 'lifetime warranty' for certain kinds of damage because it is assumed it will be sold to a second party within this period, thus ending the legitimacy of any insurance. However, the author could find no academic reference to support this.

The Residential Design Code varies among the selected routes. For example, the lots along Amelia Street are R20, while Main Street and Wanneroo Road are R40. The minimum lot area also varies between different R-Codes[16], which makes it difficult to fix a minimum lot size to select from among the potential lots. The higher the R-Code, the smaller the lot size can be to accommodate the density. Therefore, the size ranges of the lots are not bracketed in a single value because an appreciation of land value depends on other factors as well. It is expected that lot size will not be an issue that prevents owners from taking advantage of any proposed changes to R-Code zoning.

[16] The R-Codes control the design of most residential development throughout Western Australia. The R-Codes aim to address emerging design trends, promote sustainability, improve clarity and highlight assessment pathways to facilitate better outcomes for residents. They are also used for the assessment of residential subdivision proposals (www.dplh.wa.gov.au/rcodes).

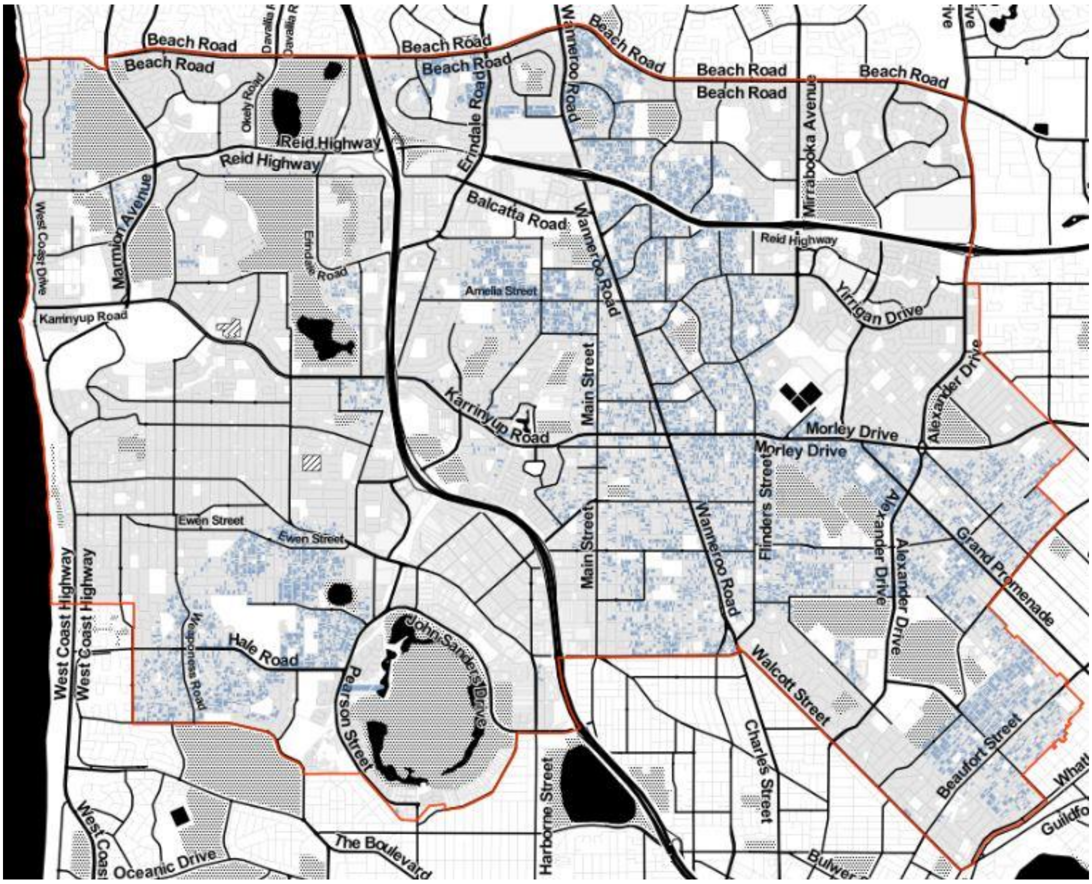


Figure 5.13: Identified potential land parcels (in blue) as per the set values for 'Precincts Identification' function

For the attributes related to proximity, under the location and transport factors, it was assumed that 800 metres is a comfortable walking distance (Untermann, 1984) from any proposed mass transit corridor. This argument is supported by the fact that the extent of influence for land value appreciation uses a similar distance of 1,000 metres for residential areas (RICS Policy Unit, 2002) for rail transit projects. McDonald, Deakin, and Aalborg (2010) studied children between the ages of 10 and 14 living in the San Francisco Bay Area, USA, by surveying their parents. They chose this age group because previous research found that children in the United States begin to travel independently around the age of 10, meaning that children of this age might be allowed to walk or cycle to school (Matthews, 1992). For trips under 2 miles (3.2 km), 42% of children in the study walked or cycled to school, a rate that is comparable to the overall USA average for this distance. In this study, we assumed that 3 kilometres would be a permissible distance for schoolchildren to walk or ride a bike to a primary or secondary school. Practical judgment was used to set the distances to medical facilities and parks as 5 kilometres and 500 metres, respectively.

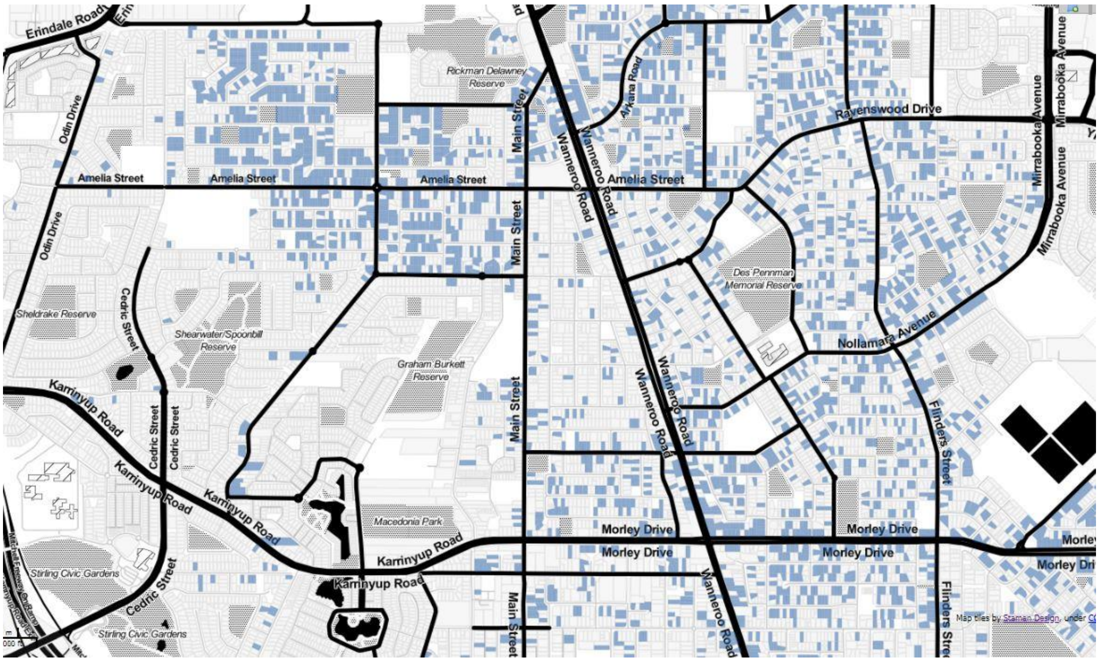


Figure 5.14: Identified potential land parcels (zoomed close to the proposed routes), shown in blue

A nearby mass transit mode, such as a bus stop, was presumed to be in close proximity if it was within the comfortable walking distance of 800 metres.

The value of the Property Redevelopment Potential Index (PRPI)[17] was set to 'more than 0.5' which means that, when the selected property value is half the land value or less, that signifies a greater likelihood of redevelopment potential. Development efficiency and dwelling capacity were set to ≤1 and ≥1, respectively, to discover the lots that could accommodate at least one more dwelling within the land parcel. The 'size of extra land' was set to ≤380 square metres as per the minimum lot size requirement for R40 of the residential design code, in the hope that the R20 lots around Amelia Street could be

[17] An index of property redevelopment potential (PRPI) can be calculated for all individual residential properties within municipalities using property valuation data held by the Valuer-General. The property redevelopment potential metric for each parcel is calculated as the ratio of the land value (numerator) to capital improved value (land value plus value of the built assets on that site—the denominator). A PRPI approaching 1.0 indicates that the value of the property is represented almost entirely by the land component and, as such, it is more economically viable for redevelopment compared to properties with PRPIs of 0.5 or less. This is commonly used as a principal selling feature at auction. The hypothesis that properties with a high PRPI that come onto the market are redeveloped at a more rapid rate than those with a low PRPI was tested and confirmed by Newton (2010).

rezoned to at least R40 in the future if that route was selected, because that would be a significant contributor in increasing residential density.

The lots identified using the selected variables and described values are shown (shaded blue) in Figures 5.13 and 5.14). It can be seen that there are more potential lots available near the Amelia Street and Wanneroo Road routes compared to Main Street. The next sub-section concentrates on the generated numerical figures to understand the potentials of the routes by monetary value.

5.9 Facts and figures

The potential sites for redevelopment along the proposed routes that were selected through the *Precincts Identification* function of Envision were exported to QGIS (version 2.14.3-Essen) as shape files, equipped with embedded properties, e.g., area, number of lots, etc. Figure 5.15 shows the identified lots within a 1,600 m buffer zone along each route. The span of the buffer zone was selected based on findings from the literature review in Chapter 2 of this thesis, whereby this span is considered to be an influential zone for land value uplift due to any mass transit transport infrastructure project. The zone can be extended up to 2,400 m for heavy rail; however, this research has considered a conservative scenario to avoid any over-hyped speculation.

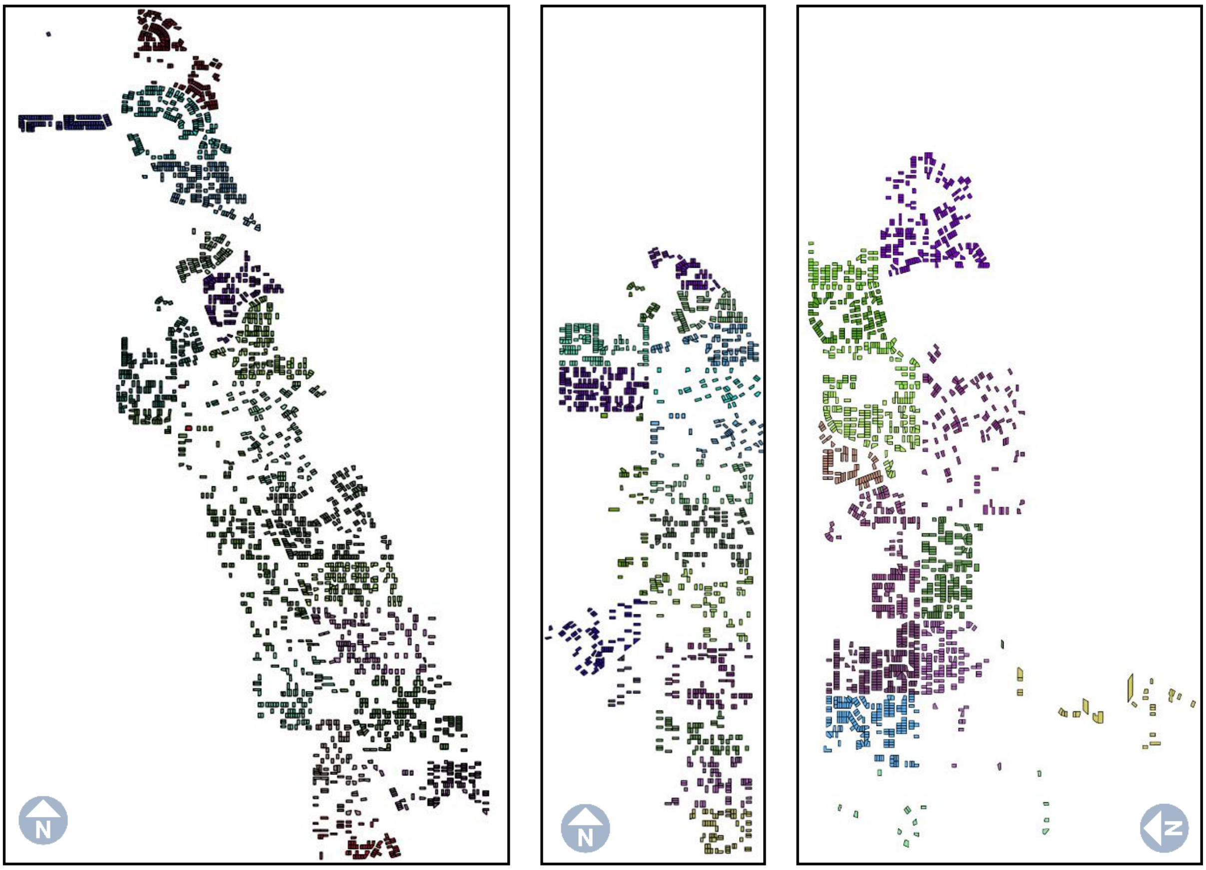


Figure 5.15 The 1,600 m buffer zones along the routes, from left to right, Wanneroo Road, Main Street and Amelia Street

Envision has the capability to select lots either by clicking on each lot or by drawing a polygon around any lot/precinct to select all the lots within the drawn boundary of the polygon, irrespective of other properties. This research decided on the first option, to enable selection only of those lots that have been identified as having potential. Of course, there is a chance of error, but it is expected to be well within the margin of error for this sort of calculation.

There are two major sections in Table 5.3 that display the residential development yields from the identified lots and the cost savings from numerous aspects of an urban lifetime over 50 years[18], based on the calculations by Trubka, Newman, and Bilsborough (2008). Their research assessed the economic costs of urban development decisions in Australia by comparing inner-city redevelopment and conventional fringe development. According to Trubka, Newman, and Bilsborough (2008), the cost saving factors for redevelopment are listed below.

a) Emissions and health savings are closely related to active forms of travel that are only realisable in areas with high levels of amenity and service, and high levels of transit access. Their cost savings over a 50-year urban lifetime are quite modest, \$19.32 million and \$4.23 million (upper estimate is \$5.85 million) for 1,000 dwellings.
b) If the redevelopment endeavours to pursue more walkable, low emission developments, the savings in transport and infrastructure for 1,000 dwellings are in the order of \$86 million up-front (capital cost) for infrastructure and \$250 million for annualised transportation costs over 50 years.
c) The research tried to accumulate a cumulative economic impact statement of alternate development patterns by comparing a consolidated, inner-city type of development with a dispersed, outer-city type of development. Combining all the cost savings from infrastructure, transport, emissions and health-related aspects, the inner and outer types of development incur costs of \$323,590,426 and \$684,103,839, respectively. The total cost savings would be around \$360 million for 1,000 dwellings over 50 years.

[18] A capitalisation period of 50 years was chosen for the entire economic assessment of urban form under the assumption that 50 years is a reasonable average life expectancy of a residential development. Beyond 50 years, the decision to redevelop an area may be made once again (Trubka et al., 2008).

This research considered that the proposed redevelopment would be single storey housing where the average size of dwelling would be 111 square metres, assuming that 75% of the dwellings would be 100 square metre units while the remaining 25% would be 220 square metre individual houses, to maintain a balance between existing and projected dwelling densities.

The statistics in Table 5.3 signify that the Wanneroo Road route has the highest number of potential lots (2,246) with a total gross land area for the redevelopment of 180,2936 m^2 that saves total cost of around $6 billion based on Trubka, Newman, and Bilsborough (2008).

Table 5.3 Monetary value of areas with redevelopment potential within a 1,600 m buffer zone of proposed routes

	Proposed routes	**Wanneroo Road**	**Main Street**	**Amelia Street**
Redevelopment possibilities within 1,600 m buffer zone	Number of potential lots	2,246	1,167	1,500
	Area Total (in m^2)	1,802,936	992,462	1,204,878
	Number of dwelling units	16,243	8,941	10,855
Cost savings over 50 years (in $million)	Emissions	313.81	172.74	209.71
	Health	68.71	37.82	45.92
	Infrastructure upfront costs	1,396.87	768.93	933.51
	Annualised transportation costs	4,060.67	2,235.27	2,713.69
	Total development costs	5,855.81	3,223.45	3,913.36

Considering the economic aspects stated above, Wanneroo Road easily secured the top position, with Amelia Street in second place and Main Street, not far behind, showing the least potential to be considered for a mass transit corridor to facilitate urban generation.

5.10 Summary

In this chapter, the concept and workflow method of the PSS tool, Envision has been described in detail. Results of the investigations for the three proposed routes for a mass transit corridor were also discussed, using the visualisation outputs from the tool. The thematic maps assisted in analysis of the potential areas along each of the routes to determine their potentiality and prospects.

This chapter helped to identify and compare the potentiality of each corridor regarding their capability to work as a catalyst to facilitate urban regeneration for the surrounding catchment area. However, to determine an 'aspirational' density for a transport mode envisaged by local government is also an important aspect to consider. The next chapter describes the Land Use and Transport Integration (LUTI) model, and its mechanism for determining the transport mode that would be most suitable for each corridor or, in other words, determining the desired population density that would be required for any transport mode that is already being considered by the authority.

5.11 Copyright Declaration

QGIS 2.14.3-Essen is a free and open source geographical information system where all content is licensed under Creative Commons Attribution-ShareAlike 3.0 licence (CC BY-SA), if not stated otherwise. Full terms at https://creativecommons.org/licenses/by-sa/3.0/

Envision is an e-tool, a decision support system where the datasets are provided via the Australian Urban Research Infrastructure Network (AURIN) Portal and their contents, to the extent they are protected by copyright, are provided under a Creative Commons licence. The e-tool is accessible at https://envision.aurin.org.au/envision and accessed on 17 December 2019.

CHAPTER 6: DETERMINING REQUIRED DENSITY FOR DIFFERENT MODES OF PUBLIC TRANSPORT FOR A MASS TRANSIT CORRIDOR

6.1 Introduction

This chapter describes the rationale behind the Land Use and Transport Integration (LUTI) Model and its workflow method. It is used to speculate on the most desirable density required to establish a corridor and the most suitable mode of transit regarding trips generation by the anticipated population densities of different land uses.

6.2 Background

The Envision tool (described in Chapter 5) helps to identify the land parcels that are potentially profitable for redevelopment to facilitate urban regeneration, after being scrutinised by a long list of factors and sub-factors. This chapter concentrates on determining the desired population density that a transit corridor needs to be viable for a particular transit mode. In doing so, the accumulated total of different land uses, e.g., residential, commercial, industrial and retail, is inspected through the spreadsheet-driven LUTI model to determine a density scenario that would generate enough patronage for a specific transit mode. The model itself is far more complex and is capable of producing more relevant information like effects on land value uplift. However, in this research the LUTI model has been used to demonstrate a few scenarios to validate a choice of transit mode (or to assess the applicability of a transit mode) for the prospective transit corridors. The model is used to determine the desired level of development density in terms of Floor Area Ratio required for each transit route to achieve enough patronage to operate for a certain period of time in a day. It validates the transport mode in terms of patronage capacity, by calculating the daily trips generated from an anticipated density under different land use options for selected developable land parcels around any proposed transit corridor, comparing the capabilities of different transport modes to accommodate the likely patronage. Additionally, it calculates the difference in real estate yields for each scenario, based on the reduction in parking spaces offered by the transit capacity of different transport modes.

6.3 The methodology of the LUTI model

The workflow method diagram in Figure 6.1 shows the required input information and the expected output of this study.

- Firstly, the land parcel area, or Gross Land Use (GLU), of each land use type is multiplied by the Floor Area Ratio (FAR) to calculate the Gross Lettable Area (GLA).

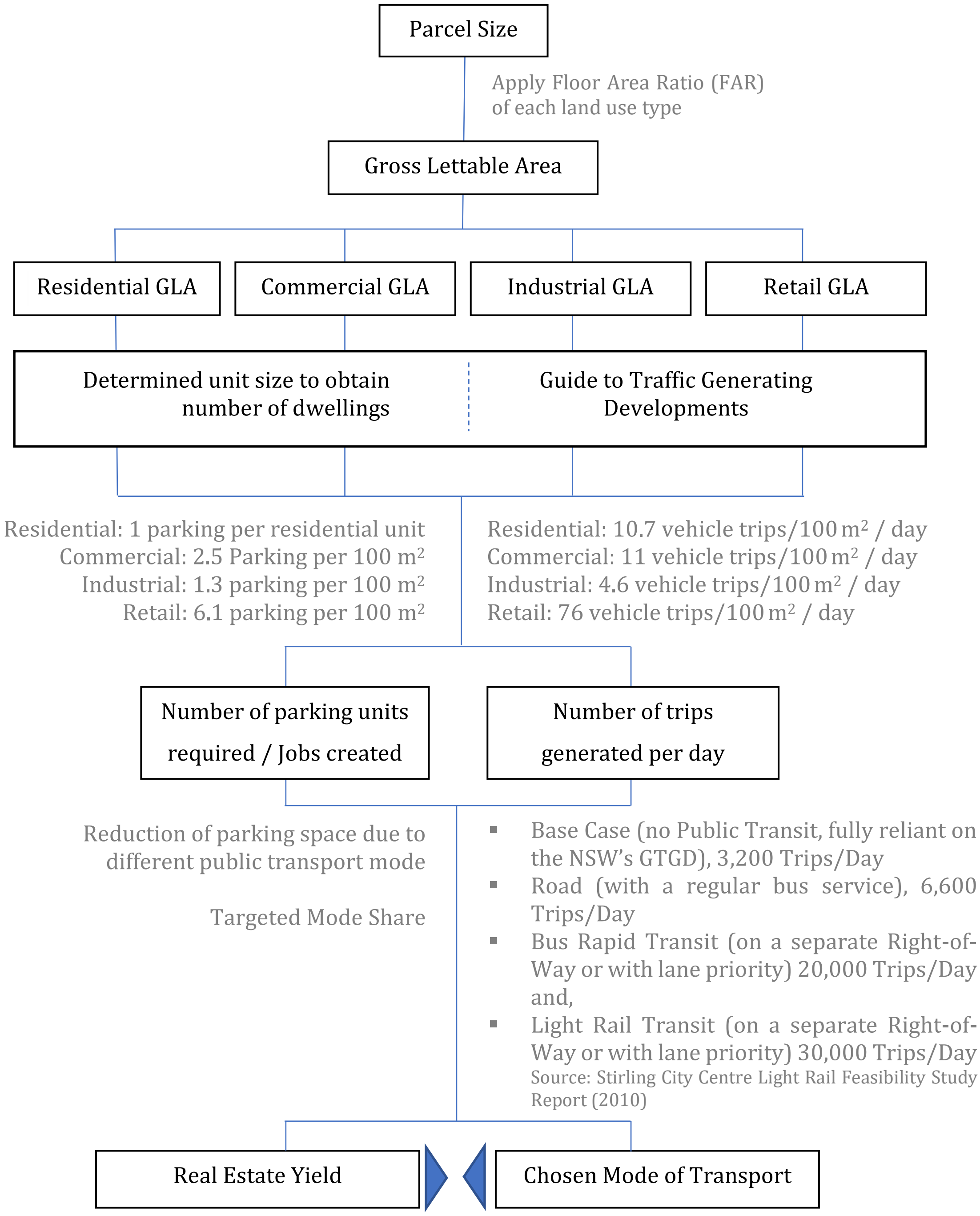


Figure 6.1 Work flow method diagram of LUTI model

- The Guide to Traffic Generating Developments (GTGD) helps to estimate the parking requirements and trips generation by each land use types.
- Based on the patronage capacity of the chosen transport mode (and expected mode share) the model calculates the real estate yields for the anticipated development via different FAR scenarios.

6.3.1 Gross Land Use (GLU) and Gross Lettable Area (GLA)

The land parcels were selected through the *Precinct Identification* tool of Envision, as described in Chapter 5. The area denoted in this model also includes amenities like roads, paths and public open spaces, etc. The gross land use area is the area that excludes all those amenities. The land parcels identified through Envision cover the net area inside each land parcel. Therefore the efficiency of the GLU area is assumed to be 100% in this case.

$$\text{Gross Land Use (GLU)} = \text{Area} * \text{Efficiency factor} \qquad \text{... (6.1)}$$

The efficiency of each land parcel, related to the designated Floor Area Ratio (FAR), determines the Gross Lettable Area (GLA) for an anticipated development. Quantitative analysis of urban development scenarios relies upon certain assumptions about the variables used in the analysis. The extent to which these assumptions hold true in the market will affect the validity of the results. In this model three distinct development scenarios were developed, using different floor area ratios to project development of different densities; conservative, intermediate and ultimate (see Tables 6.1 to 6.3) of.

$$\text{Gross Lettable Area (GLA)} = \text{GLU} * \text{Floor Area Ratio (FAR)} \qquad \text{... (6.2)}$$

6.3.2 Floor Area Ratio (FAR)

A floor area ratio (FAR), also known as plot ratio, is a measure representing the density of a building or buildings within a specified area of land. FAR measures a building's floor area in relation to the size of the lot/parcel on which the building is located. FAR is expressed as a decimal number, and is derived by dividing the total area of the building by the total area of the land parcel. FAR is an effective way to calculate the bulk or mass of building volume on a development site, and is often used in conjunction with other development standards, such as building heights, lot coverage and lot area to encourage a community's desired arrangement and form of development (Local Planning Handbook, 2015).

$$FAR = Building\ area\ (total)/Lot\ area \quad \ldots (6.3)$$

In this context, higher FAR values indicate greater building volume. For example, if a site has an area of 1,000 m^2, a FAR of 3:1 allows the construction of 3,000 m^2 of floor space. This might be a building that is built across the whole site in three storeys or a building built on half the site but with six storeys. In this model, three different scenarios, conservative, intermediate and ultimate, were considered where overall FAR varied from approximately 1.0 to 3.0.

