

**Curtin University Sustainability Policy (CUSP) Institute**

**Framework to capture the value created by urban  
transit in car dependent cities**

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**A thesis by publication submitted in partial fulfilment of the requirement for  
the Degree of Doctor of Philosophy (PhD) of Curtin University**

**November 2014**

**DECLARATION**

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

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

Signature:  .....

Date: 17/11/2014.....

## ABSTRACT

Many cities globally are dependent on cars to meet their urban transportation needs due to the evolution of their urban form and the nature of their provision of urban mass transit in the period after the Second World War. To stem or reduce their car dependence, city governments are now investing in urban rapid transit, and redeveloping their cities around it. The high cost of the investment in retrofitting rapid transit systems into cities existing urban fabric have seen many major transit projects stuck in financial and economic assessment due to inadequate links between land use, transport and funding planning and policy. This lack of investment in urban rapid transit systems have left most urban transport networks with a transit infrastructure deficit that they need to address to stem car dependence. Therefore the overarching question that is being sought to be addressed by this research PhD is: “Can land and property market value capture fund urban transit in car dependent global cities”?

To address this question, this PhD thesis by publication (five journal papers and a book chapter), focusses on five key research areas:

- i.) the causes of car dependence in cities;
- ii.) urban transport system and land development planning and policies to respond to these causes;
- iii.) quantification of the willingness to pay for transit accessibility in cities’ land and property markets;
- iv.) financial modelling of the induced government revenue generated through existing taxes and charges from the transit investment; and
- v.) development of an integrated land use and transit value capture framework to fund rapid transit investment to stem cities car dependence.

The research conducted as part of this thesis was multidisciplinary in nature. The econometric analysis conducted in (*Journal Paper 1*) on the Global Cities Database from 1960 to 2000 established the causes of cities car dependence using structural equation modelling. The results of the structural equation modelling demonstrated that that the two key factors in cities car dependence is their level of provision of transit and the densities of the urban regions which it serves. These results formed

the quantitative economic basis for the thesis premise that car dependence can be resolved by investments in transit and urban densification.

The findings of (*Journal Paper 1*) led to the need to understand the policy and planning solutions to car dependence in global cities in two papers: urban development policy analysis to stem car dependence (*Book Chapter 1*); and urban transport system planning (*Journal Paper 2*) to stem car dependence. These papers identified the urban development and transportation network policies and planning required to stem the dominance of cars in cities transport systems and urban land and property markets.

To quantify the economic implications of these policies, hedonic price modelling was used to determine the impact of transit investment on car dependent city land markets for Perth, Western Australia (*Journal Paper 3*). The results of this hedonic price modelling on urban land value demonstrated that there was a significant willingness to pay for:

- i.) access to transit infrastructure and services, and
- ii.) land parcels with the capacity for higher development density.

The financial impact on existing land and property taxes and charges of this willingness to pay for transit and urban density in Perth was demonstrated in a value capture financial model (*Journal Paper 4*). A case study established that the investment in the Mandurah Rail Line in Perth, Western Australia confirmed that significant financial revenue was generated from the investment and if captured, could have significantly defrayed the cost of the investment. To achieve the capture of these land market taxation benefits, a tax increment financing framework is proposed so that this additional revenue source could be used to defray the cost of the infrastructure investment.

Cumulatively, the research outlined above is synthesised to inform the development of a universal value capture framework (*Journal Paper 5*) to both passively and actively capture some or all of the land and property market benefits to help defray the cost of the transit investment and the regeneration of our cities urban fabric.

The outcomes of this research provide novel contributions to knowledge of the economic causes and solutions to car dependence in cities globally. The Mandurah rail line case study used across *Journal Papers 2, 3, 4 and 5* illustrates that when transit and urban densification are integrated around transit stations the passive and active value capture mechanism revenues are sufficient (over a 30-year period in real terms) to pay for the infrastructure investment. This is an unexpected result with great significance for car dependent cities, suggesting that existing economic and financial assessment methodologies have failed to account for these benefits when assessing integrated urban transit and regeneration projects.

The value capture framework proposed in *Journal Paper 5* enables a rigorous economic and financial assessment to the development of the urban infrastructure policies and practices to reduce car dependence. As the value capture framework is based on economic analysis and research, this will support more appropriate means of financially assessing the projects by understanding not only the project costs, but all the benefits created as well, and using some or all of these benefits to defray the cost of integrated transit and urban densification projects.

## ACKNOWLEDGEMENTS

Completion of this Doctoral research would not have been possible without the support and assistance of numerous people through the research project. I would firstly like to express my appreciation to my Principal Supervisor, Professor Peter Newman. Peter's support and guidance provided throughout the duration of the research has been invaluable and I am extremely grateful for his assistance.

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Tim Crane has been a professional mentor throughout my PhD, and his willingness to share his knowledge in the field of integrated transport and land use business case development has been the key factor that has enabled me to complete this research. For this I will be eternally grateful.

I would also like to acknowledge both the Department of Planning, and Landgate for the provision of the base data for the hedonic price modelling, and to Professor Jeff Kenworthy for access to the Global Cities Database for the assistance with the global car dependence analysis.

Thanks also to Dr Andrew Harwood for his assistance in finalising the thesis into its final form.

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## **DEDICATION**

I would like to dedicate this thesis to my wife Kate, sons Miles and Sean, and parents John and Annette. Their patience and understanding throughout this doctoral research has made this all possible.

## PUBLICATIONS SUBMITTED AS PART OF THIS THESIS

### Statement of Contribution of Others

All of the written materials submitted as part of this PhD by Publication were conceived and coordinated by James Robert McIntosh. The majority of the calculation and writing for each publication was undertaken by James Robert McIntosh.

Signed detailed statements from each co-author relating to each publication are provided as appendices at the back of this volume (Appendix 1).

Signed:



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James Robert McIntosh, PhD Candidate



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Professor Peter Newman, Supervisor

Date: 11/09/2014

## PUBLICATIONS SUBMITTED AS PART OF THIS THESIS

### **