Table 6.1 FAR Conservative scenario

	Primary Land Use	Floor Area Ratio			Additional	FAR Average
		Industry	Residential	Commercial	Showroom/Retail	
Conservative	Mixed Use			1.0		**1.0**
	Off Comm.			1.25	0.0	
	Residential		1.25			
	Trans Indus.	0.5			0.0	

Table 6.2 FAR Intermediate scenario

	Primary Land Use	Floor Area Ratio			Additional	FAR Average
		Industry	Residential	Commercial	Showroom/Retail	
Intermediate	Mixed Use		0.5	1.0		**2.0**
	Off Comm.			2.5	0.5	
	Residential		2.0			
	Trans Indus	1.0			0.5	

Table 6.3 FAR Ultimate scenario

	Primary Land Use	Floor Area Ratio			Additional	FAR Average
		Industry	Residential	Commercial	Showroom/Retail	
Ultimate	Mixed Use		0.5	3.0		**3.0**
	Off Comm.			3.0	0.5	
	Residential		2.5		0.5	
	Trans Indus.	1.5			0.5	

The ratios developed in this model were inspired by the FAR values suggested in the "Local Structural Plan for Herdsman Glendalough Area of the City of Stirling Area" prepared by (Taylor Burrell Barnett, 2014). The conservative scenario design was comprised of a residential density equivalent to R100 with only low-density commercial and industrial developments and no retail, while the intermediate scenario was designed with a denser commercial component, an increased residential development density equivalent to R-AC2 (with a maximum plot ratio of the residential component within a mixed-use area or activity centres), and additional retail outlets. Residential mixed-use with commercial and added retail were the additional land use components in this scenario. The ultimate scenario concentrated more on commercial and mixed-use commercial with medium-density residential (equivalent to R-AC1) and low-density industrial land use. Additional retail land use was added to the residential to generate a scenario populated with vibrant retail movement, aiming to generate more patronage for any transit mode.

6.3.3 Land use types

The land use types employed by this model to calculate daily patronage were residential, commercial, light industrial and mixed-use. The average Australian household is 2.6 persons (Australian Bureau of Statistics, 2011) and the average Australian home is 227.6 m^2, meaning that each person uses, as a standard, around 100 $m^2$for their dwelling space (for eating, sleeping and entertaining purposes) (Sorensen, 2013). However, while calculating the dwelling size for this experiment, it was assumed (due to the demand for densification near the transit corridor) that 75% of the dwellings would be 100 m^2 units while the remaining 25% would be 220 m^2 individual houses. Commercial, here defined, is space intended primarily for production that includes typical commercial enterprises such as professional offices and services, as well as institutions like universities, schools and hospitals. Retail includes consumption outlets such as clothing stores, grocery stores, eateries, pubs, equipment sales, rental agencies and others.

Usually, land use mixes are organised by several categories as per the context in which each site sits. For example, if a site is deeply situated in a residential area, 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 critical not to designate too many commercial activities deep in a residential area or to over-supply it with retail outlets. There are many examples where excess commercial space, wrongly distributed, can weaken a neighbourhood, as can too much, or too little, retail (Hendrigan, 2015).

In this study, the land use mix was assumed to be 60% residential, with 20% commercial and mixed-use, and 20% industrial, which makes it predominantly a residential land use transit corridor with a lively mix of commercial and retail.

6.3.4 Guide to Traffic Generating Developments

The daily transport patronage in regard to different land use scenarios was adopted from the Guide to Traffic Generating Development (GTGD) (Roads and Traffic Authority NSW, 2002, 2013) that was developed by Roads and Maritime Services (RMS) of New South Wales. Its audience extends beyond that of traffic authorities (Roads and Maritime Services and Councils) and is widely used throughout Australia. It provides a guide on some matters relating to the traffic impacts of land use developments, most notably on matters relating to traffic generation and required parking for different land use types (Figure 6.1). The LUTI model was used to calculate the required parking units for the anticipated developments, based on the different scenarios, using the figures in Table 6.4 to assess the real estate yields and number of jobs that can be accommodated.

Table 6.4 Required parking and trips generated by Roads and Traffic Authority NSW (2013)

Land use Type	**Required Parking Units**	**Trips Generation /100 m^2 / day**
Residential	1 parking per residential unit	10.7 vehicle trips
Commercial	2.5 parking per 100 m^2	11.0 vehicle trips
Industrial	1.3 parking per 100 m^2	04.6 vehicle trips
Retail	6.1 parking per 100 m^2	76.0 vehicle trips

In GTGD, Section 3 gives a detailed overview of traffic generation by different land use types and Section 5 provides data for parking requirements. The LUTI model used the guide as a base to calculate the daily number of trips generated by each land use type, the required parking space for the anticipated development for different scenarios and the real estate yield facilitated by specific modes of transport. Additionally, it provided an estimate of job density by land use type. According to GTGD, office and commercial space generates a job for every 21 square metres of space, while industrial space generates a job for every 57 square metres. There is no straightforward answer as to how many jobs or employees the retail space can accommodate. However, the guide has detailed data regarding retail businesses like food outlets and restaurants, which helps to draw an indirect correlation for job density with the number of indoor and outdoor seats for customers, concluding that retail activities can generate a single job for every 20 square metres of retail space (Roads and Traffic Authority NSW, 2002, 2013).

6.3.5 Transit mode capacity

This following sub-section presents the performance characteristics of the four typically available modal alternatives as a mass transit option for short distance travel. No single type of quality transit system is appropriate for all applications. The potential solution for car-based cities should be determined based on an objective and comprehensive analysis of the alternatives. In this study, the LUTI model is utilised to compare among three proposed potential LRT routes in the City of Stirling, by making an inquiry regarding maintenance of balance between patronage capacity of the chosen transit modes for short distances and generated trips from the anticipated development.

6.3.5.1 Bus

Buses are flexible, cheap to operate and easy to implement in a city. However, in attracting a significant number of people away from private vehicles, standard buses are not a good option, without priority lanes, because of the slow travelling times. Furthermore, close spacing between stops and unpredictable traffic conditions can reduce the reliability of the service and significantly slow down journey times.

Table 6.5 Typical conventional bus system characteristics by Roads and Traffic Authority NSW (2013)

Transit type: Bus on street without priority lane	
Typical maximum passengers per hour	4,000
Maximum frequency (vehicles/hr)	60-80
Average passenger trip length (km)	6.25
Typical station spacing (m)	250-400

Therefore, the appeal of buses over other transit modes, particularly for attracting ‘choice riders’ is considered to be lower. Choice riders are those passengers who can afford not to use public transport but still choose to use it, as opposed to those who need it for physical or financial reasons (Parsons Brinckerhoff Australia, 2010).

Assuming that bus services are conducted using articulated buses with 24/7 operation, they are able to provide peak hour capacity up to 6,600 passengers per direction (Parsons Brinckerhoff Australia, 2010). However, realistically, the actual capacity would be slightly lower.

We know from the available literature that there is no linear correlation between accessibility to any transport services and increased property value (Dziauddin, Powe, & Alvanides, 2015). Usually, within walking distance, there is little significance observed in value uplift of properties and attraction of new investment, especially on low- to mid-frequency routes.

6.3.5.2 Bus Rapid Transit

The main difference of Bus Rapid Transit (BRT) over a standard bus is that it provides a better quality service to passengers, with improved reliability and reduced travel times, by assuring more frequent services over a longer period and higher capacity to move larger volumes of passengers.

Table 6.6 Typical BRT characteristics by Roads and Traffic Authority NSW (2013)

Transit type: Bus in exclusive lanes with priority	
Typical maximum passengers per hour	4,000 – 20,000
Maximum frequency (vehicles/hr)	60-80
Average passenger trip length (km)	6.0
Typical station spacing (m)	400-800

The peak hour capacity of a BRT system is dependent on the level of infrastructure invested into it and the frequency at which the service operates. The theoretical capacity is closer to 20,000 passengers per hour if the service is integrated into an articulated service structure with different transit modes (Parsons Brinckerhoff Australia, 2010), e.g., the South East Busway in Brisbane is now carrying 20,000 passengers per hour in the peak hour. Properties around the Brisbane BRT have recorded increases of up to 20% in value when compared to surrounding suburbs.

Compared with rail, it is likely that BRTs can be less expensive to install, with minimum surface level disruption during construction or realignment of underground water, power, sewers and other utilities, saving on the infrastructure costs. However, the true cost of operating a BRT system is found by digging a little deeper to include the ongoing labour costs, the replacement timeframe of the rolling-stock, the capacity per hour and the level of service being provided (Parsons Brinckerhoff Australia, 2010).

6.3.5.3 Light Rail Transit

Rail public transport, of which LRT is one form, features improved performance and comfort through grade separation, larger seats and better stations, as well as lower operating costs. Rail further promotes strategically important infill development and is useful as a tool to satisfy certain planning objectives (Litman, 2007). The added benefit of LRT systems is that, often, they are segregated from regular traffic or are, at least, not limited to operating within normal traffic. Due to the exclusive right-of–ways, LRT systems are able to operate more frequently with less congestion, improved performance and, hence, higher passenger throughput. The Glenelg tram line in Adelaide is a prime example of this flexibility of operation. Throughout the line, it runs through mixed traffic using a dedicated centre lane.

Table 6.7 Typical LRT characteristics by (Transport Roads and Maritime Services NSW, 2013)

Transit type: Light Rail in exclusive lanes with priority	
Typical maximum passengers per hour	9,000 – 32,000
Maximum frequency (trains/hr)	12
Average passenger trip length (km)	6.4
Typical station spacing (m)	240-5,000

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. The LRT systems are seen as more of a 'mass transit' style service rather than a regular public transport service. The segregated right-of-ways and their ability to overcome congestion provide the public with a perception that they are a more exclusive mode of transport. LRT systems also have higher reliability and are often stylised to improve their image. These characteristics all act as a catalyst to development, as well as contributing to significant increases to surrounding property values (Parsons Brinckerhoff Australia, 2010).

The capacity of each transit mode (see Figure 6.1) to accommodate the anticipated daily trips stemming from the changed land use was then 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 conduct 15 hours of heavy transit requirements. This inverting of the numbers maintains a transparent balance to calculate real estate yields for different density scenarios.

6.3.6 Real Estate Yield

The LUTI model calculates the differences in real estate yields based on different modes of transportation. The concept behind this is to deal with the real differences rather than those arising from speculation or hype, such as the capacity of a public transport mode to convey passengers per hour and the associated reduction in parking needs which frees up surface area and capital to build toward maximum allowable heights with anticipated floor area ratio. The real estate yield can be thought of as either actual space in square metres or as capital to be expended elsewhere in the project, as part of a cash-in-lieu programme towards precinct-level parking structures, or contributions towards Land Value Capture (Hendrigan, 2015). Though it is not always clear where the benefit of the additional space or capital may end up, for this model, it is assumed to be channelled towards added real-estate yield.

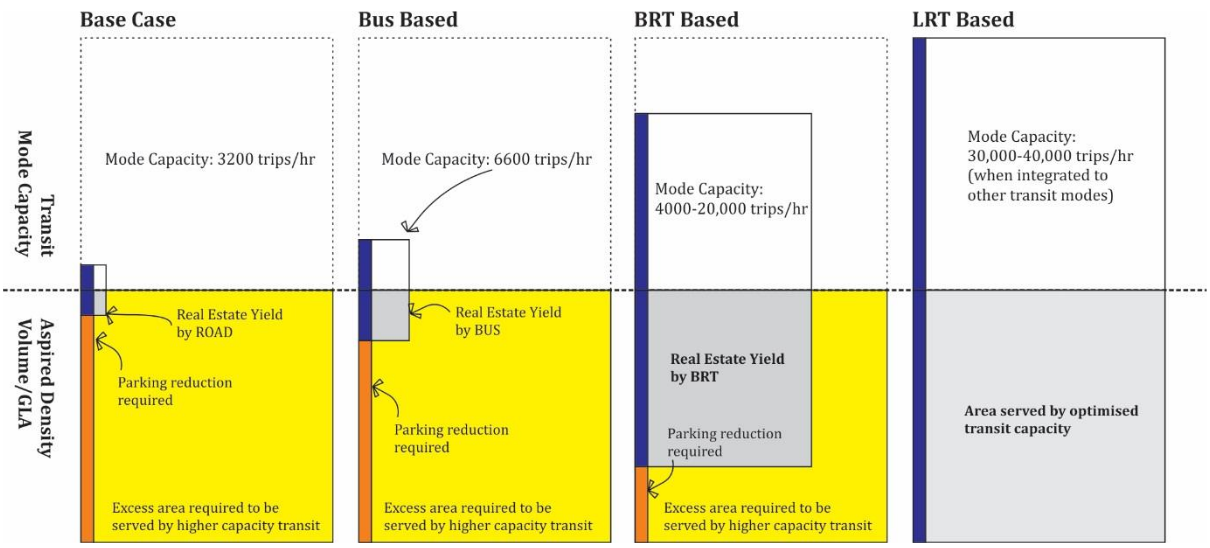


Figure 6.2 Real estate yield diagram of LUTI Model

The different transport modes, with different capacities, that were considered by this model were:

- Base Case (no public transit, fully reliant on the NSW's GTGD data);
- 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).

Each land use type generates a number of trips per day that is calculated by the guidance of GTGD. Each transit mode has a capacity to provide services with variable frequencies. The difference between the maximum capacity of transport modes and the services actually provided, reveal the required area to be served by higher capacity transit options, which are denoted as *parking reduction required*.

$$Parking\ reduction\ required = Gross\ Lettable\ Area \times Excess\ transit\ capacity \quad (6.4)$$

$$Real\ Estate\ Yields = \{\ Gross\ Lettable\ Area\ (Base\ Case\ developable \times Transit\ Capacity) - Parking\ reduction\ required\}$$
…. (6.5)

The differences between areas modified by an improved transit-capacity compared to a base case scenario, and the anticipated reduction in parking area (calculated parking unit as per GTGD) required by each density scenario (e.g., conservative, intermediate and ultimate) are the real estate yields for this study.

6.3.7 Mode Share

In order to quantify the capacity of each transport mode at its optimal performance level, it is necessary to turn to several world-leading academic experts and professional practitioners who have approached the issue of mode share and mode capacity in shaping urban growth (Cervero, 1996, 2002; Litman, 2007; Parsons Brinckerhoff Australia, 2010; Vuchic, 2005; Vuchic, 2007). Any planned development should be coupled with the most appropriate transport mode from the very outset of the schematic stage of project development. The best-laid plan will deliver nothing unless backed by an appropriate mode of transport to undertake the planned task. In other words, when the appropriate mode of transport becomes an integral part of land use planning, it helps the project to fit in both locally and regionally. When all the pieces fit together, a cohesive whole emerges, but when one piece does not fit, the composition breaks down. Mode share is a part of the whole composition, and a significant segment that binds different transit modes together. Successful assimilation of transit options works by improving mode share among different forms of transit and helps them to maintain balance with each other while developing to their maturity. Mode share can achieve up to 15% to 50% depending on the modes and usually increases overtime following the maturity of any transit improvement initiative (Parsons Brinckeroff Australia, 2010).

6.4 Interrelationship of density scenario and landuse types

The density scenarios proposed in Table 6.1 to Table 6.3 are composed of different average plot/floor area ratio ranging from 1.0 to 3.0. There are mainly four types of landuses considered in this model namely residential, commercial, industrial and retails. The capacity for generating trips per day and required parking spaces are also differed by each landuse types. As for example, the residential landuse required 1 parking per unit while retails need 6.1 parking unit for per 100 m^2 which is way higher than residential as well as other landuse types. Similarly, the trip generation capability of residential landuse types generates 10.7 vehicle trips per 100m^2 per day while retails landuse generates 76 vehicle trips per 100m^2 per day (Roads and Traffic Authority NSW, 2013). By the same consideration, commercial and industrial landuse lie in between of these residential and retails. This signifies that apart from the contextual factors when to propose a mass transit corridor the planner should consider the route where retails are one of the major landuse types. The different density scenario will sketch the trip generation capability of the route to warrant a mass transit e.g. light rail transit.

The patronage capacity of bus, BRT, LRT are ranging from 4000 to 32,000 passenger per hour (Parsons Brinckeroff Australia, 2010). In this LUTI model the generated trips from a certain density scenario for a proposed transit route compare against a transport mode capacity to decide the appropriate transport mode. If generated trips from a route is capable to warrant an LRT, conceptually it is replacing a huge number of cars along the routes and freeing up space as a capital, in other words the real estate yields, discussed in subsection 6.3.6.

Conversely, for future projection, it also may help to understand how much commercial, industrial or retails may need to transform a route to a mass transit corridor, by assigning required landuse to the land parcels where uses are not yet designated.

6.5 Summary of the model

From the planning point of view, the model ultimately delivers the correct indication of required density level to produce enough patronage to balance each public transport mode using a dedicated transit corridor under the modelled land use conditions. If it shows that even the 'Ultimate Scenario' is not capable of producing the required trips for a desired public transport mode, (e.g., LRT for a proposed route), a rezoning might be necessary to concentrate more commercial and retail activities around the stations, to regenerate the urban fabric. An average floor area ratio of 1.0 to 3.0 is an indicative number to match the current and achievable density levels (as per Residential Design Code for WA) of car-based cities, and it may vary between context and regions. In the case of the City of Stirling, Western Australia, the FAR (known under the term, 'plot ratio') varies between 0.5 and 3.0 for multiple dwellings in areas coded R30 or greater, within mixed-use developments and/or activity centres (Western Australian Planning Commission, 2013).

6.6 Results of LUTI analysis

This part of the study compares three routes, focusing on their capabilities to generate patronage in respect of different transport modes. Wanneroo Road is the longest route compared to Main Street and Amelia Street. The lengths of the three routes are approximately 8.3 km, 5 km and 8 km, respectively. The Wanneroo Road route is state-owned while the other two are within the jurisdiction of local government. An internal study by the local government found several potential routes that could be developed as transit corridors for LRT, based on such attributes as existing road reserve width, widening requirements of road reserves, required service relocation, approximate development cost (per km) and daily traffic count (2013/14). The study found that Wanneroo Road exhibited the highest potential, while Main Street and Amelia Street were both of medium potential under these circumstances. Along with these attributes, daily patronage generated by the routes themselves is an inseparable variable for consideration to establish the economic viability of the corridor with a chosen transport mode. In the LUTI model, the trip generation by any transport mode is related to the land uses of the surroundings. Along the Wanneroo Road route there is mixed land use of commercial and residential with some light industrial, and Amelia Street is mostly residential with low commercial. However, Main Street has the greatest variety in land use, comprising both commercial and mixed-use with residential developments.

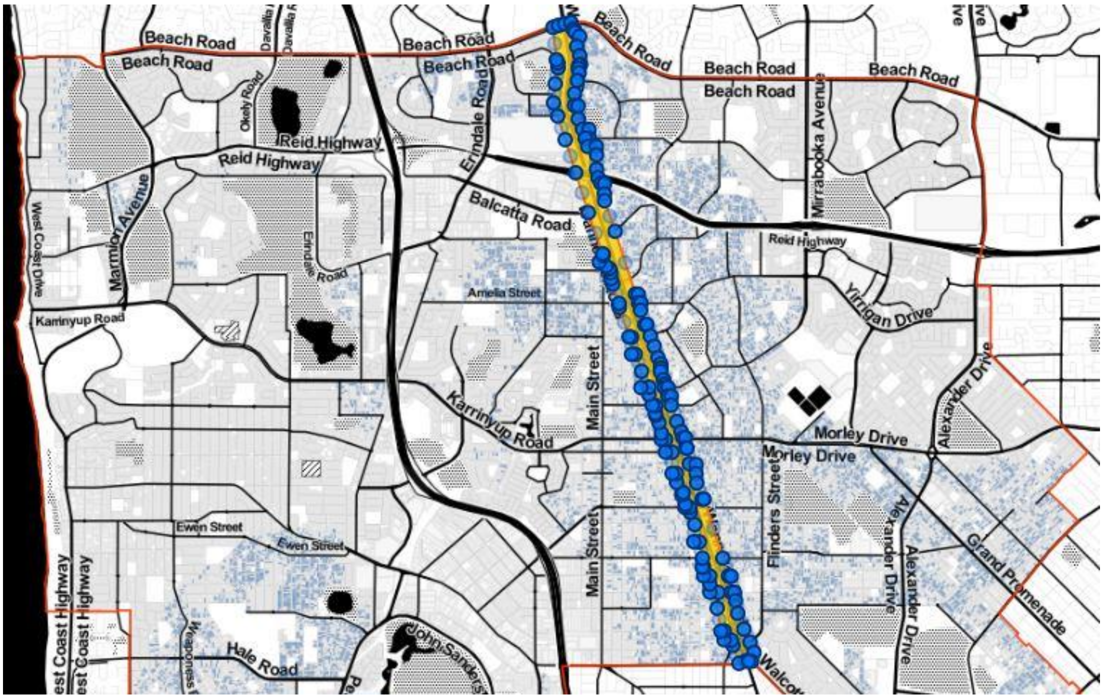


Figure 6.3 400 m buffer zone along Wanneroo Road

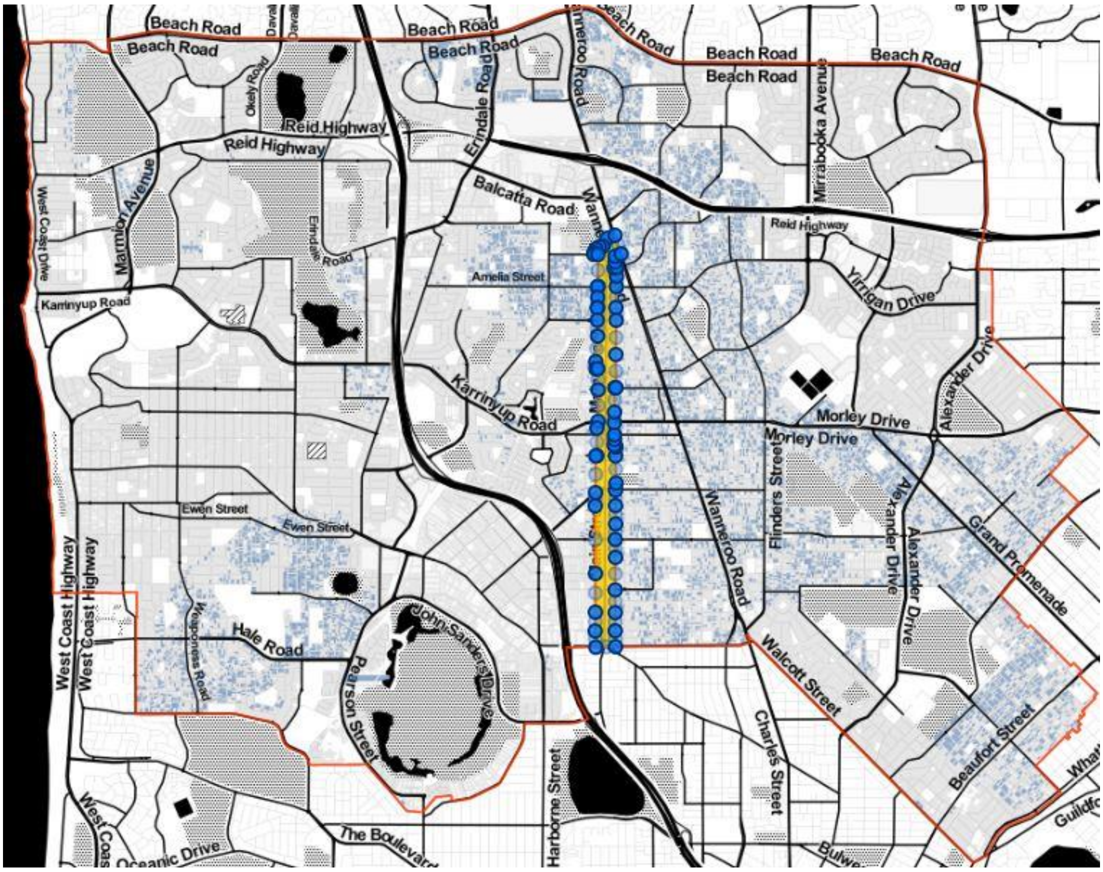


Figure 6.4 400 m buffer zone along Main Street

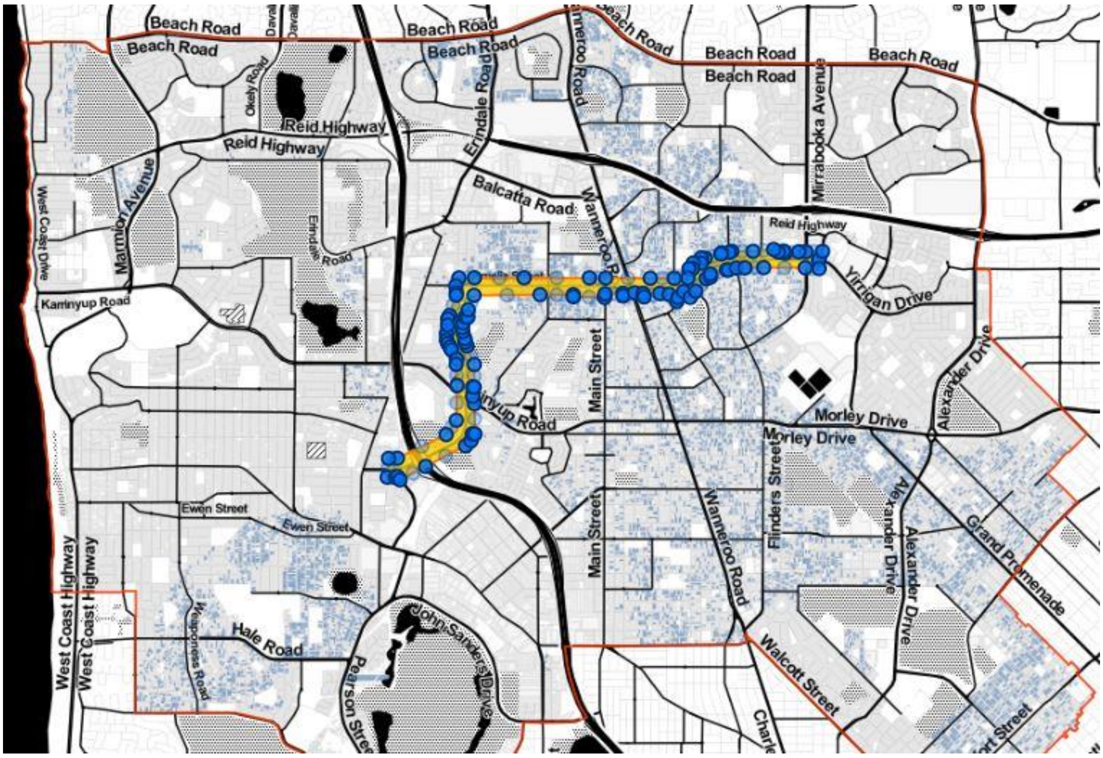


Figure 6.5 400 m buffer zone long Amelia Street

According to the reviewed literature (RICS Policy Unit, 2002; Untermann, 1984), services like bus, BRT and LRT are capable of attracting people within a walkable catchment area of approximately 800 m or 10 minutes distance. The viability of setting up a transit mode such as LRT for a main road with connecting arterials in a car-centred suburb depends on whether enough patronage will be generated by the population density within this walkable catchment. A transit corridor is usually populated with higher density directly adjacent to it. This study assumed that 200 m from the corridor would be populated with a higher density scenario and the next 600 m zone would remain unchanged in regard to density, but that value uplift would be instigated by the transport infrastructure and services that are expected to affect the lots up to 1.2 km distant from the routes. The difference between the generated trips from the density scenarios (expecting a mode share of up to 50%) for the 400 m buffer zone of the proposed transit corridor and the total trips required to validate the transport mode will give a ballpark figure for the planning professionals to estimate whether the probable trips from the rest of the catchment area would be enough to make a project viable in terms of generated patronage.

Using the PSS tool, Envision, a polygon boundary was drawn to select the land parcels that fall entirely within the 200 m catchment on each side (in other words, a 400 m linear buffer zone). The lots that fell short of being inside the drawn polygon boundary were excluded from the selection automatically. Therefore, there is always a chance of error for not to be selected. However, it would not be significant in number to affect the results of counting the land parcels or to alter the result dramatically. It is expected that the land parcel within this buffer zone will be even higher by a little margin if we count them one by one. The next subsection describes the scenario for each transit route separately, followed by a discussion that compares the three scenarios. A comparative analysis of the transit corridors' pros and cons will, thus, reveal the embedded potentialities of each route.

Table 6.8 presents the areas within the 400 m buffer zone along the corridors/routes, after compiling the sizes of all land parcels as gross land use. The gross lettable area represents the areas modified with the desired density as per the different density scenarios. The number of dwellings is calculated as per the justification described in Sub-section 6.3.3 and the number of jobs is guided by Roads and Traffic Authority NSW (2002).

Table 6.8 Comparative aspirational scenarios of density and jobs for the proposed routes

Density Scenario by route	Gross Land Use Area (in m^2)	Gross Lettable Area (in m^2)	Dwelling Units	Total Jobs
Wanneroo Road				
Conservative	1,308,106	1,629,226	14,320	16,910
Intermediate		2,895,198	36,660	41,089
Ultimate		4,057,905	57,281	73,327
Main Street				
Conservative	878,064	1,022,059	9,694	6,324
Intermediate		1,794,470	25,032	16,576
Ultimate		2,593,971	38,992	37,718
Amelia Street				
Conservative	1,117,478	1,396,848	14,893	3,542
Intermediate		2,115,934	38,125	8,572
Ultimate		3,382,190	59,570	36,439

The Wanneroo Road and Amelia Street routes are of similar length but vary in land use mixes, which is reflected in the numbers (Table 6.8) of dwelling units and jobs created by different density scenarios. The number of dwelling units expected along Amelia Street (e.g., 14,893 residential units for the conservative scenario) is slightly more than for Wanneroo Road (e.g., 14,320 residential units for the conservative scenario).

However, the number of jobs created along Wanneroo Road is significantly more than Amelia Street for both conservative and intermediate density scenarios. This disparity is considerably higher when modified by the ultimate scenario, which is backed by dense FAR for commercial and retail land use types compared to the other two scenarios (Figure 6.6).

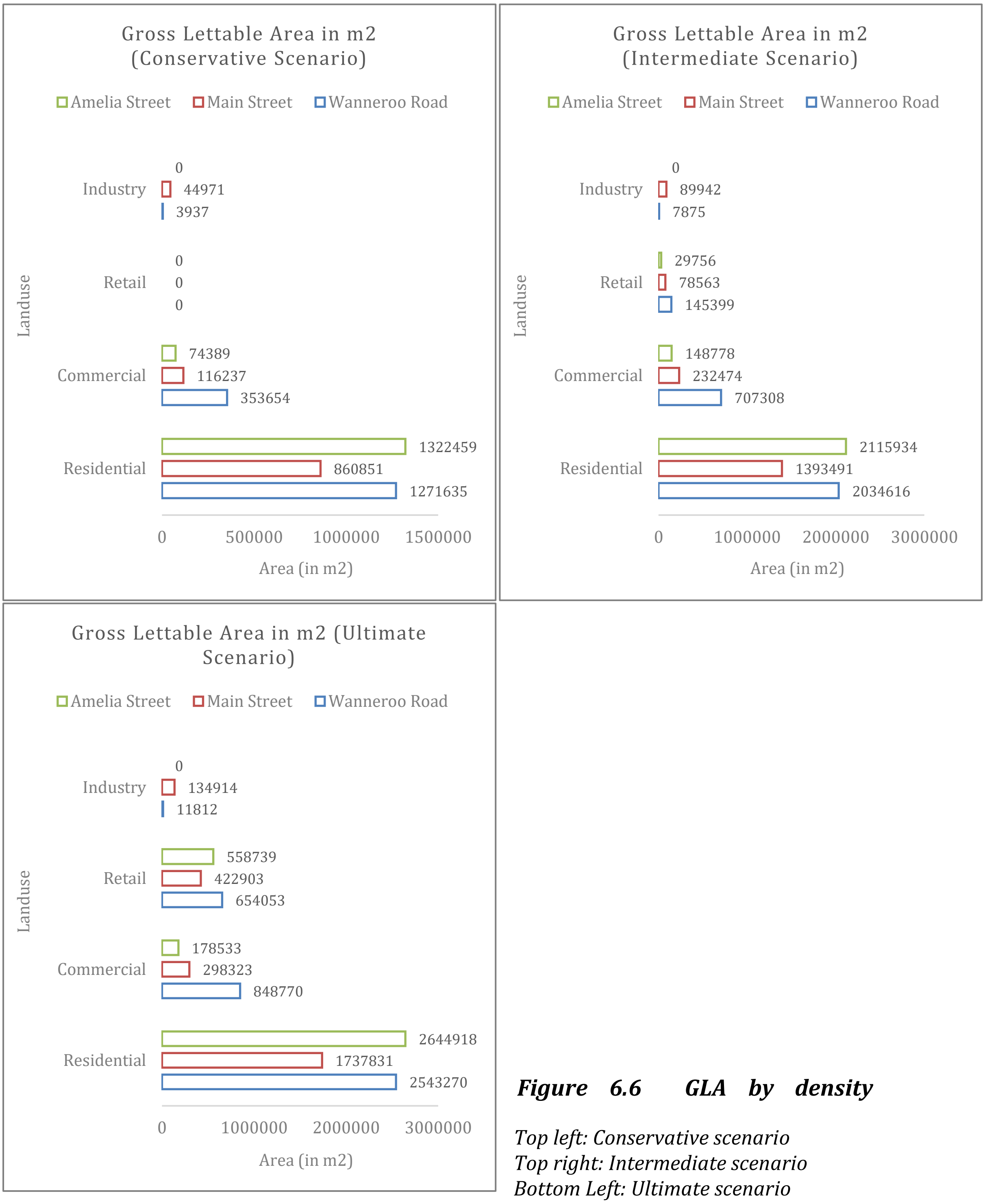


Figure 6.6 GLA by density

Top left: Conservative scenario
Top right: Intermediate scenario
Bottom Left: Ultimate scenario

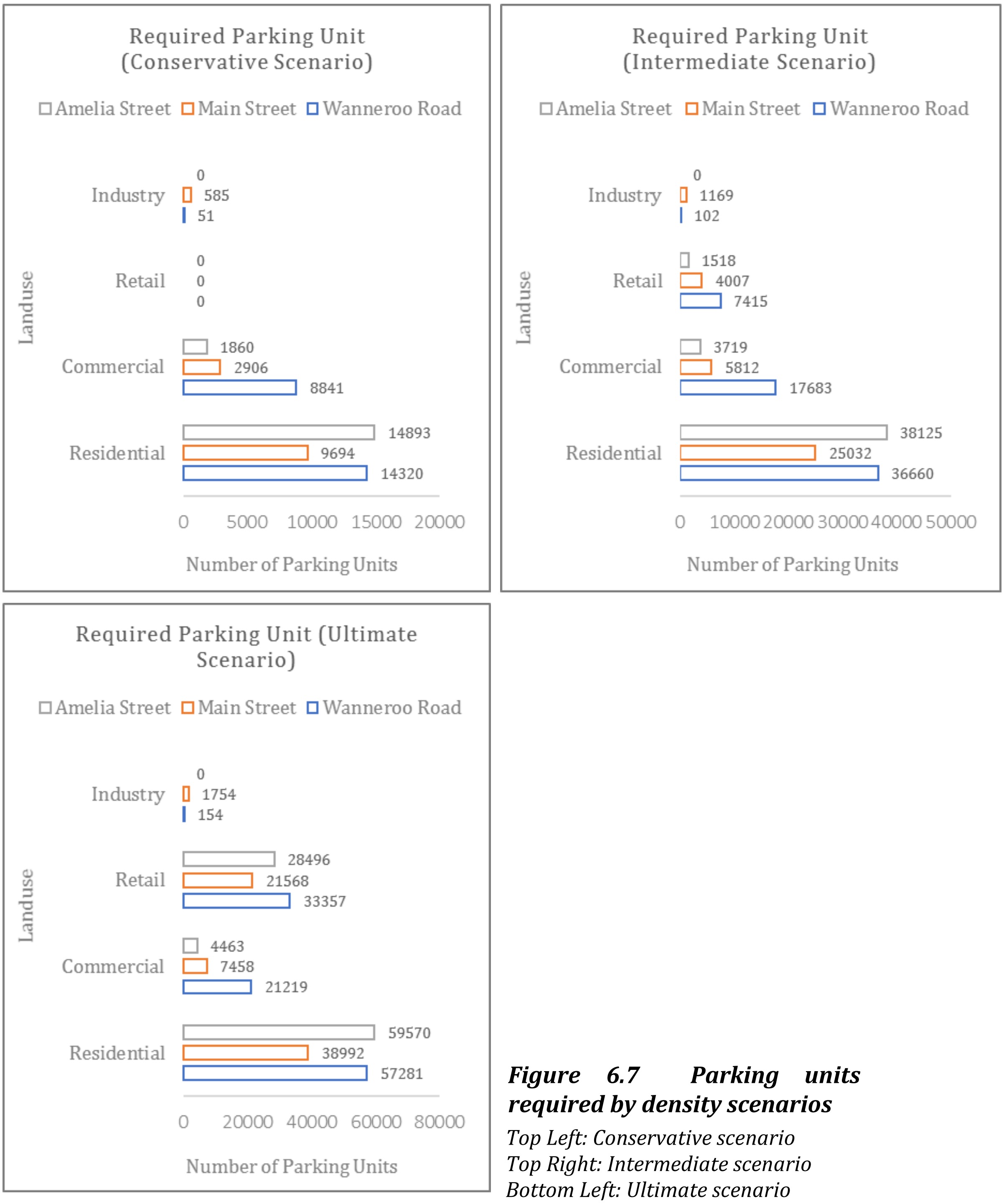


Figure 6.7 Parking units required by density scenarios

Top Left: Conservative scenario
Top Right: Intermediate scenario
Bottom Left: Ultimate scenario

Figure 6.7 presents the parking units required by the derived density scenarios, following the guidelines of NSW's GTGD; use of residential land is the principal driving force of required parking units while also being the lowest contributor in job creation (see Sub-section 6.3.4 for the number of jobs created by different land use types). Retail is the major contributor to job creation (one job generated for every 20 m^2 of retail space). This relationship signifies that a balanced land use mix, focusing on retail, would be profitable to support any transit corridor.

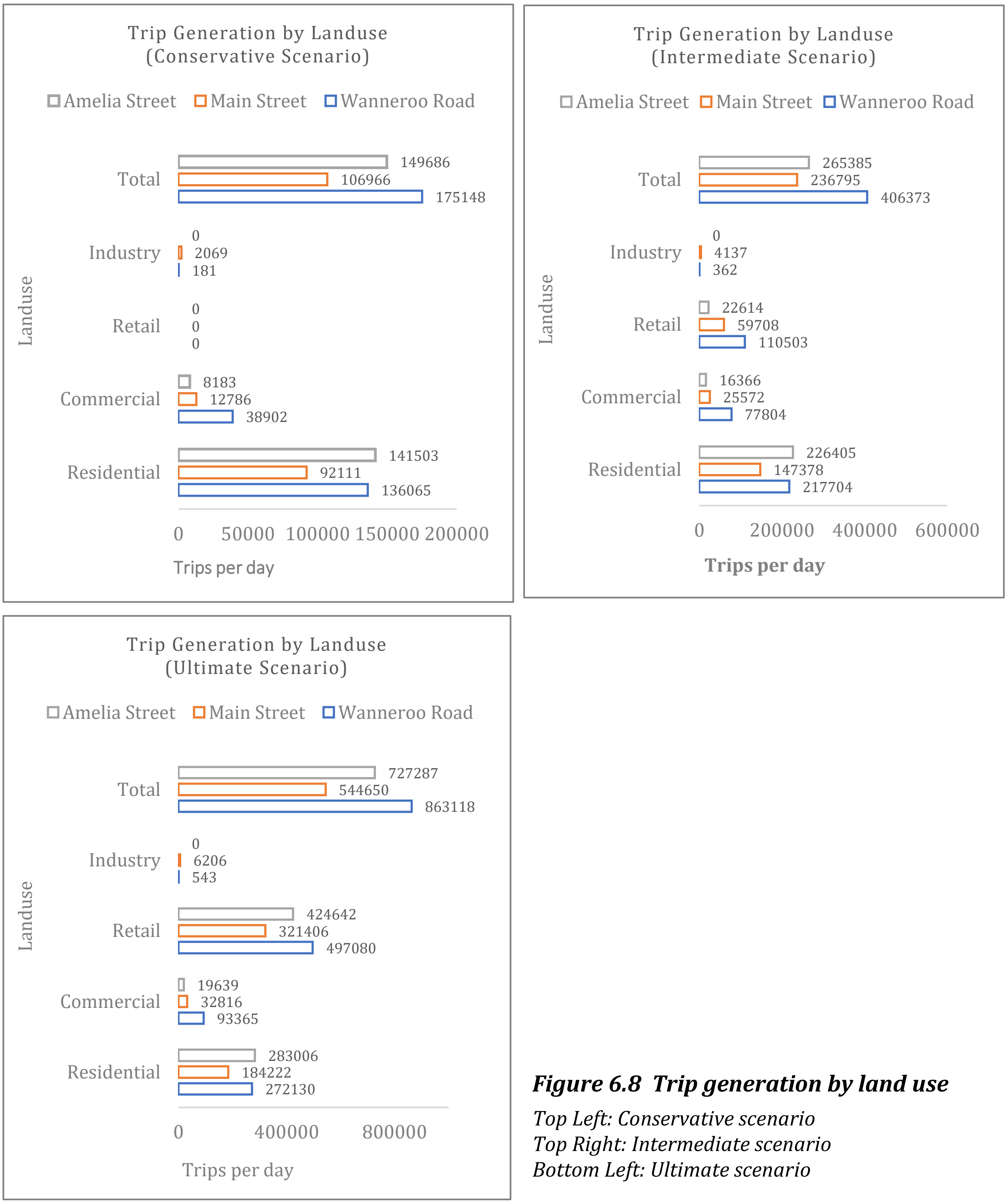
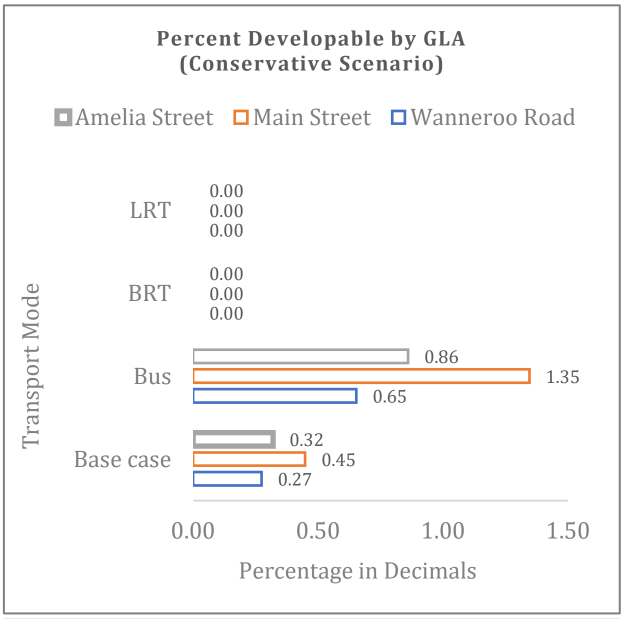


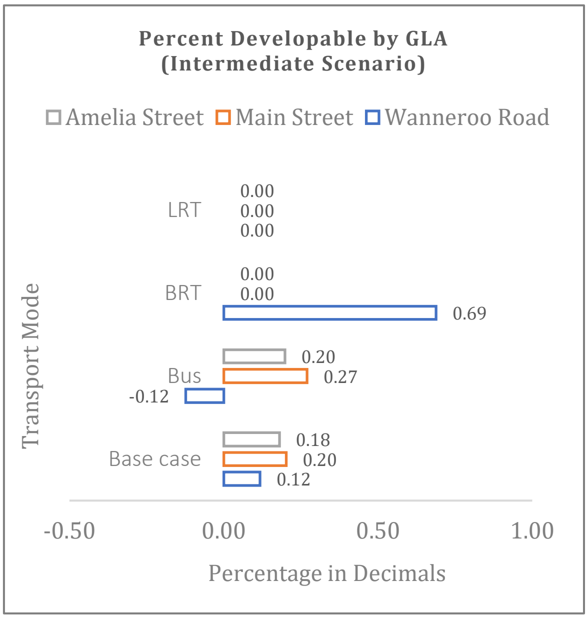
Figure 6.8 Trip generation by land use

Top Left: Conservative scenario
Top Right: Intermediate scenario
Bottom Left: Ultimate scenario

There is not a very significant difference between the Wanneroo Road and Amelia Street routes regarding length and gross area of land use. However, Figure 6.8 indicates that the Wanneroo Road route generates more trips compared to other routes, even when the conservative density scenario is considered. It should be noted that the conservative scenario is a density scenario with no retail outlets and low commercial floor area ratio.

The situation changes when additional retail outlets are included for the intermediate and ultimate scenarios. With higher density retail, the residential land use becomes a secondary contributor in the trip generation, with more trips being contributed by the retail spaces. This variation also supports the argument for retail intensification along the transit corridor to generate adequate trips for a proposed transport mode and to make public spaces more vibrant. It is secured by welcoming commercial and retail activities close to the dense residential developments.





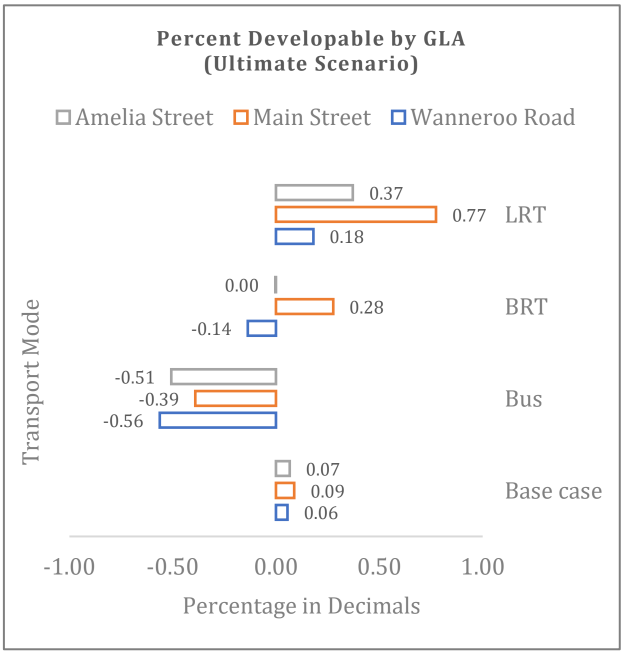
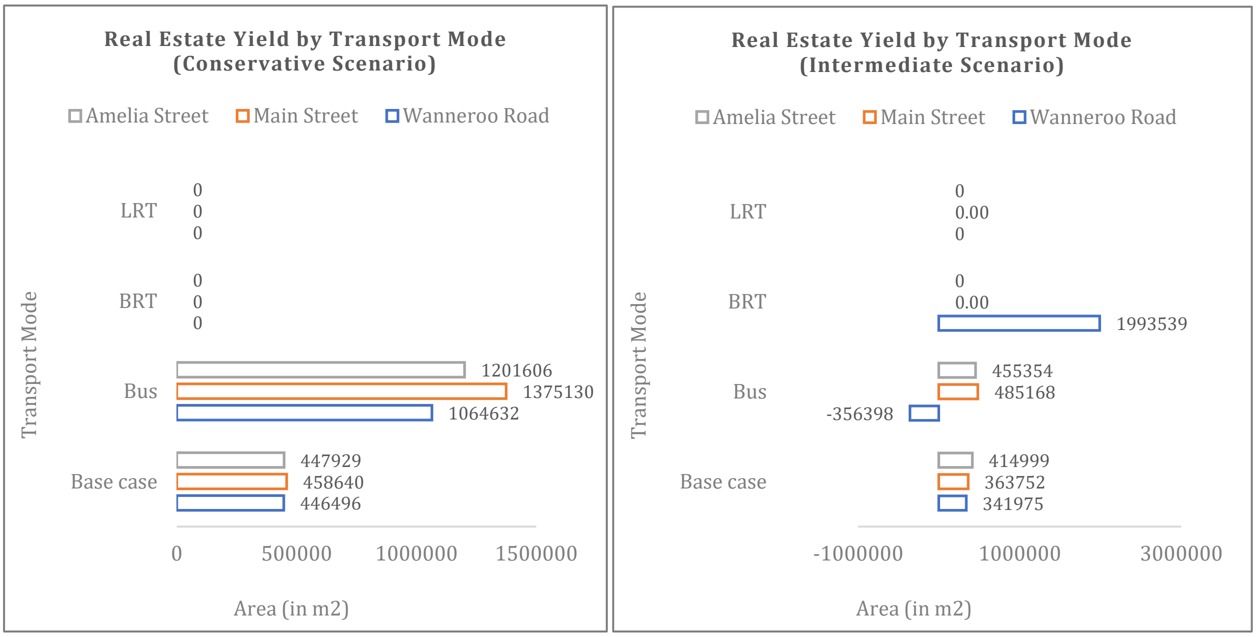


Figure 6.9 Percent developable by GLA

Top Left: Conservative scenario
Top Right: Intermediate scenario
Bottom Left: Ultimate scenario

The *percent developable* means the portion of the development that is going to be served by a transport mode. In other words, if a particular mode of transport is introduced against a density scenario, the decimal figure signifies the percentage of transport demand that is going to be mitigated by the particular mode of transport. Figure 6.9 contains the charts comparing percent developable of total GLA for the different transport modes over the three different density scenarios. They illustrate that, for the conservative density scenario, bus would be an appropriate transport mode for all the routes. For example, the Main Street (135%) and Amelia Street (86%) routes would be well served by bus, while for the Wanneroo Road route, even though bus mode would only satisfy 65% of the transport demand, it still does not warrant BRT or LRT.



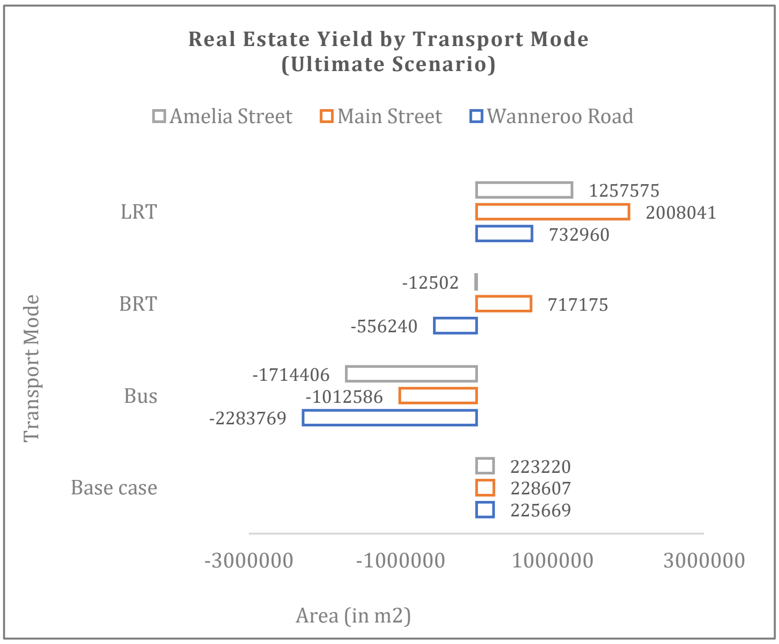


Figure 6.10 Real estate yield by transport mode for proposed

Top Left: Conservative scenario
Top Right: Intermediate Scenario
Bottom Left: Ultimate Scenario

If the intermediate density scenario is considered, only the Wanneroo Road route will reach the point of transport demand that requires BRT, where nearly 70% of the GLA (intermediate density) would be expected to be served.

The ultimate density scenario signifies the endorsement of LRT for all the routes. The chart in Figure 6.9 for the ultimate scenario (bottom left) shows that LRT will satisfy the transport demands for Wanneroo Road, Main Street and Amelia Street by 18%, 77% and 37%, respectively. A density scenario (with a FAR value ranging from 2.0 to 3.0) in between the intermediate and ultimate scenarios would be an optimal solution to validate LRT for all the routes.

The number of parking units (or area sum of the units) required in respect of land use type can be calculated for an area (e.g., transit corridor) through the help of the GTGD of NSW. If a particular public mode of transport is introduced to a corridor, it serves for a portion of the area generated by the modelled density scenario, depending on its mode capacity. The difference between this area served by the particular mode of transport and the area required to reduce parking is referred to as 'real estate yield' in this model. When the area served by a particular transport mode is larger than the required parking area to be reduced, it produces surplus area that a developer can use (in physical square metres) or as liberated capital to be expended elsewhere in the project.

On the positive side, if the objective is to find the feasibility of the proposed routes for transit corridors in regard to trip generation capability of LRT by the present use of land, when the ultimate density scenario is considered, we can clearly see that LRT, or a transit mode of similar hourly capacity, can provide enough non-single occupant vehicle movements to reduce the parking requirements sufficiently enough to allow the highest real estate yields for all the proposed routes.

According to the thematic maps produced by Envision measuring the impacts of the identified contextual factors, the Main Street route fell short of being considered because of its lack of potentially redevelopable lands or properties along the corridor. Surprisingly, keeping that consideration apart, as can be seen in Figure 6.10 (ultimate scenario), it generated the highest figure for real estate yields: 2,008,041 m^2, compared to Wanneroo Road (732,960 m^2) and Amelia Street (1,257,575 m^2). This complementary circumstance once again reveals the certainty of the fact that versatility in land use mix (intensification of retail and commercial with dense residential development) with an integrated transit option can validate the appropriateness of a particular transport mode. However, the presence of potentially redevelopable sites within a close catchment area is essential. Additionally, change of land use to attain the desired density should be considered carefully to uphold the spatial appeal and value of the development itself.

However, mode share is a crucial and practical matter to consider before making a final decision about any proposed route. The next sub-section highlights the facts and figures required to make assumptions about the mode share needed to generate enough patronage for a particular transit option.

6.7 Mode share scenarios

The previous sub-section concluded that the ultimate scenario generated enough trips for LRT to be suitable for all the routes because of its higher density and landuse mix. This sub-section provides information regarding the proportion of trips to be captured by LRT from the modelled density within the 400 m buffer zone of the proposed transit corridor that would be needed to generate enough patronage for a public transport mode such as LRT.

The Wanneroo Road route was estimated to generate 863,118 trips per day, as per the calculation of the GTGD of NSW. Theoretically, the operation of LRT for 15 hours per day can take up 52.1% of the total trip load. However, it is obvious that not all the trips will be accommodated by LRT and there will be some considerable factors that compel people to choose a particular transport mode, particularly when they have already self-selected themselves to a low-density car-dependent neighbourhood. We can consider that more than 20,000 trips per hour (PTA, 2010) would be enough to justify LRT for a proposed route. Based on this argument, 35% of the generated trips from the anticipated density along Wanneroo Road (within the 400 m buffer zone) should be captured by LRT to balance the patronage capacity. Similarly, the Main Street route would generate 544,650 trips per day, where 56% of the trips should be captured by LRT, which is a big ask. The situation of Amelia Street is similar to Wanneroo Road. Amelia Street would generate 727,287 trips per day, where 42% of the trips should be captured by LRT, in the same circumstances. This means Wanneroo Road is sitting in an advantageous position where 35% of the generated trip from the mentioned buffer zone can warrant a LRT in terms of generated patronage.

6.8 Summary

This chapter described Land Use and Transport Integration (LUTI), which is a spreadsheet-driven model used to establish an integral relationship between land use and transport. The model was applied to investigate three proposed transit routes in the City of Stirling, Perth, to calculate the real estate yields for different density scenarios, so as to justify their potential regarding generation of daily patronage. The results showed that, if a density with an average FAR value of 3.0 is applied to the proposed corridors, all three of the proposed routes (Wanneroo Road, Main Street and Amelia Street) would be able to generate enough patronage to warrant LRT. The Wanneroo Road route is in a strong position regarding the number of trips generated from an anticipated density along the route and is in an advantageous position to be considered as the most potential route for a transit corridor and Main Street would be considered as a viable option as the required mode share exceeds more than 50% (56%). The next chapter concludes the arguments in light of the aims and objectives set at the outset of this research.

6.9 Copyright Declaration

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Envision is an e-tool, a decision support system where the datasets are provided via the Australian Urban Research Infrastructure Network (AURIN) Portal and their contents, to the extent they are protected by copyright, are provided under a Creative Commons licence. The e-tool is accessible at https://envision.aurin.org.au/envision and accessed on 17 December 2019.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This research presents the importance of redeveloping the dilapidated middle-suburbs of car-dependent cities. It has brought the inherent causes to the surface and suggests a conceptual framework to facilitate urban regeneration through the inseparable agent of public transport services with lane priorities. Firstly, this research illustrates the interrelationship between the evolution of car dependency and the development of the physically declining middle suburbs as an after effect of the inhabitants' self-selection to an unsustainable transport mode. Secondly, it justifies the mass transit corridor as a dependable solution to instigate urban regeneration, being precise about the significant contextual factors that work as moderators before selecting a route for commencing any development. Finally, it develops a conceptual framework to facilitate urban regeneration in the middle suburbs of car-dependent cities with the help of a planning support system tool, Envision, and the spreadsheet-driven land use and transport integration tool, the LUTI model. Three proposed routes in the City of Stirling, Perth, Western Australia, have been examined through the developed framework and comparative scenarios have been delivered to help the planning professionals to make any concrete (or alternative) decisions when assessing the feasibility of developing any of them as a mass transit corridor.

7.2 Revisiting the research questions, aims and objectives

This concluding chapter summarises the achievements of the research by reviewing its outlined significance, scope, aims and goals compared with the results and outcomes of the study to answer the overarching research question:

"How can urban regeneration be facilitated in the middle suburbs of car-dependent cities?"

The research in this thesis was a effort to develop a methodology that could build a framework to facilitate urban regeneration in the middle suburbs of car-dependent cities. Four research aims, to be achieved by accomplishing three definite objectives, were established at the beginning of the research, as stated in Chapter 1.

Table 7.1 illustrates how each of the research aims and objectives has been addressed by the chapters of this thesis.

Table 7.1 Correlation between the research aims and the individual chapters

Research aim/objective	Chapter of the thesis
Aim 1: To examine the socio-technical parameters of redevelopment that are significant for urban regeneration in middle suburbs of car-dependent cities.	**Chapter 2** This chapter defined the key socioeconomic and technical parameters that relate to automobile dependency, middle suburbs and urban regeneration.
Aim 2: To examine the relationship between transit infrastructure and urban redevelopment to facilitate urban regeneration.	**Chapter 2** As a basis for this research, Chapter 2 explored the relationship, as well as the interdependency, between urban regeneration and transport infrastructure. This chapter also identified the possibilities and prospects of a mass transit corridor as a catalyst to instigate redevelopment in car-dependent middle suburbs.
Aim 3: To determine the contextual factors that play important roles in the instigation of urban regeneration by transport infrastructure and services.	**Chapter 2** The contextual factors that help to activate the redevelopment process in response to a transport infrastructure service were detailed in Chapter 2.
Aim 4: To determine the potentiality of particular infrastructure and transport services based on contextual factors derived from both qualitative and quantitative models.	**Chapters 3, 4, 5 and 6** Chapter 3 illustrated the overarching methodology of the thesis, which was described in detail in Chapters 4, 5 and 6. Chapter 4 described the conceptual basis and process of using a Multi-Criteria Decision-Making method, the Pair-wise Comparison Method and Analytic Hierarchy Process (AHP), to obtain the weights of individual contextual factors and sub-factors. A survey of experts was conducted to facilitate the process. Chapters 5 and Chapter 6 detailed the workflow processes of the PSS tool, Envision, and the Land Use and Transport Integration (LUTI) model.
Objective 1: To develop a methodology to assess the roles of contextual factors that facilitate urban regeneration in the middle suburbs of car-dependent cities.	**Chapter 3** Chapter 3 described the methodology of the framework, which was then detailed in Chapters 4, 5 and 6.

Research aim/objective	Chapter of the thesis
Objective 2: To identify the potential of transport infrastructure to regenerate the middle suburbs of car-dependent cities.	**Chapters 4, 5 and 6** Chapter 4 described the weight determination process of individual contextual factors and sub-factors before their use as input values in the PSS tool, Envision. The work described in Chapter 5 produced thematic maps for each contextual factor. This chapter also analysed the results qualitatively and partially quantitatively to develop meaningful comparisons to assist in decision-making as to the most preferable route for developing a mass transit corridor. Chapter 6 determined the feasibility of each corridor regarding its capability of generating patronage for specific transport modes.
Objective 3: To establish a conceptual framework that can be used to facilitate urban regeneration in the middle suburbs of car-dependent cities.	**Chapters 3, 4, 5 and 6** As a holistic approach to addressing the methodology, the whole framework was described briefly in Chapter 3 and detailed in Chapters 4, 5 and 6. Each chapter compared the performance of the three proposed routes. Results from each chapter carried forward to the next chapter to complete the workflow process of the developed framework, which eventually revealed the potentialities of the investigated routes for instigating redevelopment to facilitate urban regeneration.

7.3 Findings and recommendations

Car dependence has developed over time in accordance with the options open to travellers and the facets of their daily lives, such as employment, education and residential household structure. Cities were transformed in the post-war era because of falling energy prices and the rise of car ownership that allowed physical separation of activities and progressive spread of urban areas with low-density housing.

Characterised by a single-family house on the iconic 'quarter acre block' and sandwiched between inner and outer suburbs are the middle suburbs that have lost their lustre over time, due to lenient planning strategies that failed to stop development at the fringes and allowed people to self-select themselves to a specific unsustainable transport mode.

A sub-optimal solution to urban densification, such as 'battle-axe' lot subdivision, may marginally increase (or even double) the density but it is not a solution to address the urban infill target set for all the major cities in Australia. Urban intensification is an obvious choice, as is the regeneration of the greyfields in middle suburbs by redevelopment. Retail-led urban redevelopment along a mass transit corridor can be a model for regenerating the middle suburbs of car-dependent cities because, according to the literature, 10-15% of jobs are usually occupied by the locals (Dixon, 2005). A well-integrated mass transit network is necessary for this circumstance to be enabled to enhance the accessibility and security of the middle suburbs.

A transport network and the growth of a city cannot be separated. Therefore, a pragmatic solution to regenerate urban areas also needs to be coupled with considerations that include transportation. Among many alternatives, a mass transit corridor with medium-density development is a working solution that is being practised worldwide. It is evident from the literature that a dedicated corridor with mass transit such as light rail to heavy rail can make an enormous impact on the surroundings to uplift land value, as well as helping to instigate redevelopment. It is also true that the impact is not always positive. This research has investigated the published literature to sort out the factors that do make an impact and under what circumstances it has resulted in negative outcomes. A thorough literature review listed the contextual factors and their degree of impact upon achieving success in a project involving a mass transit corridor. This research articulated a set of contextual criteria and an applicable method to identify a potential transit route with the ability to facilitate urban regeneration in the middle suburbs of car-dependent cities.

Based on the reviwed literature and findings of this research, in proposing a transit route, a priority lane for a particular transport mode is not enough to deliver the expectations outlined above. The traffic-generating capabilities of the surrounding land use is a major thing to consider, along with development density. This developed framework draws on the interrelationship between a transport mode and the desired population and building densities of any proposed route, based on existing land use of the surroundings. It would be helpful for the planning professionals to choose a particular transport mode, based on the associated required density, and compare this with the density proposed in any planning strategy.

An expert survey was conducted to determine the relative weights of the individual sub-factors. Experts expressed their opinions that housing and locational contextual factors are more significant than transport and economic factors. The survey results also revealed a few observations regarding the contextual sub-factors.

1. Assets with a single house and bigger land size are considered to have the greatest potential and are expected to be impacted positively if any transit service project is initiated nearby. In such circumstances, dwelling age will not be an obstacle to agree to redevelopment.
2. The location of amenities in relationship to residential premises is always important because it relates to the everyday lifestyles of the users. Results show that close proximity to a shopping mall or any commercial facility is far more important to residents than close proximity to a main road.
3. The number of personal vehicles owned by a family has little influence on car dependency. Rather, it is proximity to a mass transit option that has a greater effect on the choice of the user in selecting a transport mode for the journey to work.
4. Components like dependency of the owner on the property (for rent or occupancy), mortgage status, development efficiency, and dwelling capacity with extra land are all, more or less, equally important to trigger redevelopment (see Figure 4.4). However, RPI is one of the most dependable criterion to consider in regard to the redevelopment of a property.

Three potential routes in the City of Stirling were selected to identify their capacity to contribute in the redevelopment of their surroundings, in order to facilitate urban regeneration. Comparing all the major contextual factors (using the Envision outputs) Amelia Street and Wanneroo Road were found to have equal potential for setting up a mass transit corridor. However, regarding the cost effectiveness (over the next 50 years) in redeveloping the potential sites within a 1,600 m buffer zone of the routes, with comparably higher density, Wanneroo Road stood out by a considerable margin compared to the other two. The LUTI model also supported, with facts and figures, that the Wanneroo Road route is in a strong position regarding the number of trips that would be generated from an anticipated density along the route and it is in an advantageous position to be considered as the most potential route for a mass transit corridor.

7.4 Summary of contributions and significance

This study fills the research gap to address a method of urban regeneration in the middle suburbs of car-dependent cities. It investigated the possible role of a transport infrastructure service as a contributor to initiate redevelopment of its urban surroundings. Finally, it identified the significant contextual factors that should be considered as moderators before commencing development of a mass transit corridor in order for it to contribute to urban regeneration. The advantages of this research offer a framework that:

a) conceptualises the inter- and intra-relationships among regeneration, automobile dependency and middle suburbs of car-dependent cities;
b) bases all the determination processes and results on quantitative statistical analysis, most relevantly the PSS tool and an appropriate land use and transport integration model; and
c) locates the areas along a mass transit corridor that could potentially benefit from redevelopment to facilitate urban regeneration, through identifying and categorising the contextual factors.

By 2050, it is estimated that 75% of the global population will be urban(Nations, 2018). Many of the car-dependent cities in the world are trying to change their dependency pattern by starting new, or expanding existing, railway systems to encourage mass transit-oriented development. In 2011 there were a total of 643 potential new fixed guideway projects in 106 metropolitan regions have been identified, where 138 of them are in construction or at the engineering stage in the United States. Most of them have witnessed an upsurge in every sector, with residential, commercial and office developments being served directly by a rail transit system (Reconnecting America, 2011) . The world view is changing about cities and it is time to adjust to new perspectives. The framework of this research has been developed for low dense car based cities. In future work could be to develop and test this approach in other cities with different means of data collection and with tuned attributes of different contexts. This will be particularly useful in car-dependent cities with recognised inadequacies to regenerate their middle suburbs and who are planning to make their cities less car dependent.

There is a growing body of literature that informs about the impacts of mass transit corridors upon the land value uplift of their surroundings, but there is a scarcity of literature that identifies contextual factors and their influences on uplifting land values consequently helping in urban regeneration. A major significance of this study is that it articulates the contextual factors that work as moderators to instigate urban redevelopment and this will contribute much to the published literature. It also informs about the contextual factors such as walking distance to transit or amenities, related to ease of mobility and factors like development efficiency and capacity of a land parcel related to economic gain from a transport infrastructure project that facilitates urban regeneration, especially in the greyfield areas of middle suburbs.

The goals were to develop a framework that is supported by a defendable method using the current literature and an applicable model that is applicable to other cities with similar problems. The framework is suitable for all cities, with an affinity for developing denser neighbourhoods and sustainable transport modes. Available data that supplies the required information is the raw material that this framework requires in order to answer strategic questions for the planning professionals, developers and related stakeholders.

This framework may be considered as a dependable method to develop and realise a strategic plan for low-density car-dependent cities. It can demonstrate the positive impacts of having a medium- to high-density development with a synchronised transport option that is carefully optimised for the intended redevelopment. This framework is useful in achieving political aims by revealing the monetary gain and favourable outcomes inherent in building any transport infrastructure through a strategic planning approach. The framework and tools used in this research are flexible and transparent. Moreover, they are presented in a simple way to make them easy to grasp and useful to anyone who is interested. The input variables are clearly shown, making them flexible enough for any individual context or region. There is very little room for making any assumption because the used logical assumptions are well supported by transparent and dependable literature with citations to the source of the original documents.

According to Newman and Kenworthy (2015), the world's developed cities are declining in their car use and the developed world is witnessing the end of building cities around cars as the primary goal of planning. The world's cities have been slowing down for last three decades, while rail transit is faster than road, enabling travel time savings and better space efficiencies, with greater carrying capacities that are no longer achievable by car and bus (Newman, 2015). Today or tomorrow, cities will realise this trend and orient themselves to adapt more sustainable ways of living, allowing mass transit and permissible densification while sacrificing nothing of their perceived qualities of life to adapt to a walkable, mixed-use, transit-oriented lifestyle. Without regenerating the middle suburbs, cities will not be able to respond to the wave of changing needs. Planning strategies may get the ball rolling but, to involve all sectors to overcome the associated challenges, investment needs to be ensured. This research fills the gap in strategic planning to allow guided speculation on the outcome of a policy, such as judging a route to be transformed as a mass transit corridor. It also can help in determining the desired density (change of FAR or R-Code for Western Australia, for example) along a corridor if there is already a proposal for a strategy to utilise a particular public transport mode, such as rapid bus transit or light rail. In the end, the framework is a useful rational approach in uncovering the capacity and yields of the urban lands to deliver the 21st century goals of higher equity in quality of life.

7.5 Limitations of the research

The MCE tool Envision allows users to run multi-criteria evaluation (MCE) assessments using property level and ABS SA1 level data by selecting a variety of demographic, proximity-based and market-based attributes (decision criteria), weight their significance, and from them calculate a single composite index to visualise areas suitable for redevelopment as a choropleth (thematic map). The data required in the LUTI model comes from the Guide to Traffic Generating Developments. Prepared by Transport Planning Section, Sydney Client Services. Both of the tools rely on data that needs to be updated when available by proper authority. As the research is dependent on the MCE tool, Envision and LUTI model, a progressive update is required to make them applicable to any investigation.

The tool Envision has limited access and not open to the public. Therefore, it was not possible for the author to arrange access for the survey participants. However, the publicly available resources regarding the tool that includes published paper or video link of the tutorials were sent to them for a better understanding of the tool. It would have much easier for the survey participants to contribute more effectively if the access could be obtained.

Practically, an infrastructure (mass transit corridor) cannot or should not be considered to contain in a single municipality area. Firstly, the routes for the case study were taken from the prepared list of potential routes by the City of Stirling. In the list, the routs were ranked with priority based on the associated cost involved to remove or relocate underground and overground infrastructure services. In this research, the author has to consider the proposed route as a test case due to the limitation of available data for adjacent local government areas during the time of conducting the research.

The tool Envision is capable of producing output as PDF format to visualise areas as a choropleth (thematic map) where the potential areas reflect through the concentration of chosen colour. However, a shapefile is also available as an output but only supplies the polygon area information with associated basics such as area, landuse types etc. It is not capable of embedding the related information associated with any resulting output comes from a query. Improvement of such capability will be beneficial to acquire detailed quantitative information behind a thematic map, rather than merely a PDF to inform the researcher in evaluating scenarios. Any comparative analysis between scenarios will be a lot easier and dependable to rank them in order. Some of the limitations have overcome in this research by using supporting open source software such as QGIS to calculate the polygon area and reveal their typology with associated land values.

Every city is different and so do their contexts. Therefore, it is a difficult to address the all relevant contextual factors by a single academic research. This research endevoured to find the maximum number of conxtual factors from the available literature that reflect any impact over urban regeneration. The outcome of this research set a framework to follow that will work as a background benchmark. A deeper investigation is always necessary supported by required relevant dataset while applying for any city even with similar sort of problems to get better result that respond effectively to the needs.

7.6 Recommendations for future research

As with many research projects, there are often more questions raised than resolved by the analysis, and these questions require further investigation. The topics proposed below appeared during the process of developing this research.

Future research question 1

How to identify potential areas for mass transit corridor to support urban regeneration?

Apart from the contributions discussed in previous sub-section, more research to be undertaken to identify further dimensions of contextual factors that facilitate urban regeneration. Most importantly, the whole model needs to be trialled on many more locations with variable population density, in other Australian cities. It will be a useful tool, not just to compare potentiality between given transit routes, but to identify prospective areas of setting mass transit corridors.

Future research question 2

How contextual influences of urban regeneration varies between continents? A case studies of Australia, USA and Western Europe

Additionally, the reason behind the dis-urbanisation and urban shrinkage varies between continents. A comparable study between continents will help the model to grow versatile. This research will ensure a broad understanding of the qualitative and quantitative benefits of each context and how they play their parts in urban redevelopment for the cases with similar urban problems in different urban context.

Future research question 3

High density or high rise development in activity centres: How would the transformed streetscape look in redeveloped middle suburbs? A case study of major Australian cities.

People in car-dependent low-density suburbs are always uncomfortable with the question of urban densification. Allowable maximum height, privacy and density are the major concerns that work against the concept of luxury, invoked by a garden city type of development. Therefore, to change the perceptions of common people to accept at least a medium-density development, research is necessary to understand the values of low-density suburbs that people cherish and how they can be restored acceptably within a medium-density development. All major Australian cities are growing fast with positive signs for future improvement with strong focus on developing integrated transit systems, addressing affordability and embracing sustainability in construction. Recently introduced new lines for light rail in Sydney and Melbourne eventually will offer new shape in density scenario for central city where transformation of streetscape would be a challenging task to amalgamate with old urban fabrics.

Future research question 4

How can apartments be made more liveable for all, to support smart growth principles?

People (mostly pensioners) like to downsize their houses with the intention of bringing comfort into their lifestyle in regard to maintenance, payment for services, reducing mortgage repayments to fit their budget, etc. However, apartments, compared to a typical single house, are often too costly for pensioners. Moreover, the apartment always remains a choice for a small family but hardly designed to the expectations and needs of a full-sized family that fits into a three by two single house. Therefore, there should be a comprehensive study on precinct developments with medium- to high-density residences to support smart living for all.

Future research question 5

How can the new paradigm of infill be unlocked to reach the target of major Australian cities?

As we already know that the 'battle-axe' subdivision is a sub-optimal solution for redevelopment in fulfilling the infill targets set for all the major cities of Australia (Newton, 2010). Envision and ESP can be used to compare between a precinct-level and a battle-axe development. The research would include site selection by Envision and visualisation of the proposed developments by type generation in ESP, modelling through sketch design and urban design, cost estimates of planning and construction processes that incorporate time allowances for community engagement and land, and a life cycle assessment of the proposed environmental and community benefits.

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APPENDIX I: MAJOR POTENTIAL LRT ROUTES IN CITY OF STIRLING

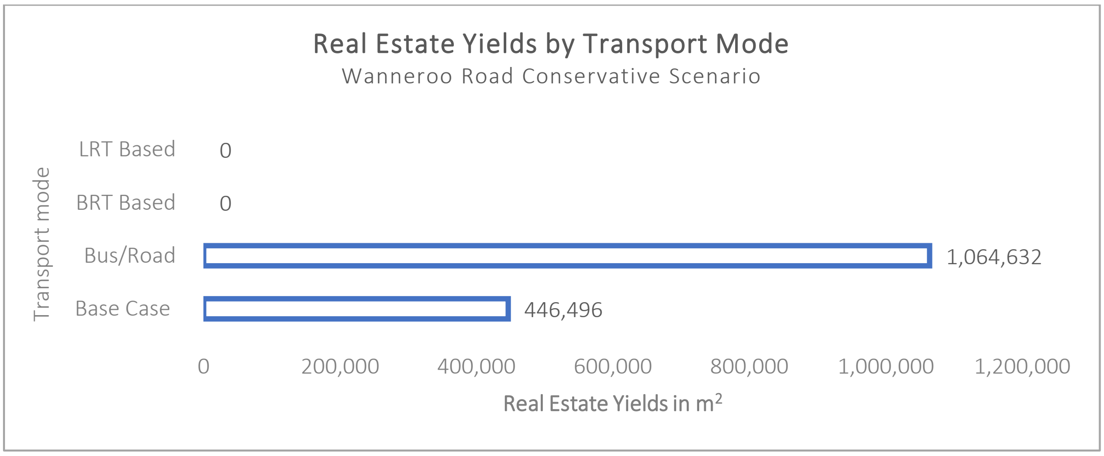
The Table I(a) represents the potential routes in the City of Stirling by their internal study supplied in a meeting at the City of Stirling on 02.03.2016. The data used to determine the selection of routes to study in this research only. Author suggests not to use them (facts and figures) until published in a referable document with permission.

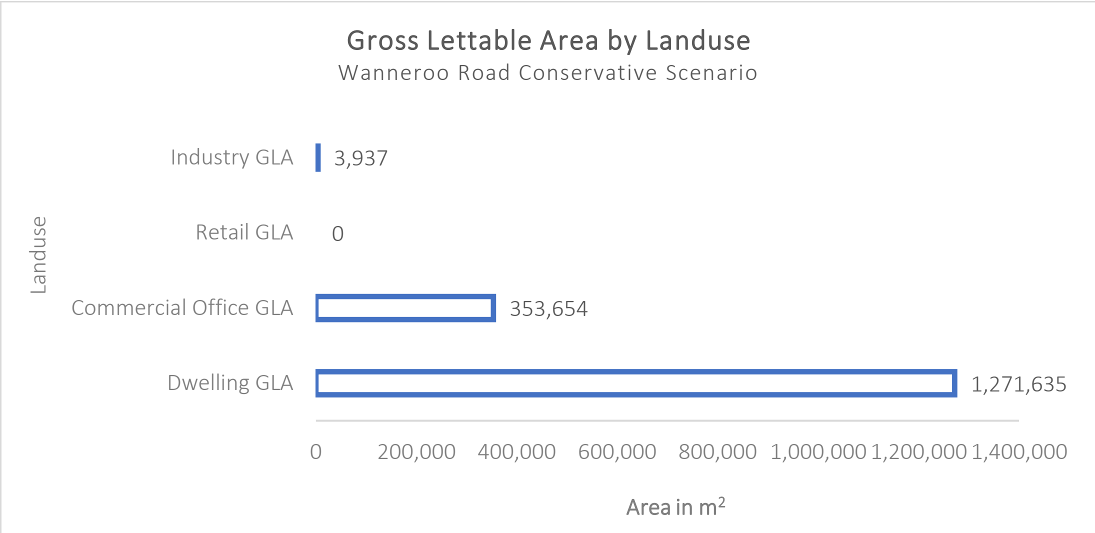
Table I(a): Potential routes for LRT in the City of Stirling

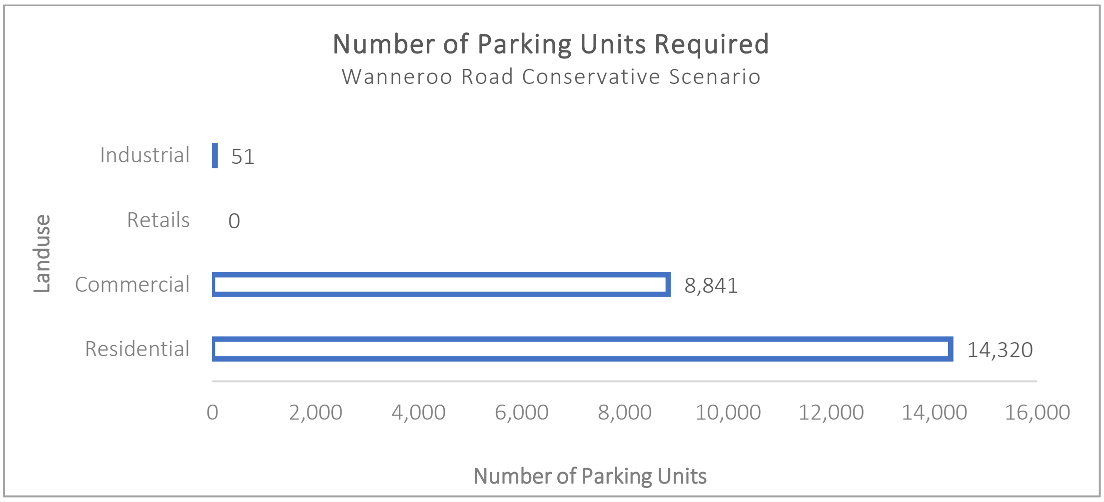
Major Potential LRT Routes in Stirling								
Corridor Name	**Rank**	**Existing Road Reserve Width**	**Road Reserve Widening required**	**Service Relocation**	**Approximate Cost (per km)**	**Daily Traffic Count 2013/14**	**Development Potential**	**Patronage (per day)**
Alexander Drive	3	35m	Minor in a few locations	Major relocation	$25M Road Widening $21M LRT Construction $20M service relocation $2M land $68M Total	Walcott **35,140** Grand Prom **30,660**	Low	100,000
Karrinyup Road/Morley Drive	3	40m – 50m	Minor in certain locations	Certain sections	$25M Road Widening $21M LRT Construction $5M service relocation $2M land $53M Total	Mitchell Fwy **36, 790** Cedric St **27, 960**	High	
Scarborough Beach Road	1	20m – 42m	Major widening throughout	Major relocation	$25M Road Widening $21M LRT Construction $20M service relocation $2M land $68M Total	King Edward **37,750** Huntriss **25, 530**	High	40,000
Wanneroo Road	2	25m – 60m	Major widening in sections	Major relocation	$25M Road Widening $21M LRT Construction $20M service relocation $2M land $68M Total	London **36,370** Royal **30,120**	High	
Minor Potential LRT/tram Routes in Stirling								
Corridor Name	**Rank**	**Existing Road Reserve Width**	**Road Reserve Widening required?**	**Services under carriageway ?**	**Approximate Cost (per km)**	**Daily Traffic Count 2013/14**	**Development Potential**	**Patronage**
Cedric, Amelia, Ravenswood, Yirrigan	1	20m	Widening at stops	Minor	$21M LRT construction $2M service relocation $2M land for stops $25M Total	Amelia **10,850**	Medium	
Royal, Flinders, Blythe, Woodrow Grand Prom, Walters.	2	Grand Prom – 30m Others – 20m	Widening at stops	Minor	$21M LRT construction $2M service relocation $2M land for stops $25M Total	Royal St **14, 760** Blythe **13, 910** Flinders Ave **21, 520** Woodrow **11,030** Walters Rd **24,120**	Medium	
Green Street-Walcott Street-Central Avenue	3	20m	Widening at stops		$21M LRT construction $2M service relocation $2M land for stops $25M Total	Walcott **29,270**	Medium / Low	
Main Street	1	20m	Yes to 25m	Next Gen reports third party duct	$21M LRT construction $2M service relocation $2M land for stops $25M Total	Royal St **20,910** Morley Dr **25,790**	Medium	
Source: Supplied documents in meeting at City of Stirling								

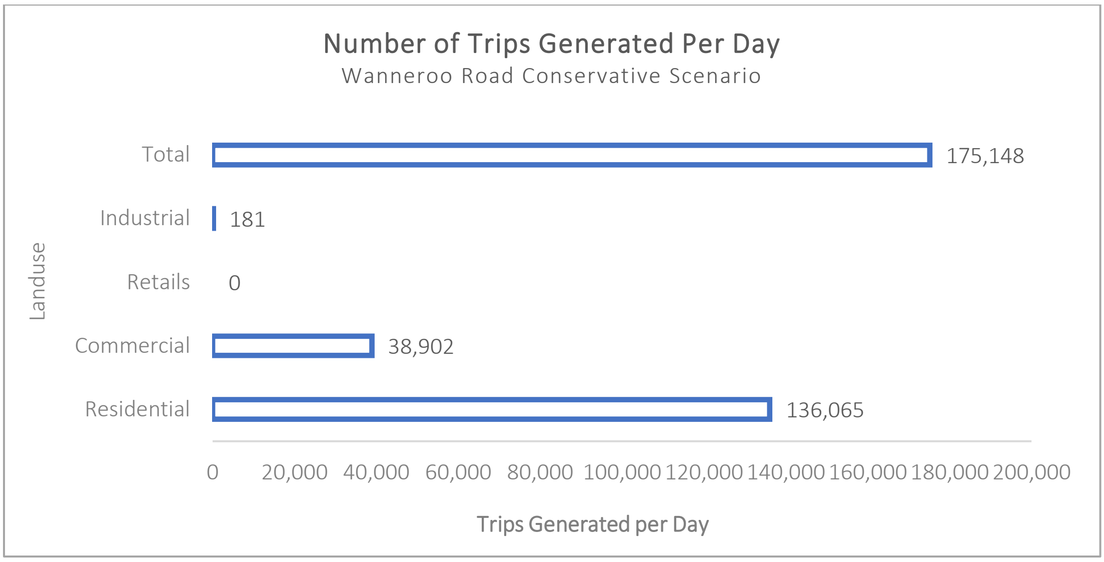
APPENDIX II: RESULTS (FIGURES) OF INDIVIDUAL ROUTES

Wanneroo Road (Conservative Scenario)

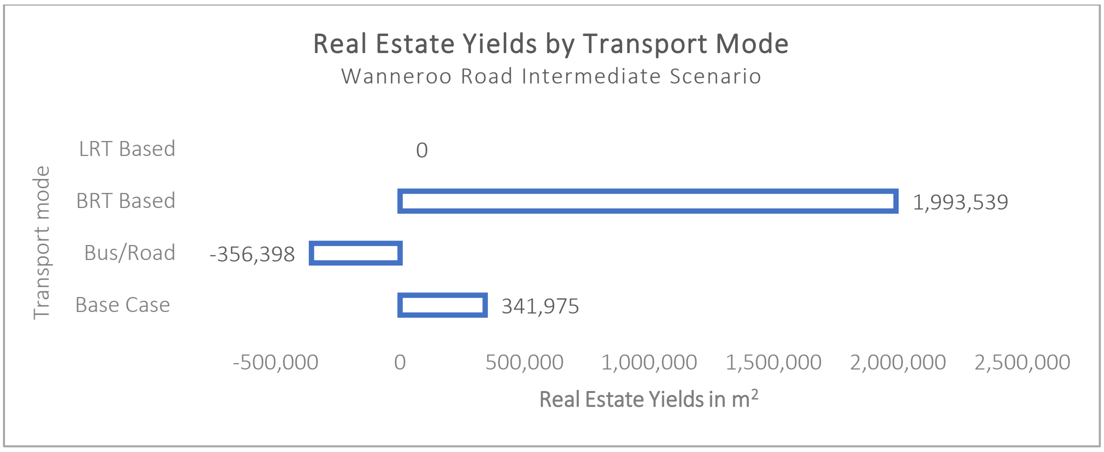


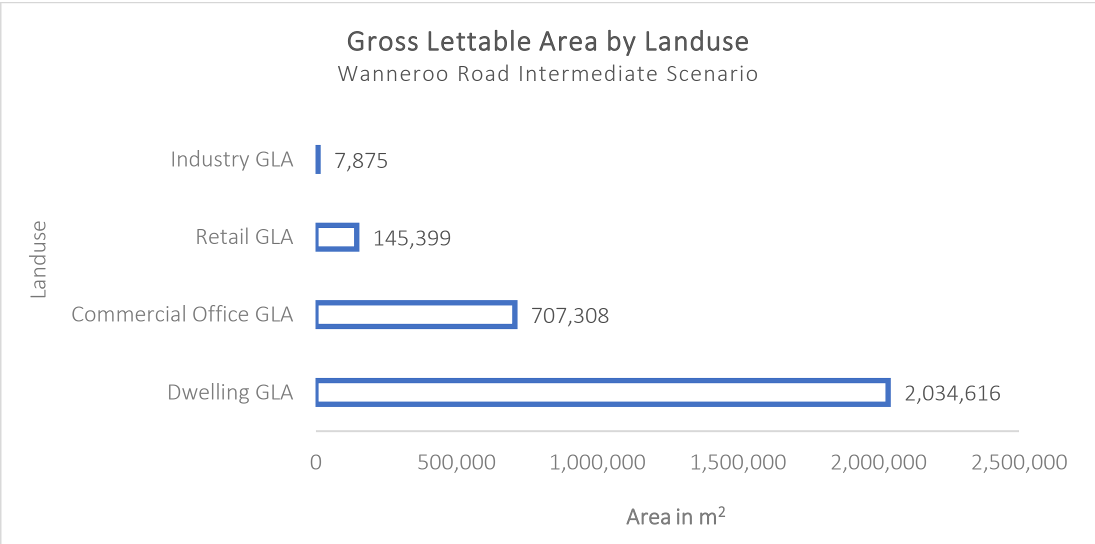


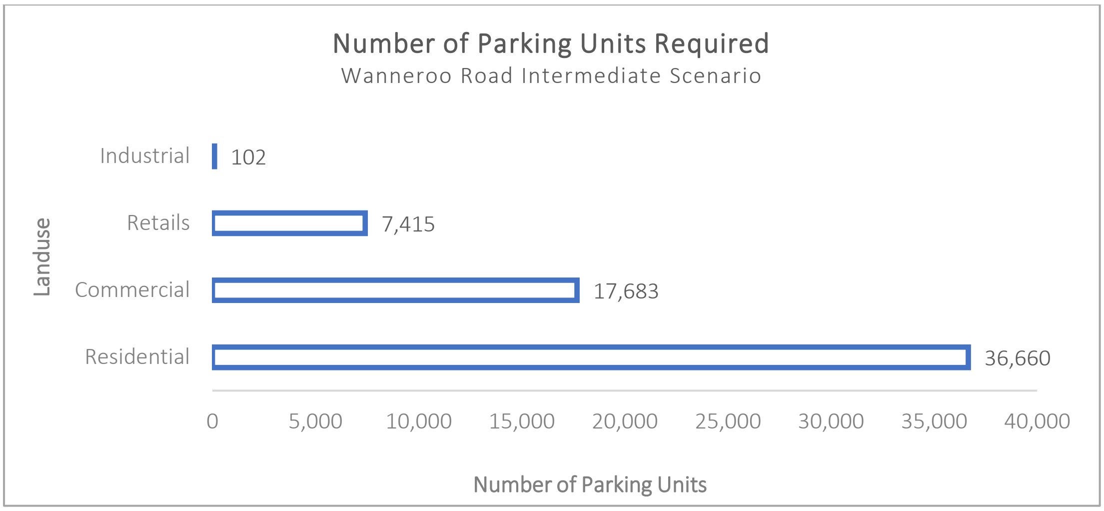


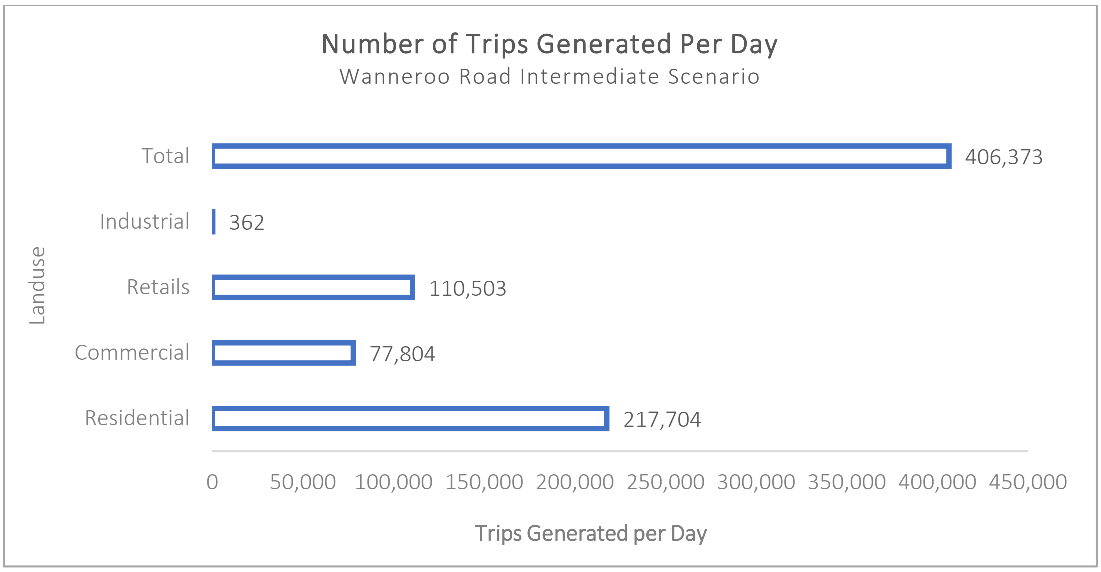


Wanneroo Road (Intermediate Scenario)

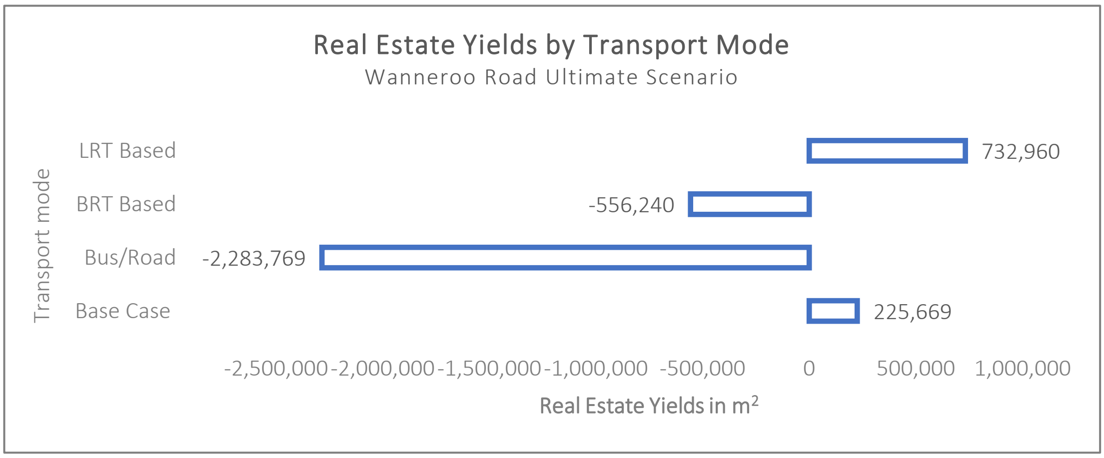


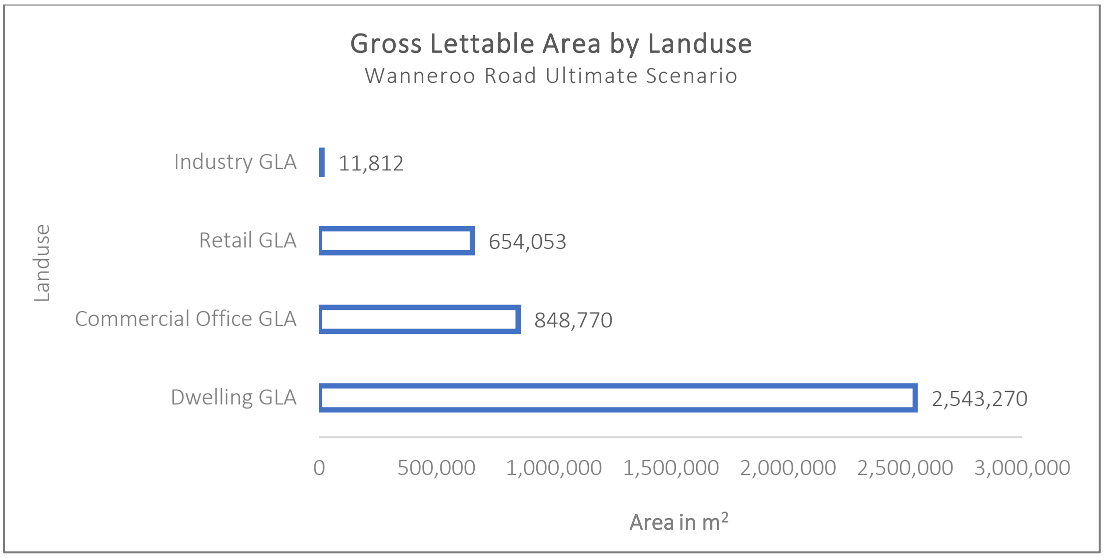


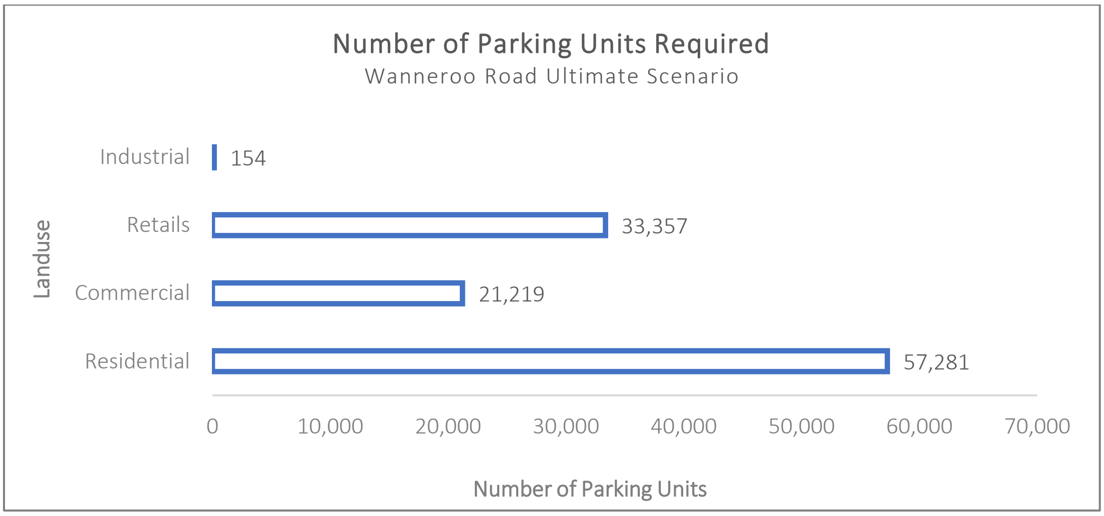


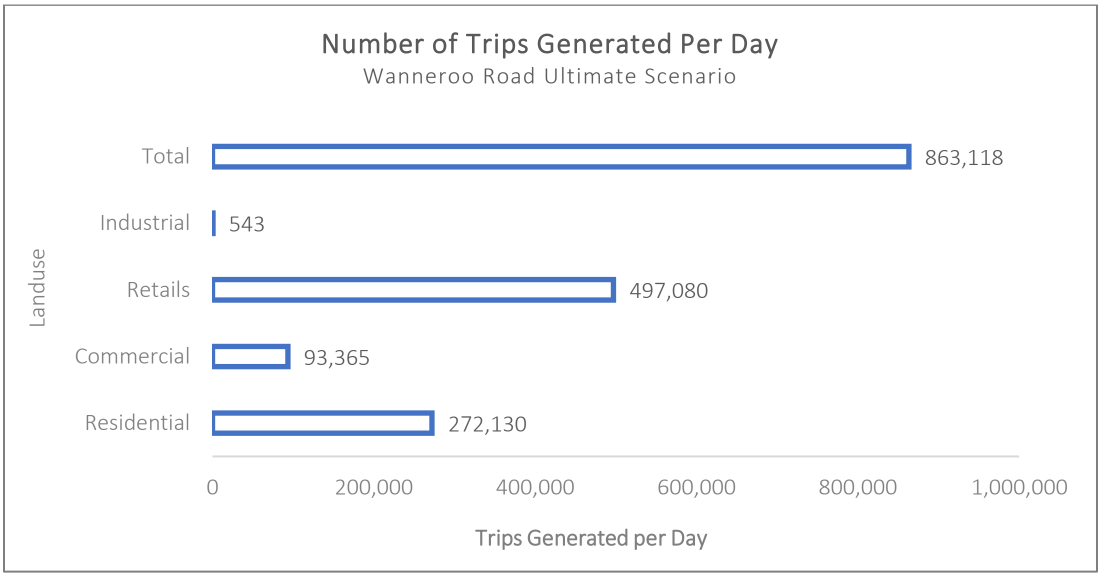


Wanneroo Road (Ultimate Scenario)

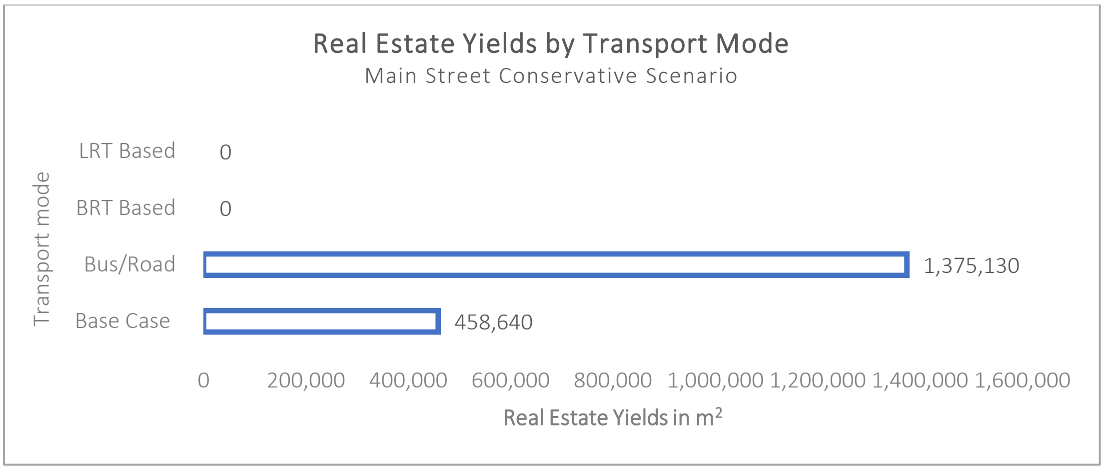


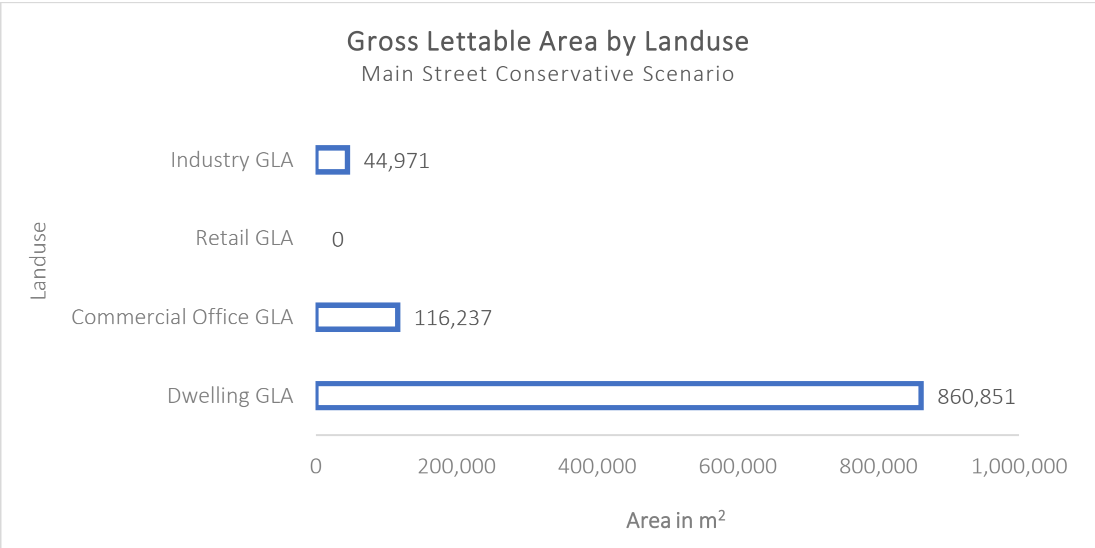

Gross Lettable Area by Landuse
Wanneroo Road Ultimate Scenario
Landuse
Industry GLA
11,812
Retail GLA
654,053
Commercial Office GLA
848,770
Dwelling GLA
2,543,270
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
3,000,000
Area in m2

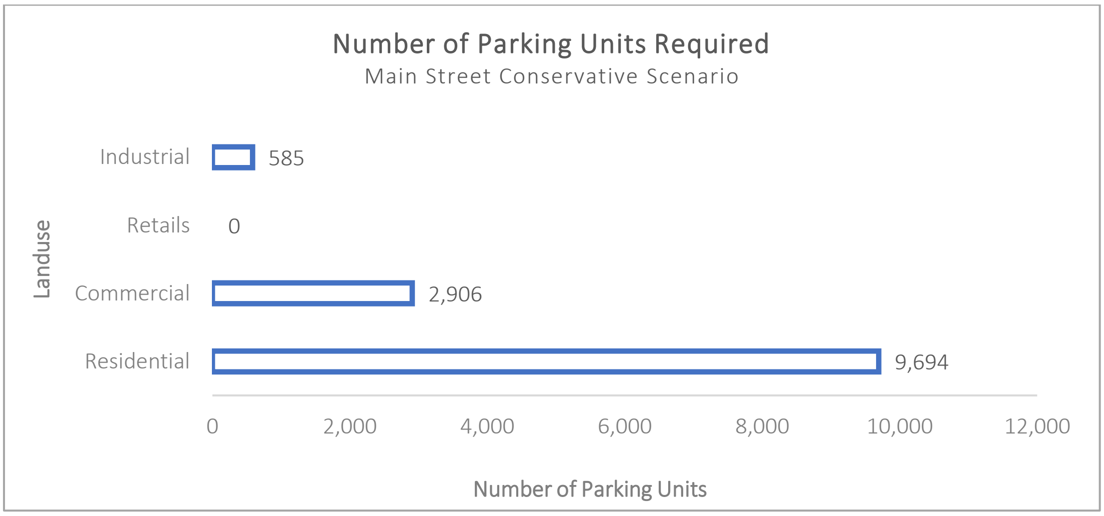

Number of Parking Units Required
Wanneroo Road Ultimate Scenario
Landuse
Industrial
154
Retails
33,357
Commercial
21,219
Residential
57,281
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
Number of Parking Units

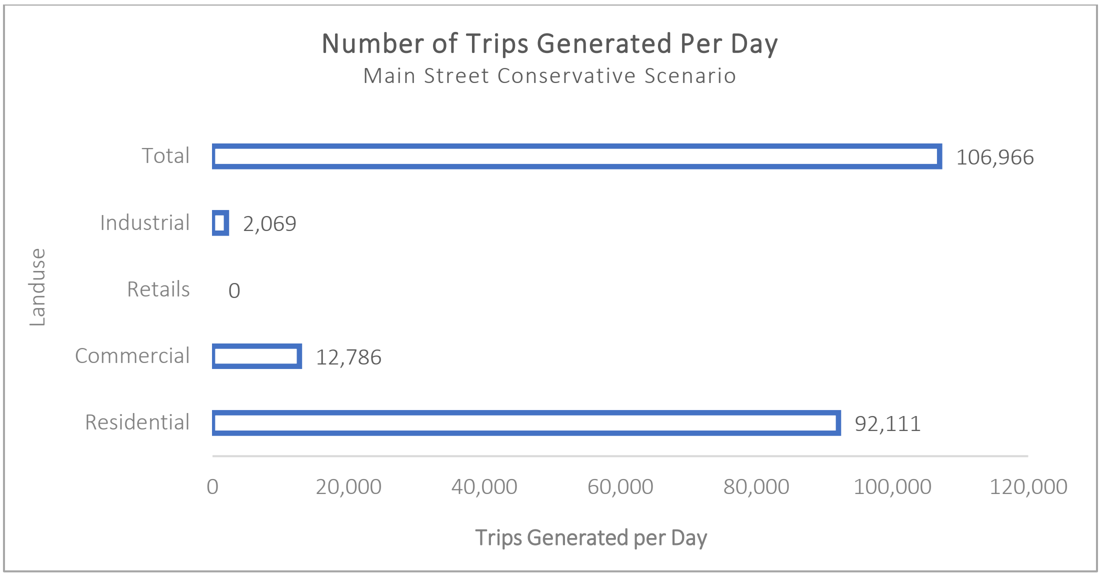

Number of Trips Generated Per Day
Wanneroo Road Ultimate Scenario
Landuse
Total
863,118
Industrial
543
Retails
497,080
Commercial
93,365
Residential
272,130
0
200,000
400,000
600,000
800,000
1,000,000
Trips Generated per Day

Main Street (Conservative Scenario)

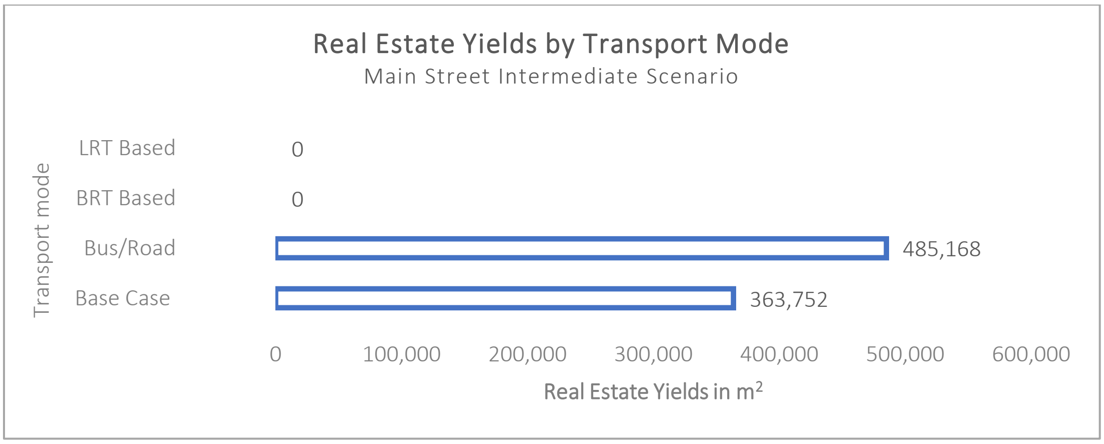


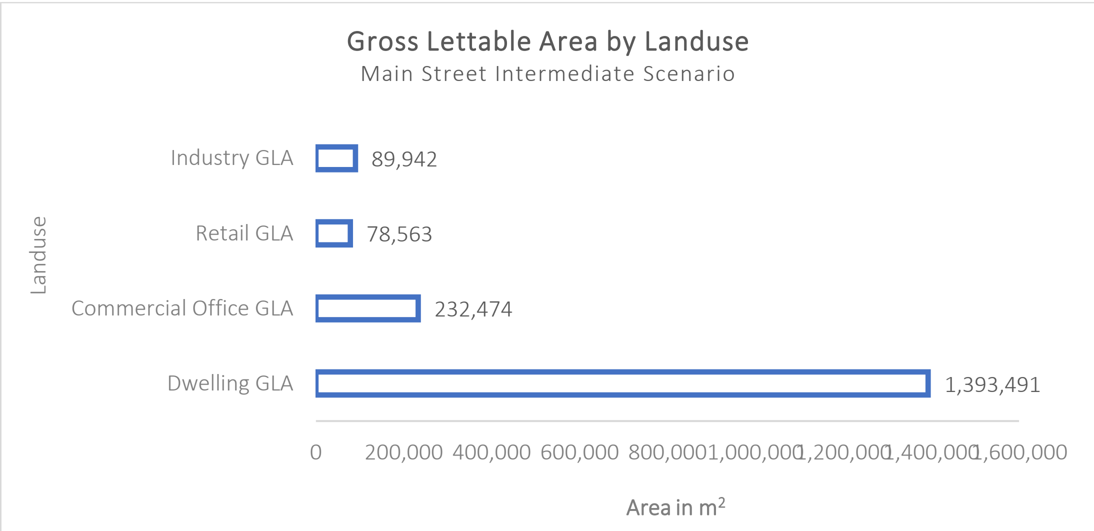


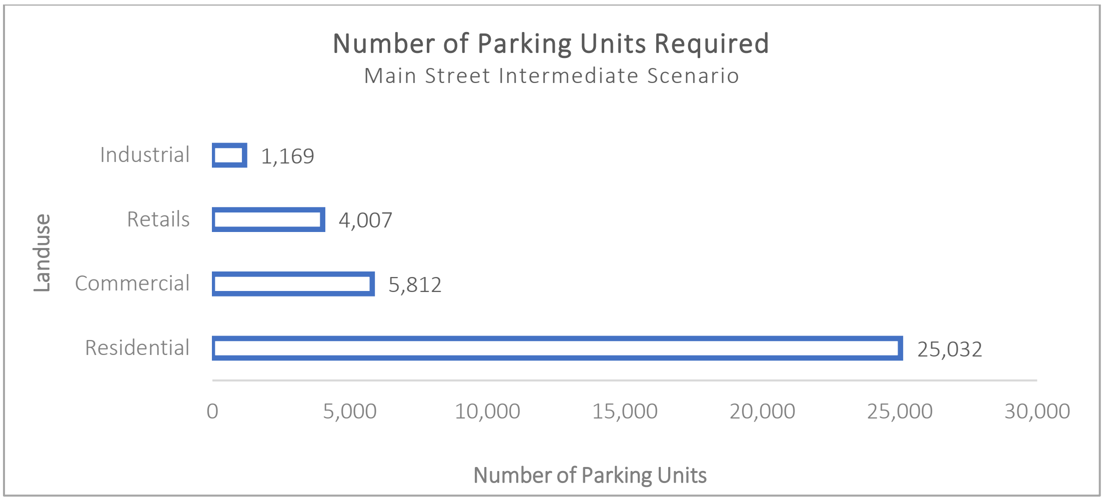


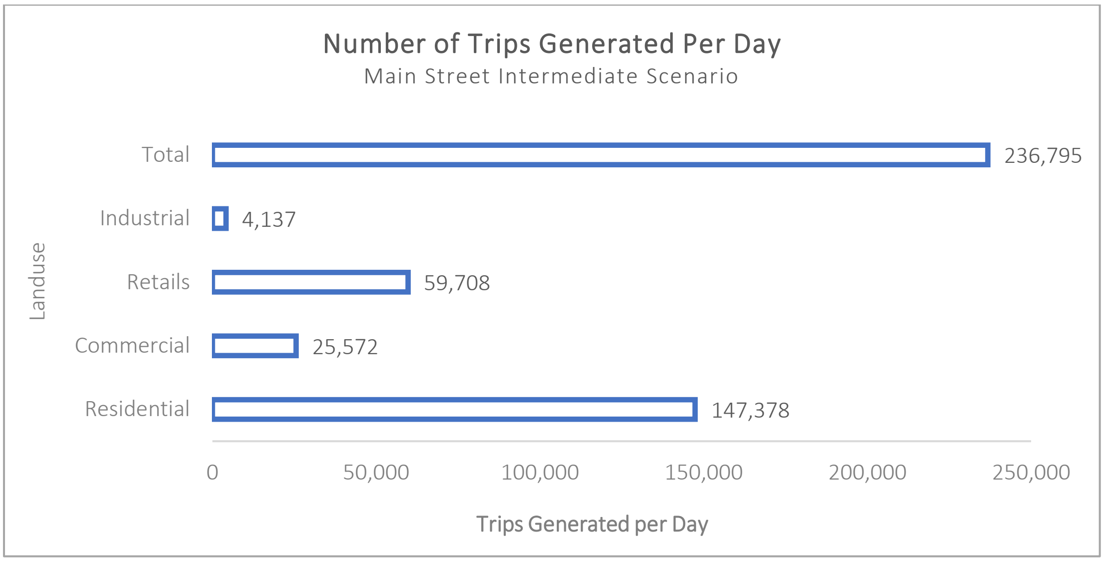


Main Street (Intermediate Scenario)

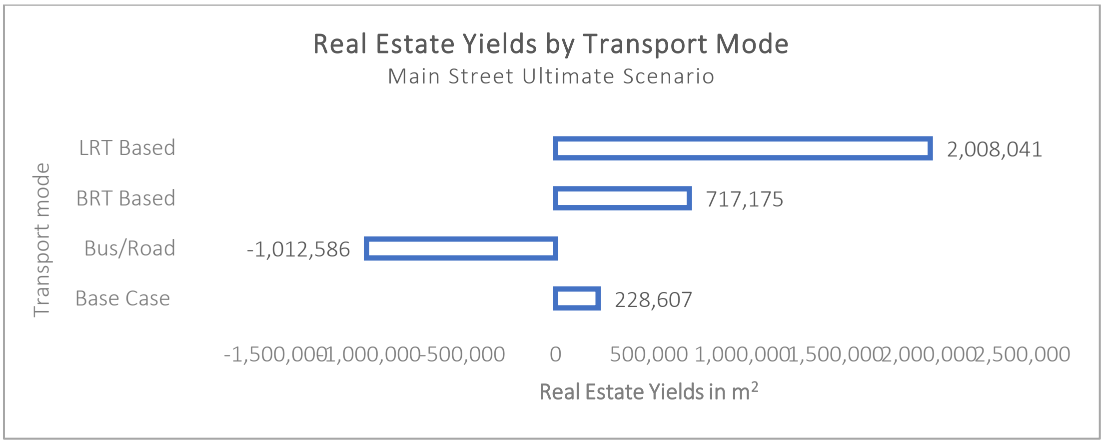


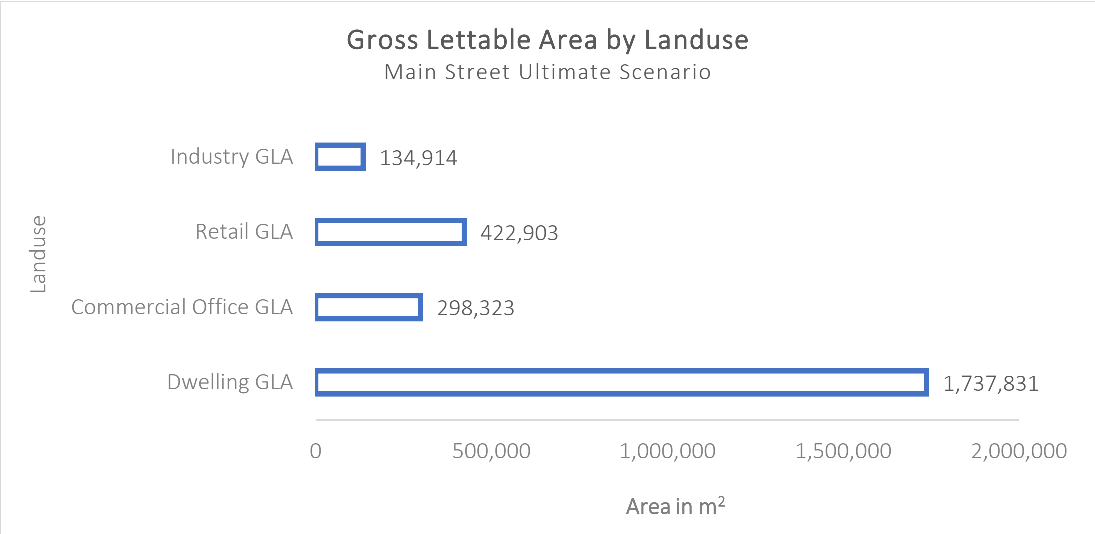




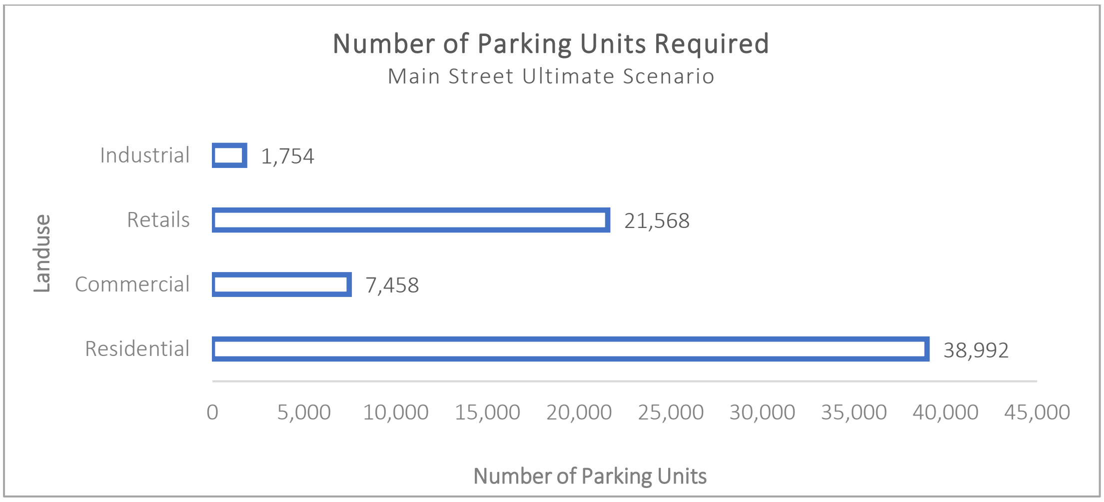


Main Street (Ultimate Scenario)

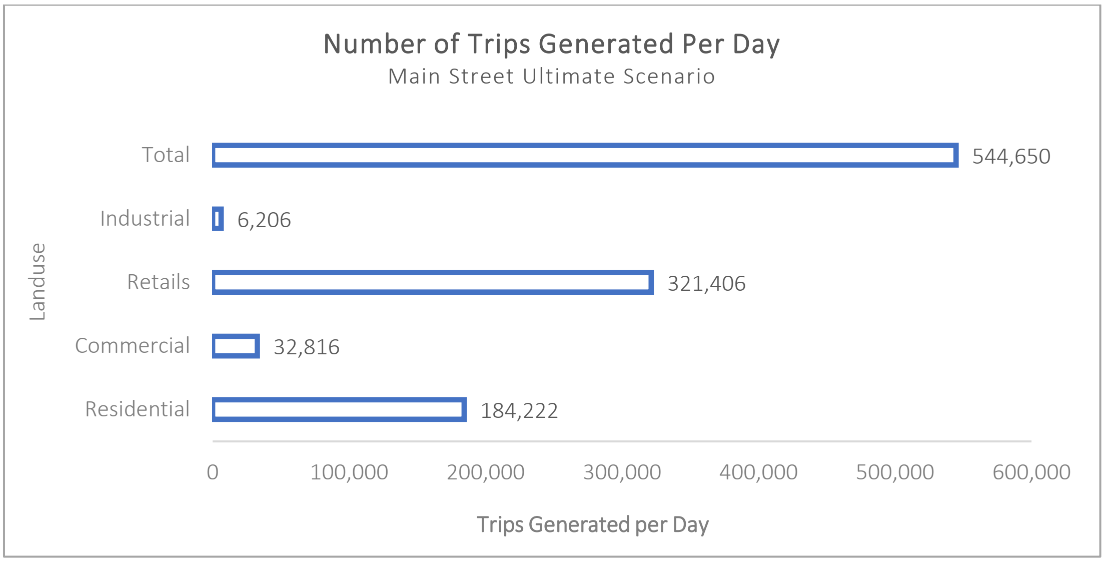




Gross Lettable Area by Landuse
Main Street Ultimate Scenario
Landuse
Industry GLA
134,914
Retail GLA
422,903
Commercial Office GLA
298,323
Dwelling GLA
1,737,831
0
500,000
1,000,000
1,500,000
2,000,000
Area in m²

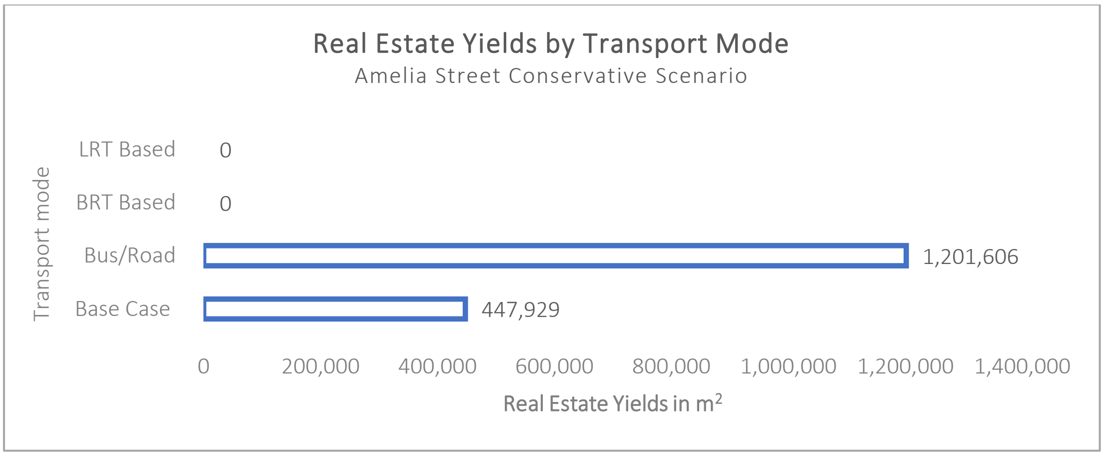


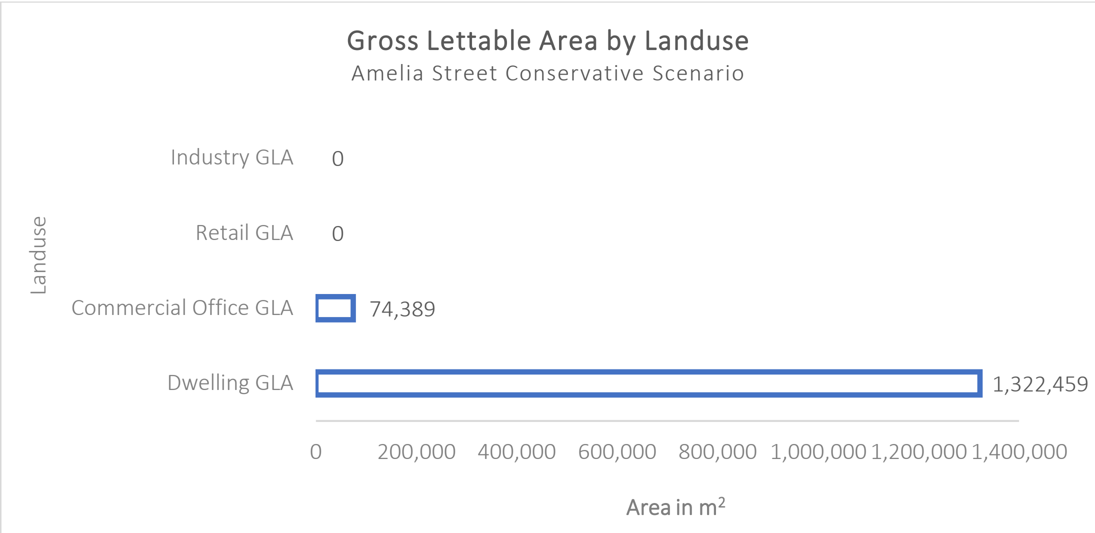
Number of Parking Units Required
Main Street Ultimate Scenario
Landuse
Industrial
1,754
Retails
21,568
Commercial
7,458
Residential
38,992
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Number of Parking Units

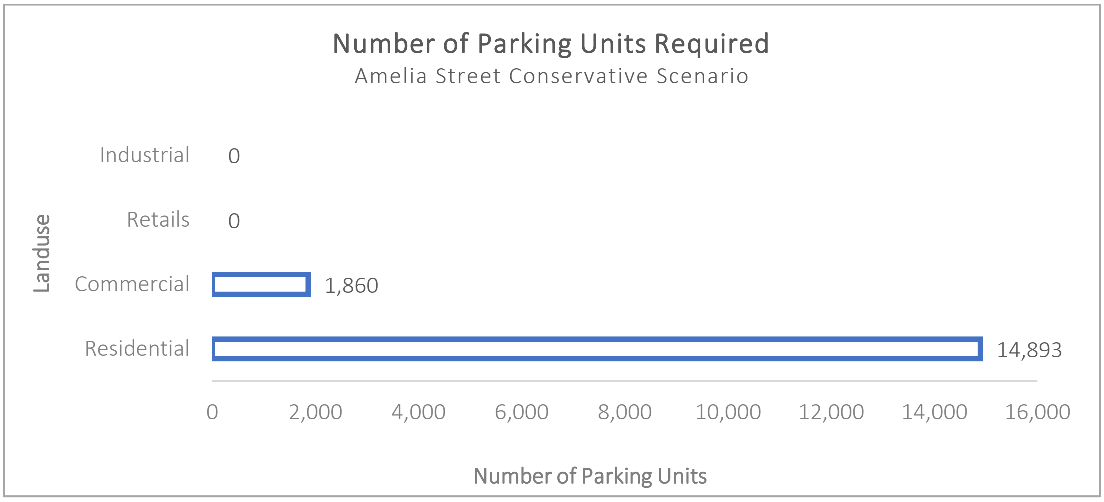


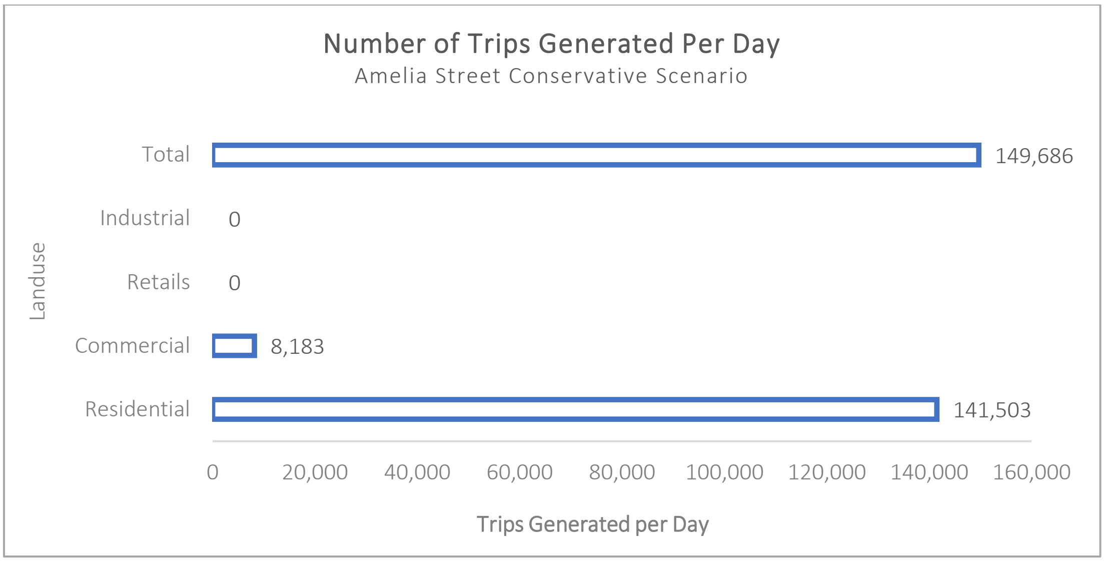
Number of Trips Generated Per Day
Main Street Ultimate Scenario
Landuse
Total
544,650
Industrial
6,206
Retails
321,406
Commercial
32,816
Residential
184,222
0
100,000
200,000
300,000
400,000
500,000
600,000
Trips Generated per Day

Amelia Street (Conservative Scenario)

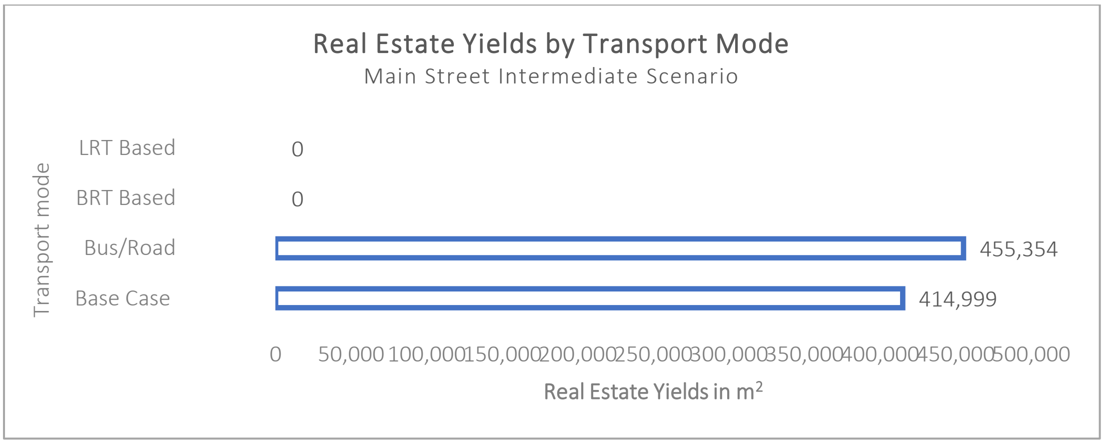


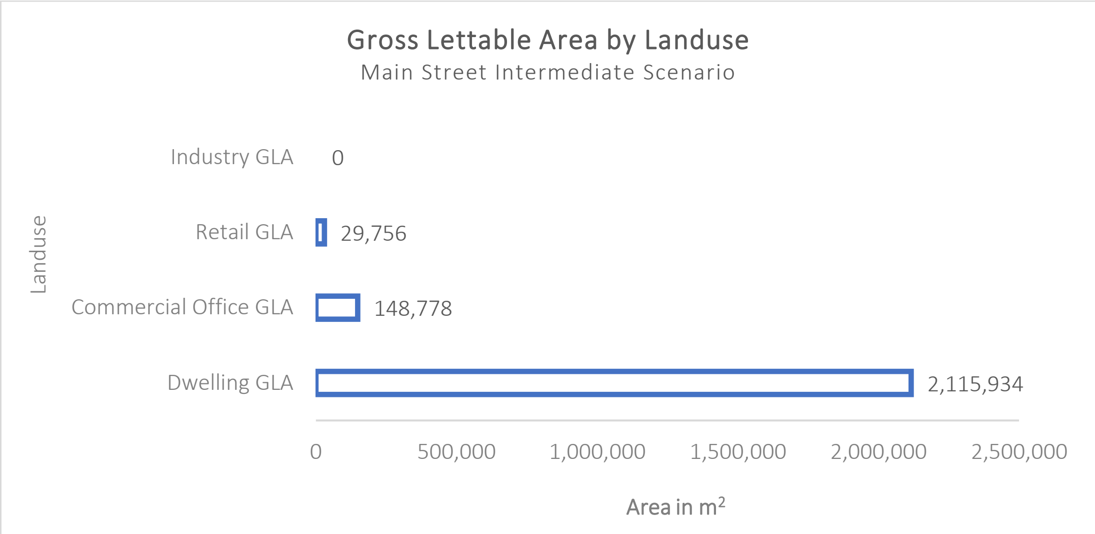


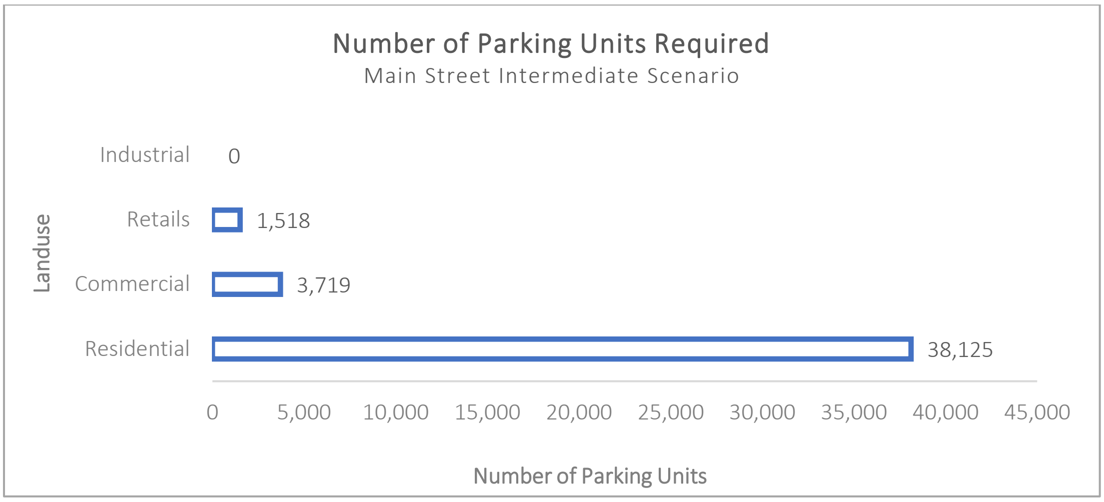


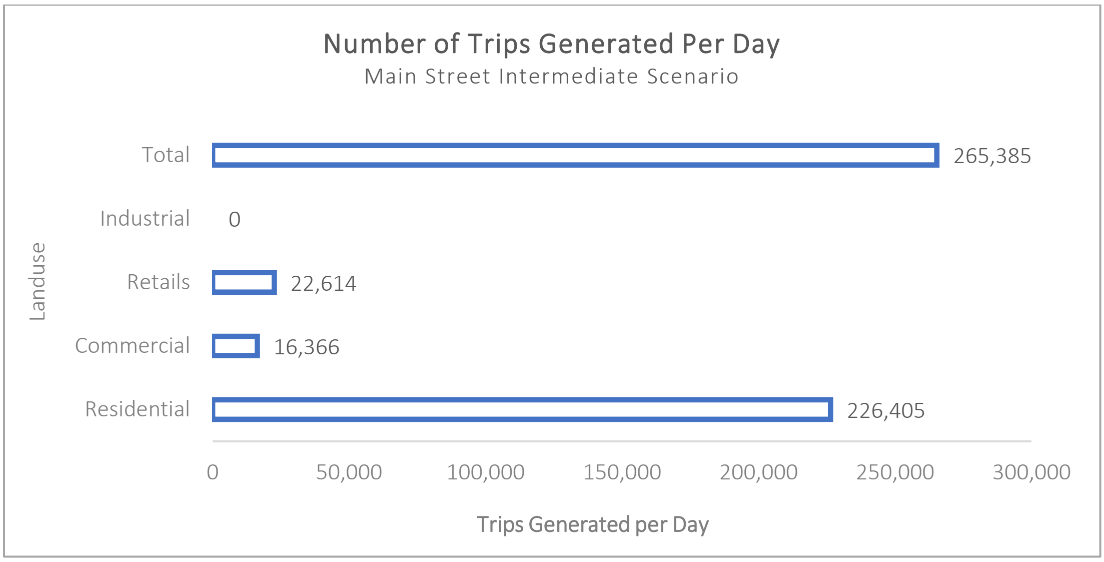


Amelia Street (Intermediate Scenario)

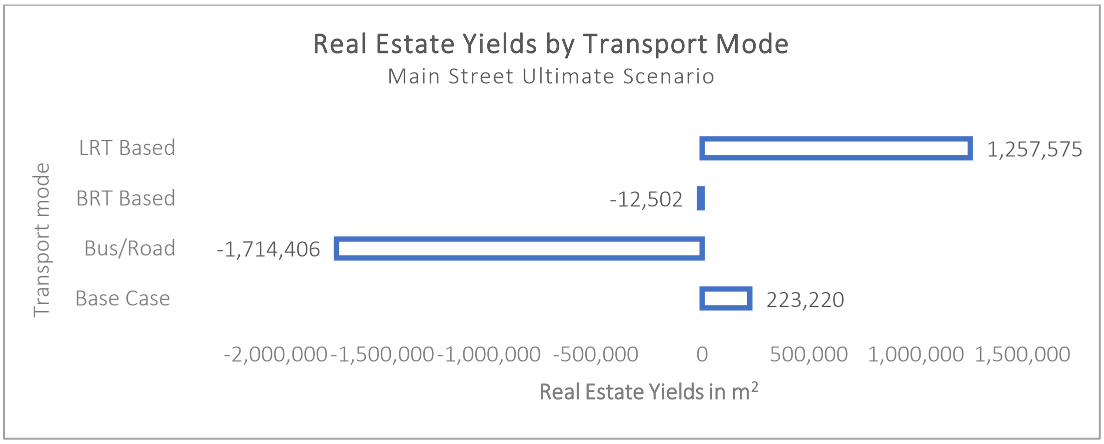


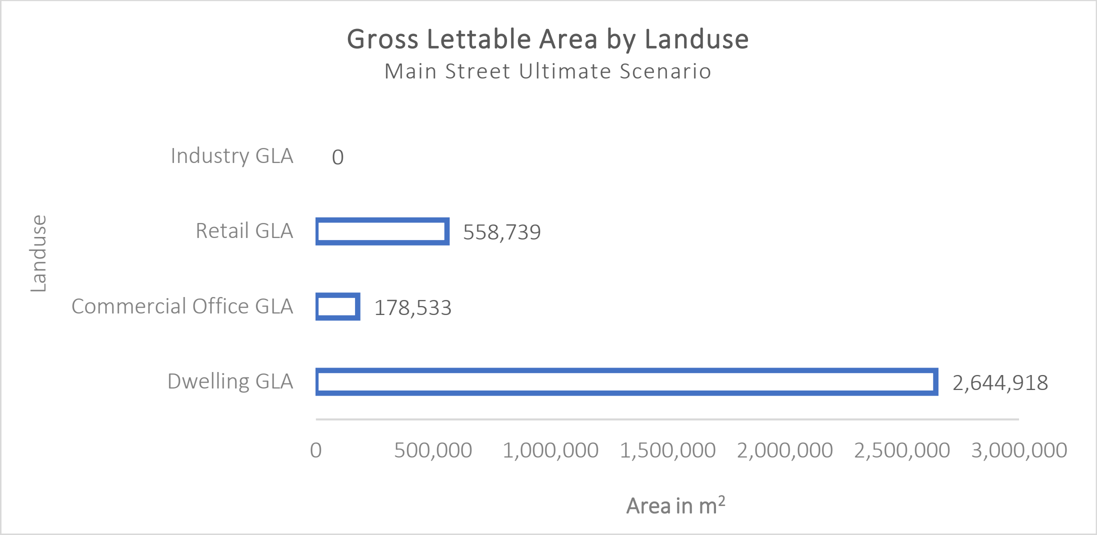


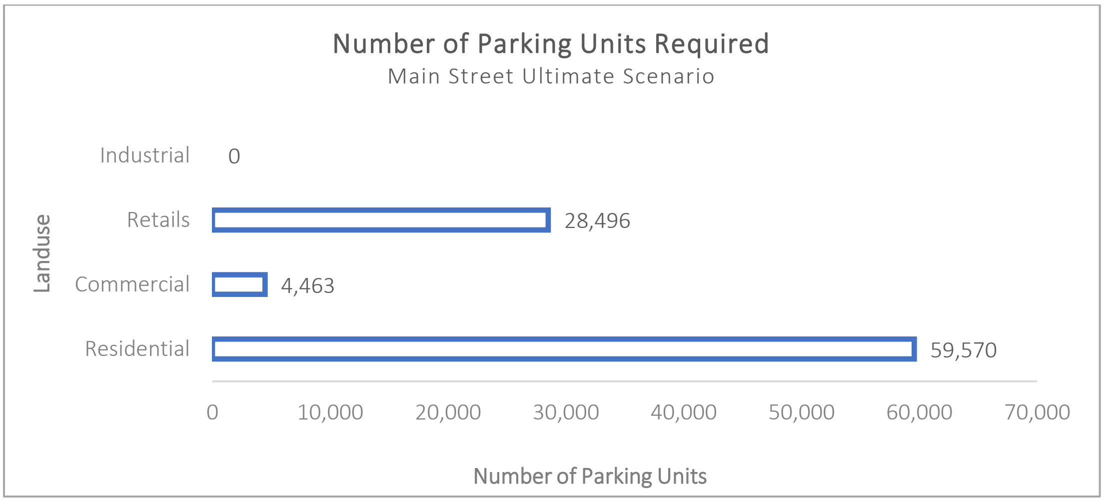


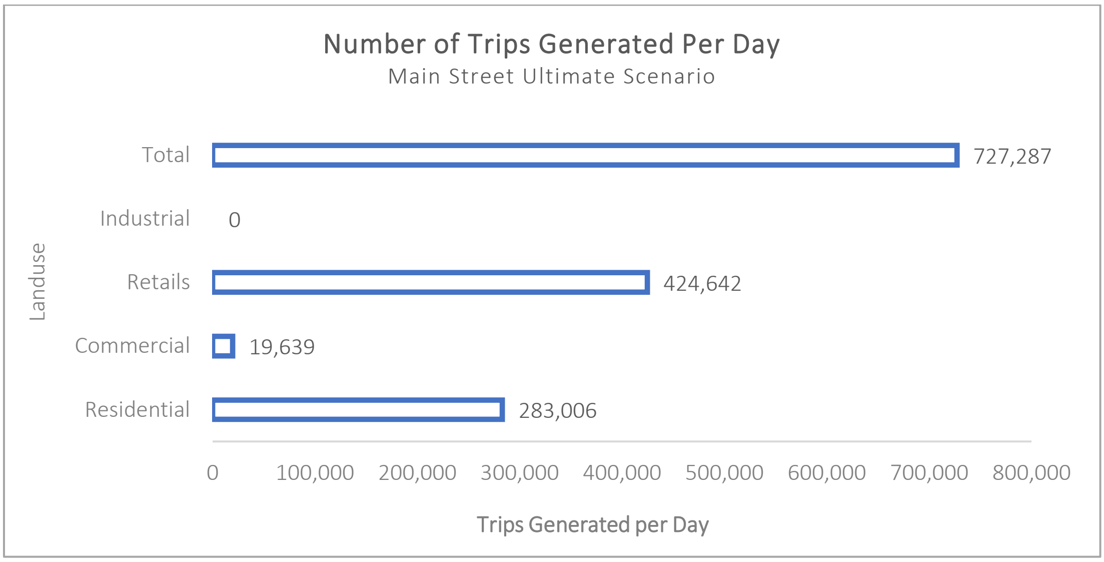


Amelia Street (Ultimate Scenario)




Gross Lettable Area by Landuse
Main Street Ultimate Scenario
Landuse
Industry GLA
0
Retail GLA
558,739
Commercial Office GLA
178,533
Dwelling GLA
2,644,918
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
3,000,000
Area in m2


Number of Parking Units Required
Main Street Ultimate Scenario
Landuse
Industrial
0
Retails
28,496
Commercial
4,463
Residential
59,570
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
Number of Parking Units


Number of Trips Generated Per Day
Main Street Ultimate Scenario
Landuse
Total
727,287
Industrial
0
Retails
424,642
Commercial
19,639
Residential
283,006
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
Trips Generated per Day

APPENDIX III: RELATION OF PLOT RATIO WITH RESIDENTIAL DESIGN CODE

The table III (a) extracted from State Planning Policy 3.1 Residential Design Code (Page 60) to demonstrate the relationship of R-Code and Plot Ratio for multiple dwellings in areas coded R30 or greater, within mixed use development and/or activity centres.

Table III (a): General site requirements for multiple dwellings in areas coded R30 or greater, within mixed use development and/or activity centres

1	2	3	4		5			6	
R-Code	Maximum plot ratio	Minimum open space (% of site)	Minimum primary street boundary setback (m)	Secondary street setback (m)	Maximum height [a] (m)			Maximum height of walls built up to boundary (m)	
					Top of external wall	Top of external wall (concealed roof)	Top of pitched roof	Maximum height	Average
R30	0.5	45	4	1.5	6	7	9	3.5	3
R35	0.6	45	4	1.5	6	7	9	3.5	3
R40	0.6	45	4	1.5	6	7	9	3.5	3
R50	0.6	45	2	2	9	10	12	3.5	3
R60	0.7	45	2	2	9	10	12	3.5	3
R80	1.0	(b	2	2	12	13	15	7	6
R100	1.25	(b)	2	2	12	13	15	7	6
R160	2.0	(b)	2	2	15	16	18	7	6
Multiple dwellings within mixed use development and activity centres									
R-AC0(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
R-AC1	3.0(c)	(c)	2	2(c)	27(c)	28(c)	30(c)	14(c)	12(c)
R-AC2	2.5(c)	(c)	2	2(c)	20(c)	21(c)	23(c)	10.5(c)	9(c)
R-AC3(d)	2.0(c)	(c)	2	2(c)	18(c)	19(c)	21(c)	7(c)	6(c)

Notes:

(a) Maximum height as defined in Table 4 does not supersede any height controls which are defined in **scheme**, the relevant **local planning policy**, **local structure plan** or **local development plan**.

(b) Refer to local structure plan or local development plan which sets out **development** requirements.

(c) Controls can be varied when R-AC is introduced into a scheme.

(d) Residential elements of **mixed use development** within non R-Coded land is to be assessed against R-AC3 provisions.

(e) **Residential development** in land zoned "R-IC" is to be assessed under the provisions of R-AC3.

(f) **Plot ratio** defined within R-AC R-Codes are for the residential component within mixed use development and **activity centres**.

APPENDIX IV: GENERAL RQUIREMENTS FOR DWELLINGS AREAS CODED LESS THAN R30

The table IV (a) is extracted from State Planning Policy 3.1 Residential Design Code (Page 58) to shows the general requirement such as minimum dwelling area, minimum lot size, maximum site coverage for all single house(s) and grouped dwellings; and multiple dwellings in areas coded less than R30. This table helps to understand the density variation for low dense suburbs when we compare with aspirational medium dense scenario.

Table IV(a) General site requirements for all single house(s) and grouped dwellings; and multiple dwellings in areas coded less than R30

1 R-Code	2 Dwelling type	3 Minimum site area per dwelling (m^2) ◆	4 Minimum lot area/rear battleaxe (m^2) ▼	5 Minimum frontage (m) ▼	6 Open space		7 Minimum setbacks (m)		
					min total (% of site)	min outdoor living (m^2)	primary street	secondary street ●	other/rear
R2	Single house or grouped dwelling	Min 5000	-	50	80	-	20	10	10
R2.5	Single house or grouped dwelling	Min 4000	-	40	80	-	15	7.5	7.5
R5	Single house or grouped dwelling	Min 2000	-	30	70	-	12	6	*/6
R10	Single house or grouped dwelling	Min 875 Av 1000	925	20	60	-	7.5	3	*/6
	Multiple dwelling	1000	-	20	-	-	7.5	3	*/6
R12.5	Single house or grouped dwelling	Min 700 Av 800	762.5	17	55	-	7.5	2	*/6
	Multiple dwelling	800	-	20	-	-	7.5	2	*/6
R15	Single house or grouped dwelling	Min 580 Av 666	655	12	50	-	6	1.5	*/6
	Multiple dwelling	666	-	20	-	-	6	1.5	*
R17.5	Single house or grouped dwelling	Min 500 Av 571	587.5	12	50	36	6	1.5	*
	Multiple dwelling	571	-	20	-	-	6	1.5	*
R20	Single house or grouped dwelling	Min 350 Av 450	450	10	50	30	6	1.5	*
	Multiple dwelling	450	-	20	-	-	6	1.5	*
R25	Single house or grouped dwelling	Min 300 Av 350	425	8	50	30	6	1.5	*
	Multiple dwelling	350	-	20	-	-	6	1.5	*
R30	Single house or grouped dwelling	Min 260 Av 300	410	-	45	24	4	1.5	*
R35	Single house or grouped dwelling	Min 220 Av 260	395	-	45	24	4	1.5	*
R40	Single house or grouped dwelling	Min 180 Av 220	380	-	45	20	4	1	*
R50	Single house or grouped dwelling	Min 160 Av 180	380	-	40	16	2	1	*
R60	Single house or grouped dwelling	Min 120 Av 150	380	-	40	16	2	1	*
R80	Single house or grouped dwelling	Min 100 Av 120	380		30	16	1	1	*
All standards for single house or grouped dwellings within R100, R160 and R-AC areas are as for the R80 Code									

Legend

- ◆ subject to variations permitted under clause 5.1.1 C1.4
- ▼ only applies to **single houses**
- ● **secondary street**: includes **communal street**, private street, **right-of-way** as street
- \- indicated not applicable
- * see **Tables 2a and 2b** and clause 5.1.3
- Av. average **site** area

APPENDIX V: A NEW MODEL FOR THE REGENERATION OF THE MIDDLE SUBURBS

The figures V (a) and V (b) shows comparative demonstration of developing the Hybrid Greyfield Precinct super imposing on piecemeal infill development in an indicative area of the City of Monash developed by Murray, Newton, Wakefield and Khor (2011). The Table V (a) provides the Design Framework Comparison between them.

Figure V(a): Piecemeal infill redevelopment – City of Monash 2002-2006

Figure V (b): Alternative design for a Hybrid Greyfield Precinct in the same location

Table V (a): Design Framework Comparison - piecemeal infill and hybrid greyfield precinct

	Typical Infill	Greyfield Residential Precinct
Dwelling types		
Yield/Density	30 dwellings.	68 dwellings.
Density	28 dwellings per hectare.	63 dwellings per hectare.
Diversity	Single storey detached and semi detached units.	A range building forms, dwelling designs and room numbers, responding to a diverse housing market and supporting several possible tenures and procurement methods.
Flexibility	None provided.	Dwelling and precinct designs that allow a variety of household types and occupations as well as various levels of visitation (within dwelling or shared on-site).
Accessibility	To legislated minimum	All dwellings are accessible or adaptable.
Private open space	Small courtyard to each dwelling; front garden setback.	Min. 2.4m deep balconies; Range of generous private courtyard spaces.
Public open space	Concrete driveway; Otherwise none provided.	Secure shared open space provided within development; public open space enhancements provided to streetscape.
Cars	1-2 per dwelling	1 per dwelling
Building performance		
Passive	To legislated minimum	Optimised solar orientation; 7-star construction energy rating.
Energy	To legislated minimum	5-6 star fittings and appliances; Smart metering
Water	To legislated minimum	Max. WELS rated fixtures
Waste	None provided	Grey water re-use
Construction type	Brick veneer construction	High thermal performance SIPs cladding system
Precinct wide initiatives		
Energy	None provided	Precinct-wide tri-generation system.
Water	None provided	Rainwater collection and reuse; Storm/ground water treatment.
Waste	None provided	Space provided for community wide waste minimisation and recycling
Transport	None provided	Upgraded bicycle lanes to street networks; Ample lockable bike storage; Allowances for car sharing; Bus shelters for public services and private shuttle.
Technology	None provided	Fibre optic communications network; Digital interface for precinct services, e.g. car sharing register and booking shared facilities.
Community capital and shared amenity		
Shared facilities	None provided	Multi-purpose community and entertainment room; Shared work shed, community kitchen and BBQ; Recreation facilities; Suitable areas for informal child minding
Local business/retail	None provided	On-site general store Adaptive dwelling use as small commercial leases and shared/home offices Food cooperative Private shuttle service

APPENDIX VI: A NEW BUS RAPID TRANSIT AND LIGHT RAIL TRANSIT, AN OVERVIEW OF COSTS AND BENEFITS

This sub-section demonstrated the cost and benefit overview comparing BRT and LRT. The table extracted from the research report developed by Committee for Perth Ltd (CPL, 2014).

2.0 A Comparison of the Benefits and Costs of Bus Rapid Transit and Light Rail Transit

Bus Rapid Transit Benefits	Light Rail Benefits
Require fewer special facilities - Buses can use existing roadways and general traffic lanes can be converted into a busway[8] - although a higher level of conversion is generally required to achieve high quality BRT system.	**Greater demand** - LRT has been found to attract more discretionary riders —those who leave cars at home— than BRT. This bias can be partially attributed to perception of greater comfort, speed, safety and reliability but also due to rail having a better general public image and greater psychological appeal than bus[9 10].
Lower average construction cost - Construction costs of BRT run approximately one-half lower than LRT, depending on the sophistication of the BRT line[11]. The more BRT emulates LRT with grade separation, higher levels of service and with better vehicles and stations, the higher the capital cost [12] with the cost of a number of sophisticated BRT systems meeting or exceeding the cost of LRT systems[13]. Recently completed BRT systems in the United States have been constructed at a cost of between $11 Million and $58 Million USD per kilometre to achieve ridership of between 4,000 and 40,000 passengers per day[14].	**Higher Capacity** – Light rail systems generally have a higher daily ridership and capacity to accommodate more passengers than BRT systems. This is primarily due to the higher capacity of LRT vehicles compared to buses which allow LRT systems to carry more passengers with fewer vehicles (and therefore fewer negative externalities than bus systems). Up to date light rail systems can carry up to 25,000 to 30,000 passengers per hour per direction[15] and usually attract more riders per day than BRT systems[16]. Existing LRT systems in the United States attract between 5,900 and 230,200 passengers per weekday[17].

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[8] Litman T, 2013, *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[9] Ibid

[10] Litman T, 2012, Rail Transit in America, Victoria Transport Policy Institute, Thttp://www.vtpi.org/railben.pdf

[11] Zang, Ming. "Bus Versus Rail: Meta-Analysis of Cost Characteristics, Carrying Capacities, and Land Use Impacts". Transportation Research Record: Journal of the Transportation Research Board, Transit 2009, Volume 1, 87-95. http://dx.doi.org/10.3141/2110-11.

[12] Zang, Ming. "Bus Versus Rail: Meta-Analysis of Cost Characteristics, Carrying Capacities, and Land Use Impacts". Transportation Research Record: Journal of the Transportation Research Board, Transit 2009, Volume 1, 87-95. http://dx.doi.org/10.3141/2110-11.

[13] Hidalgo, D, Carrigan, A 2010, BRT in Latin America High Capacity and Performance, Rapid Implementation and Low Cost, Built Environment, Volume 36, Number 3, 13 October 2010, pp. 283-297(15), Alexandrine Press

[14] Hartford Ct Fastrack, 2014, http://www.ctfastrak.com/files/CTfastrakGreeningtheCommunity_2014.pdf; Greenland J, 2013, CTA Officials Share Details of the Plan for Gold-Standard BRT on Ashland http://chi.streetsblog.org/2013/04/19/cta-officials-share-details-of-the-plan-for-gold-standard-brt-on-ashland/; Institute for Sustainable Communities, The Cleveland Healthline Transforming an Historic Corridor, http://sustainablecommunitiesleadershipacademy.org/resource_files/documents/the-cleveland-healthline.pdf; http://www.fta.dot.gov/documents/FTA_Research_Report_0004_FINAL_2.pdf

[15] Bombardier, 2014,Flexity Freedom, http://www.bombardier.com/en/transportation/products-services/rail-vehicles/light-rail-vehicles/flexity-freedom.html

Bus Rapid Transit Benefits	Light Rail Benefits
Can deliver frequent, high capacity services – High quality BRT lines can achieve high levels of ridership. Depending on vehicles used and the design of the service, passenger capacity of BRT systems can approach LRT systems with an estimated capacity of up to approximately 12,000 passengers per hour in peak periods if buses with a capacity to carry 120 passengers are used[18]. However existing BRT systems in the United States and Australia report maximum ridership of between 1,000 people per day to 40,000 people per day[19].	**Lower land acquisition costs** – LRT systems usually have lower land acquisition costs than BRT systems ($1.52 Million USD per mile versus $3.018 Million USD per mile for BRT)[20].
Cost with lower passenger numbers – Research indicates that BRT systems are more cost efficient to operate and maintain than LRT systems where ridership is 1,600-2,000 passengers per hour or less[21][22]. For lines carrying less than about 1,600 passengers per hour, adding capacity tends to be cheapest for BRT. Above 2,000 passengers per hour BRT headways become so short that traffic signal priority becomes ineffective, reducing service efficiency and increasing unit costs, making LRT more cost efficient to operate and maintain[23].	**Lower cost per passenger mile** – LRT systems have a lower cost per passenger mile than BRT systems with an estimated cost of $578 per thousand passenger mile compared to $616.4 for BRT[24].
Can stimulate redevelopment and have positive impact on property values – Recent studies indicate	**Higher Speed** – LRT usually operates at higher speeds than BRT[25]. While buses could be expected to reach

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[16] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[17] American Public Transportation Association (APTA), 2013, APTA Ridership Report - Q4 2013 Report" (pdf). American Public Transportation Association (APTA) (via: http://www.apta.com/resources/statistics/Pages/RidershipArchives.aspx

[18] Calgary Transit, A Review of Bus Rapid Transit, http://www.calgarytransit.com/pdf/brt_report.pdf

[19] Levinson H et al,2003 , Bus Rapid Transit, Volume 1 Case Studies in Bus Rapid Transit, Transit Cooperative Research Program, TCRP Report 90 http://www.nbrti.org/docs/pdf/tcrp_rpt_90v1.pdf

[20] Hidalgo, D, Carrigan, A 2010, BRT in Latin America High Capacity and Performance, Rapid Implementation and Low Cost, Built Environment, Volume 36, Number 3, 13 October 2010, pp. 283-297(15), Alexandrine Press

[21] Bruun, E. (2005). Bus Rapid Transit and Light Rail: Comparing Operating Costs with a Parametric Cost Model. *Transportation Research Record: Journal of the Transportation Research Board.* 1927 (11–21).

[22] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[23] Bruun, E. (2005). Bus Rapid Transit and Light Rail: Comparing Operating Costs with a Parametric Cost Model. *Transportation Research Record: Journal of the Transportation Research Board.* 1927 (11–21).

[24] Hidalgo, D, Carrigan, A 2010, BRT in Latin America High Capacity and Performance, Rapid Implementation and Low Cost, Built Environment, Volume 36, Number 3, 13 October 2010, pp. 283-297(15), Alexandrine Press

Bus Rapid Transit Benefits	Light Rail Benefits
that high quality rapid bus services can stimulate transit oriented development[25][26], and raise property values along their routes[27] [28]. It is noted however that examples and evidence of this occurring are limited and primarily relate to very high capacity, costly BRT systems operating in existing high density urban environments such as along BRT lines in South America.	speeds similar to light rail, buses are required to slow and stop at intersections more frequently than light rail due to the increased frequency of service required to provide carrying capacity which means that they are generally not provided with full signal pre-emption[30]. For example light rail lines in Los Angeles which have predominate exclusive right of way and full signal pre-emption achieve average speeds that are between 36% and 40% faster than those achieved by BRT (which do not have full signal pre-emption)[31]. In Australia LRT has been estimated to travel at an average of 35km per hour, compared to 30km per hour for BRT[32].
Several routes can converge onto one busway thereby reducing the need for transfers - BRT can be more flexible and more suitable for dispersed land use, such as suburban locations[33].	**Lower operating and maintenance costs** – LRT is more cost efficient to operate and maintain on routes carrying more than 2,000 passengers per hour[34]. Operating and maintenance costs for LRT systems in the United States have been found to be 4% to 46% lower per passenger mile travelled than BRT[35].

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[29] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[25] Hidalgo, D, Carrigan, A 2010, BRT in Latin America High Capacity and Performance, Rapid Implementation and Low Cost, Built Environment, Volume 36, Number 3, 13 October 2010, pp. 283-297(15), Alexandrine Press

[26] Levinson H et al,2003 , Bus Rapid Transit, Volume 1 Case Studies in Bus Rapid Transit, Transit Cooperative Research Program, TCRP Report 90 http://www.nbrti.org/docs/pdf/tcrp_rpt_90v1.pdf

[27] Tann H, 2009, Land Use Impacts of Bus Rapid Transit, Effect of BRT Station Proximity along the Pittsburgh Martin Luther King Jr, East Busway, Federal Transit Administration, Report Number: FTA-FL-26-7109.2009.6

[28] Du H, Mulley C, 2013, Understanding spatial variations in the impact of accessibility on land value using geographically weighted regression, Journal of Transport and Land Use, Vol 5 No.2

[30] Reconnecting America, 2009, Comparing Performance of Bus Rapid Transit Vs. Light Rail http://www.reconnectingamerica.org/assets/Uploads/lrtvsbrtstanger2009.pdf

[31] Reconnecting America, 2009, Comparing Performance of Bus Rapid Transit Vs. Light Rail http://www.reconnectingamerica.org/assets/Uploads/lrtvsbrtstanger2009.pdf

[32] Tirachini A, Hensher D, Jara-Diaz S, 2009, Comparing Operator and User Costs of Light Rail, Heavy Rail and Bus Rapid Transit over a Radial Public Transport Network, 11th Conference on Competition and Ownership in Land Passenger Transport, Deflt University of Technology. Available at: http://www.thredbo-conference-series.org/downloads/Thredbo11_Tirachini_Comparing_operator_and_user_costs_of_light_rail.pdf

[33] Levinson H et al,2003 , Bus Rapid Transit, Volume 1 Case Studies in Bus Rapid Transit, Transit Cooperative Research Program, TCRP Report 90 http://www.nbrti.org/docs/pdf/tcrp_rpt_90v1.pdf

[34] Bruun, E. (2005). Bus Rapid Transit and Light Rail: Comparing Operating Costs with a Parametric Cost Model. *Transportation Research Record: Journal of the Transportation Research Board*. 1927 (11–21).

Bus Rapid Transit Benefits	**Light Rail Benefits**
	This is because LRT vehicles last three times as long as BRT vehicles, require less ongoing maintenance and are cheaper to power[36]. In addition far fewer LRT vehicles are required to move large passenger volumes compared to BRT.
Is used more by people who are transit dependent - Bus service improvements can provide greater equity benefits for people living in suburban locations, however high quality BRT systems have also been found to attract more discretionary users than ordinary bus services[37].	**More positive land-use impacts** - Rail has capacity to be a catalyst for more accessible development patterns, including higher density urban form and transit oriented development[38] [39]particularly when accompanied by positive planning policies. This positive effect on land use and infrastructure efficiency and positive economic impact can offset the higher capital costs of LRT.
Can serve a larger geographical area – Bus has the flexibility to serve long routes with multiple local routes merging on to BRT routes, reducing the need for passenger transfers[40].	**Increases property values** – There is substantial evidence that rail, including LRT generally has a positive impact on property values along its route[41]. Studies of transit corridors in the United States have identified property price increases of up to 25% along rail transit routes[42] [43]although the premiums delivered have been found to be highly variable.
Can be built incrementally – Systems can be built incrementally and service can be phased in as sections of the system are completed instead of waiting for entire system to be completed[44].	**Improves community image** – LRT has more psychological appeal than bus systems, is more visually appealing has been found to have a positive impact on community image.

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[35]McGreal R, 2014, Comparing LRT and BRT for the B Line, http://www.hamilton.ca/NR/rdonlyres/1065F84D-A0CC-4B72-9748-15253523F527/0/OperatingCostsFactSheet.pdf

[36] https://www.raisethehammer.org/article/2236/comparing_lrt_and_brt_for_the_b-line

[37] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[38] Knapp, G.J., Ding, C. and Hopkins, L.D. (2001). "Do Plans Matter? The Effects of Light Rail Plans on Land Values in Station Areas." Journal of Planning Education and Research, Vol. 21 (1, Fall), pp. 3

[39] Grattan D et al, 2013,Light Rail as the Catalyst for Ottawa's Transit-Oriented Development: Planning for Sustainable Growth, Transportation Research E-Circular, Issue Number: E-C177, Transportation Research Board

[40]Jacksonville Transportation Authority http://www.jtafla.com/JTAFuturePlans/Media/PDF/BRT-LRT%20Comparison.pdf

[41] Diaz R, , Impacts of Rail Transit on Property Values, Booz Allen & Hamilton Inc, Mclean VA

[42] Du H, Mulley C, 2013, Understanding spatial variations in the impact of accessibility on land value using geographically weighted regression, Journal of Transport and Land Use, Vol 5 No.2

[43] Pan Q, 2013, The impacts of an urban light rail system on residential property values: a case study of the Houston METRO Rail transit line, Transportation, Planning and Technology Vol 36 Issue 2, Routledge, London

[44] Levinson H et al,2003 , Bus Rapid Transit, Volume 1 Case Studies in Bus Rapid Transit, Transit Cooperative Research Program, TCRP Report 90 http://www.nbrti.org/docs/pdf/tcrp_rpt_90v1.pdf

Bus Rapid Transit Benefits	Light Rail Benefits
Faster than ordinary bus – BRT has been estimated to reduce travel times by 23% to 47% compared to ordinate bus services[45].	**Provides Certainty** – Once constructed an LRT route will remain, long term, and is not likely to face pressure for conversion back to a traffic lane as has occurred with a number of BRT routes internationally.
	Lower Subsidies – Higher passenger volumes and lower operating and maintenance costs mean that high volume light rail routes usually have lower average subsides than rapid bus[46]. For example in Los Angeles bus operates at 0.46 cents per passenger mile while light rail operates at a subsidy of 0.41 cents per passenger mile[47].
	Higher voter support – Studies in the United States have found that voters are more likely to support spending on rail than on bus.
	Less air and noise pollution – LRT is not reliant on fossil fuel and therefore does not contribute to vehicle pollution and will have the capacity to provide a sustainable transport option as the world moves towards peak oil[48].
	Less pedestrian and traffic disruption on high volume routes – Moving high passenger volumes on a BRT system requires shorter headways/more vehicles than LRT. This increases disruption to pedestrians and other traffic.

Bus Rapid Transit Costs	Light Rail Transit Costs
Lower Ridership – BRT does not usually attract as many users as LRT with systems in Australia and the United States accommodating between 1,000 and 40,000 passengers per day, compared to LRT systems, some of which accommodate in excess of 200,000 passengers per day.	**Higher Capital Costs** – LRT systems generally have higher capital costs than BRT systems, with costs estimated to be approximately twice as much as BRT on average[49].

[45] Levinson H et al,2003 , Bus Rapid Transit, Volume 1 Case Studies in Bus Rapid Transit, Transit Cooperative Research Program, TCRP Report 90 http://www.nbrti.org/docs/pdf/tcrp_rpt_90v1.pdf
[46] http://www.vtpi.org/railben.pdf
[47] Ibid.
[48] All Part Parliamentary Light Rail Group, 2014, Why Light Rail, http://www.applrguk.co.uk/
[49] Hidalgo, D, Carrigan, A 2010, BRT in Latin America High Capacity and Performance, Rapid Implementation and Low Cost, Built Environment, Volume 36, Number 3, 13 October 2010, pp. 283-297(15), Alexandrine Press

Bus Rapid Transit Costs	Light Rail Transit Costs
Higher costs per passenger mile - Bus systems have the lowest cost per vehicle revenue mile and revenue hour, $3.1 and $45, respectively, but the highest cost per thousand passenger mile, $616.4[50]. This is associated with both higher operating costs and lower passenger capacity and ridership than LRT.	**Longer Development Timeframe** – The planning and construction phase for LRT is usually longer than BRT[51].
Higher land acquisition costs – BRT is associated with greater land-acquisition costs ($3.018 million per mile, versus $1.52 million). In addition, dedicated BRT guideways average a cost of $6.459 million per mile versus $4.289 million for light rail. Station costs are also slightly higher for BRT than LRT[52].	**Disruptive** – Developing LRT is disruptive to traffic, businesses and residents along the route and disruptions occur for longer than similar disruptions for the construction of BRT[53].
High maintenance and operating costs - BRT requires a lot more vehicles (and vehicle operators) than LRT to carry an equivalent number of passengers and has been found to be less cost efficient to operate on high volume routes than LRT (with a threshold of 1,800 passengers to 2,000 passengers per hour)[54] [55].	**Skewed Benefits** - Rail investments can be perceived to be less equitable because they tend to benefit higher-income people whereas basic bus services tend to service lower-income, transit-dependent people[56].
Disruptive during construction - Developing high quality BRT is highly disruptive to existing traffic, businesses and residents along the route[57].	
Disruptive during operation - BRTs with signal priority systems (changes signal lights to green when a bus approaches) cause severe traffic disruptions to traffic flow on major cross streets, particularly when the number of buses using the system is high.	

[50] Hidalgo, D, Carrigan, A 2010, BRT in Latin America High Capacity and Performance, Rapid Implementation and Low Cost, Built Environment, Volume 36, Number 3, 13 October 2010, pp. 283-297(15), Alexandrine Press

[51] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[52] Hidalgo, D, Carrigan, A 2010, BRT in Latin America High Capacity and Performance, Rapid Implementation and Low Cost, Built Environment, Volume 36, Number 3, 13 October 2010, pp. 283-297(15), Alexandrine Press

[53] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[54] McGreal R, 2014, Comparing LRT and BRT for the B Line, https://www.raisethehammer.org/article/2236/comparing_lrt_and_brt_for_the_b-line

[55] Bruun, E. (2005). Bus Rapid Transit and Light Rail: Comparing Operating Costs with a Parametric Cost Model. *Transportation Research Record: Journal of the Transportation Research Board*. 1927 (11–21).

[56] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

[57] McGreal R, 2014, Comparing LRT and BRT for the B Line, https://www.raisethehammer.org/article/2236/comparing_lrt_and_brt_for_the_b-line

Bus Rapid Transit Costs	Light Rail Transit Costs
This doesn't alleviate traffic it just redistributes traffic congestion problems.	
Can be temporary – There are numerous examples of BRT lanes being converted back to High Occupancy Vehicle lanes in response to public pressure – reducing the speed, efficiency and attractiveness of the bus service. In addition, as ridership increases and BRT becomes less cost efficient and less effective pressure can mount to convert BRT to LRT. For example in Vancouver two BRT lines have been successful, but have lower capacity and higher operating costs than the region's LRT lines. Conversions have also been planned in Ottawa. As a result, Vancouver plans to convert its BRT routes to light rail as funding permits. One former BRT route was replaced by a rapid transit line in 2009[58].	
Higher Negative Externalities – BRT has higher impacts on pollution, noise and the pedestrian environment. Buses are fossil fuel dependent, generate pollution and noise and, if shorter headways are required, can suffer from congestion within the system, have a bigger impact on traffic congestion and the pedestrian environment than LRT systems with longer headways[59].	

[58] Lambert B, 2012, How BRT to LRT Conversions are Addressed in the Transit Corridor Planning Process, 2012 APTA Conference Paper, Available at www.apta.com
[59] Litman T (2013), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

2.0 BRT and LRT – A Photographic Comparison

Many of the key costs and benefits of LRT and BRT systems can be illustrated through international photographic examples of the two modes in operation.

	
Max BRT Station Fort Collins[60]	LRT line and station Gold Coast[61]
High quality BRT systems require infrastructure that is very similar to that required by LRT systems – which can come at a similar cost.	
	
BRT Bogota[62]	LRT Phoenix[63]
Even with high capacity BRT vehicles, vehicle capacity is significantly lower than contemporary light rail.	

[60] Darrell Clark, light-rail.blogspot.com as shown by Maryland Transit Administration
[61] Image source: Daily Telegraph; www.dailytelegraph.com.au
[62] Image source: www.bettercitiesnow.com
[63] Image source: HDR Inc: http://www.hdrinc.com

BRT Bogota[64]

Yerushalayim Light Rail, Israel[65]

High capacity BRT lines require large numbers of vehicles and significant space to enable buses to pass stationary buses at stations while fewer vehicles are required to operate high capacity light rail routes.

BRT Brisbane[66]

Light rail Strasborg[67]

BRT systems can suffer from on route congestion as the number of vehicles using the system increases. Large numbers of buses can also have a significant negative impact on other vehicles, pedestrian safety and air pollution. Light rail is, by comparison, more compatible with pedestrian oriented environments and can add to local amenity as well as provide the capacity to move large passenger volumes.

[64] Image source: www.bettercitiesnow.com
[65] Image source: Hamodia, http://hamodia.com/2013/06/30/light-rail-gets-okay-for-big-expansion/
[66] Image source: Rail for the Valley : http://www.railforthevalley.com/latest-news/cardinal-fang/brisbane-australia-brt-bus-rapid-transit/
[67] Image source: www.liveablecities.org

	
Images of proposed Bus Rapid Transit and Transit Oriented Development in the United States[68]	Transit Oriented Development in the United States[69]

Rail and light rail have been shown to act as catalysts for transit oriented development and higher density urban forms, particularly when accompanied with progressive land use planning policy and initiatives. While recent studies have indicated that BRT systems can also stimulate transit oriented development, there are few examples available for examination.

[68] Image source: www.metrolinx.com

[69] Image source: Planetizen, http://www.planetizen.com/node/38695

APPENDIX VII: COPYRIGHT PERMISSION STATEMENT

Copyright Declaration

QGIS 2.14.3-Essen is a free and open source geographical information system where all content is licensed under Creative Commons Attribution-ShareAlike 3.0 licence (CC BY-SA), if not stated otherwise. Full terms at https://creativecommons.org/licenses/by-sa/3.0/

Envision is an e-tool, a decision support system where the datasets are provided via the Australian Urban Research Infrastructure Network (AURIN) Portal and their contents, to the extent they are protected by copyright, are provided under a Creative Commons licence. The e-tool is accessible at https://envision.aurin.org.au/envision and accessed on 17 December 2019.

APPENDIX VII: SURVEY QUESTIONNAIRE

Survey to analyse the priority of contextual factors to assess potentiality of proposed Light Rail Transit (LRT) corridor to support urban regeneration.

Request to participate in a PhD research survey

Dear experts,

I am writing to invite you to take part in a research study entitled framework to facilitate urban regeneration in the middle suburbs of car dependent cities. I am currently enrolled in the PhD program at Curtin University and in the stage of writing my PhD thesis. As an intrinsic part of this research, the purpose of the questionnaire survey is to determine the priority of contextual factors to assess potentiality of any proposed Light Rail Transit (LRT) corridor to support urban regeneration. Your participation in this research will provide valuable inputs in developing a consolidated ground to articulate the local contextual factors in an order to enhance the understanding of the broader context and measure the impacts of a proposed transit corridor in the urban regeneration of the middle suburbs in car dependent cities.

All the attributes of contextual factors have been distributed in four major categories that include housing, locational, transport and economic. The interpretation of the attributes of each contextual factor is briefly described in the following page to understand the context. Responses from the experts will be evaluated through Analytic hierarchy process (AHP) (Satty T.L. 2008) to produce a comparative priority scenario of mentioned contextual attributes in the attached questionnaire.

Your participation in this study is voluntary. The survey is expected to take no more than 5-10 minutes of your time. The questionnaire is in the following pages.

All information collected will be kept strictly confidential and will be used for this study only. The survey is completely anonymous, thus information collected from the survey will not include names but will include affiliation information, which will facilitate the discussion of the survey results. You will be free at any time to withdraw consent to further participation without prejudice or need not to give any justification for such a decision. In such cases, any records of your participation in the interview will be destroyed unless stated otherwise.

This research has been approved by the Human Research Ethics Committee, Research Services, at the Curtin University of Technology with approval number RDHU-03-14.

We look forward to your participation in this study and thank you for your co-operation.

Yours sincerely,

AFM Ashrafur Rahman
UID: 17659059
PhD Candidate
Curtin University Sustainability Policy Institute
Curtin University

Brief description of the attributes

The following table describes the properties of a lot/area/land parcel of a middle suburbs[i] in respect of its potentiality to contribute in setting up light rail transit as an option in surrounding area to facilitate urban regeneration.

<table>
<tr><th colspan="3">Housing Factors</th></tr>
<tr><td>Single house property

Single House in a single lot with enough room for redevelopment.</td><td>Higher size/density of land/property
Area of the land and/or property/ size of the household, R-Code</td><td>Older age property

Dwelling age in years</td></tr>
<tr><td colspan="3">Expected outcome: to determine the values of the attributes, tuned to identify the concentration of lots where older buildings, with more than two bedrooms, populated with more than average household population, 2.6 persons per household (ABS, 2011) and single house property with non-strata titles as they are more potential to go for redevelopment being bigger in size with close to end of their physical life.</td></tr>
<tr><th colspan="3">Locational Factors</th></tr>
<tr><td>Closer distance from commercial core/amenities

Closer distance from district centre, strategic centre etc. / distance to medical / distance to primary/secondary/tertiary school in meter / distance to park meter / distance to local shops</td><td>Closer distance from main street

Closer distance from nearby main road</td><td>Presence of low-income neighbourhood

Presence of nearby low income neighbourhood determined by Socio-Economic Indexes For Areas (SEIFA)[ii]</td></tr>
<tr><td colspan="3">Expected outcome: to determine the priority of the factors those reserve potential for redevelopment related to locational advantages present in current circumstances. As for example, the localities sated with people who take transit and also a walk for the journey to work are considered to be the current sample of riders who potentially will be the customer of the LRT established in future. Conversely, the adjusted (prioritized after this survey) value of contextual transport factors also identifies the negative hotspots of localities who prefer to take a vehicle to work, likely the preferable consumer of LRT who can contribute in the reduction of traffic congestion as well.</td></tr>
<tr><th colspan="3">Transport Factors</th></tr>
<tr><td>Means of journey to work

Use transit in JTW / Use cycle or walk in JTW</td><td>Proximity to transit option(s)

Proximity of nearby bus stop and train station within walking distance</td><td>Car ownership status

Number of car per family.</td></tr>
<tr><td colspan="3">Expected outcome: to determine what affect the end user more with factors related to their self-selected transit option along with proximity of their availability and catchment of services they offer.</td></tr>
<tr><th colspan="3">Economic Factors</th></tr>
<tr><td>Economic solvency of the owners
Solvency / economic status of the owners to go for redevelopment of their properties</td><td>Land Tenureship

Tenure owned/rented/mortgaged or mortgage already paid off.</td><td>Redevelopment potentiality of land/property
Redevelopment Potentiality Index (RPI)[iii], redevelopment efficiency, dwelling capacity and presence of extra land for development</td></tr>
<tr><td colspan="3">Expected outcome: In response to the infill target set for Perth, 47% (WAPC, 2010) it is necessary to adopt a mechanism in planning system that discourages development at the fringe. To identify the area potential for redevelopment around the prospective transit corridor, potentiality might be lies within the attributes like non-strata title, dwelling capacity (number of dwelling the lot can accommodate) and development efficiency (ratio of existing dwellings to the dwelling capacity reserve in current zoning) along with older buildings that have extra bit of land. As for example, it can be assumed that the lot occupied by the owner, where the mortgage has already been paid off will likely to be redeveloped and the owner might respond more enthusiastically to any development project proposed.</td></tr>
</table>

All the value (percent ratio) identified through the outcome of this survey will be used to set priority-value in Envision, a web-based multi-criteria evaluation tool.[iv]

START OF QUESTIONNAIRE

Research Title: Framework to facilitate urban regeneration in the middle suburbs of car dependent cities.

This research has the Curtin Human Research Ethics Committee approval number RDHU-03-14.

Statement:

Please compare the contextual factors in terms of housing, location, transport and economy plays important part to assess the potentiality of any proposed light rail transit corridor to support urban regeneration in car dependent cities.

How to fill up the questionnaire:

Please fill up the yellow marked cells only, with the preferred value using the scale (Figure 1a) below. **<u>Please remember to compare row relative to column</u>.**

Scale	
Degree of preference	**Value**
Extremely less important	1/9
Very strongly less important	1/7
Strongly less important	1/5
Moderately less important	1/3
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9

Figure 1a: Scale to understand degree of preferences

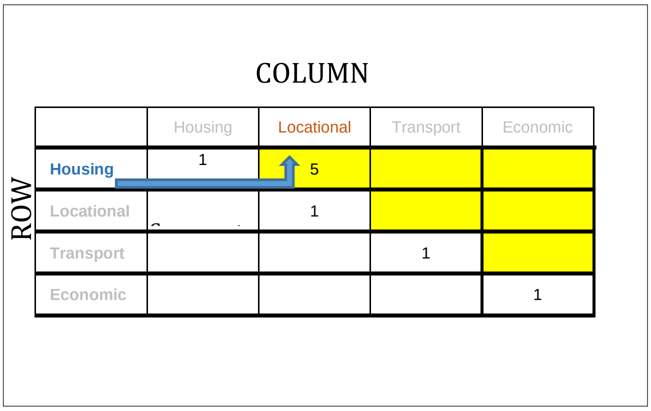

Figure 1b: Demonstration of filling up cells with values

As for example (in Figure 1b), if you find '**Housing**' factor (positioned in row) is '*strongly more important*' compare to 'Locational' factor, please put 5 in the yellow marked cell below the Locational (positioned in column) or if you find this relation *'strongly less important'* put 1/5.

Words like 'preferred' or 'relevant' may use instead of 'important', depending on the context of application.

Contextual Factors

	Housing	Locational	Transport	Economic
Housing	1			
Locational		1		
Transport			1	
Economic				1

Housing Factors

	Single house property	Higher size of land/property	Older age property
Single house property	1		
Greater size/density of land/property		1	
Older age property			1

Locational Factors

	Closer distance from commercial core/amenities	Closer distance from main road	Presence of low-income neighbourhood
Closer distance from commercial core/amenities	1		
Closure distance from main road		1	
Presence of low-income neighbourhood			1

Transport Factors

	Means of journey to work	Proximity to transit option(s)	Car ownership status
Means of journey to work	1		
Proximity to transit option(s)		1	
Car ownership status			1

Economic Factors

	Economic solvency of the owners	Land/ property tenureship status	Redevelopment potentiality of land/property
Economic solvency of the owners	1		
Land/ property tenure status		1	
Redevelopment potentiality of land/property			1

END OF QUESTIONNAIRE!

Thank you for completing the survey. Your participation with valuable responses are greatly appreciated.

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Mitchell Shire Council Website explored on 22/07/2107; https://www.mitchellshire.vic.gov.au

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[i] Newton et al (2012) characterize middle suburbs as being predominantly low to moderate income suburbs, created between the late 1930s and the late 1960s, and mostly developed through the post-Second-World-War housing boom. Those suburbs are generally characterized by a single-family house on the iconic 'quarter acre block', and are sandwiched between the gentrified and revitalised inner cities and the newer and increasingly up-market post-1980 outer suburbs.

[ii] SEIFA is a suite of four summary measures that have been created from 2006 Census information. The indexes can be used to explore different aspects of socio-economic conditions by geographic areas. For each index, every geographic area in Australia is given a SEIFA number which shows how disadvantaged that area is compared with other areas in Australia. Each index summarises a different aspect of the socio-economic conditions of people living in an area. They each summarise a different set of social and economic information. The indexes provide more general measures of socio-economic status than is given by measuring income or unemployment alone, for example. From Australian Bureau of Statistics (http://www.abs.gov.au/).

[iii] An index of property redevelopment potential (PRPI) can be calculated for all individual residential properties within municipalities using property valuation data held by the Valuer-General. The property redevelopment potential metric for each parcel is calculated as the ratio of the land value (numerator) to capital improved value (land value plus value of the built assets on that site—the denominator). A PRPI approaching 1.0 indicates that the value of the property is represented almost entirely by the land component and as such is more economically viable for redevelopment compared to properties with PRPIs of 0.5 or less. This is commonly used as a principal selling feature at auction. The hypothesis that properties with a high PRPI that come onto the market are redeveloped at a more rapid rate than those with a low PRPI was tested and confirmed by Newton et al (2012).

[iv] A software tools which is possible to bring multiple layers of property, planning, utility and demographic data together into a distributed (shared) urban spatial information system (Newton et al., 2013). Such a platform, with dynamic, up-to-date information and real-time access, provides a basis for professionals like planners, property developers, design and construction professionals, investment organisations, local government and neighbourhood communities (in various combinations) to explore development opportunities.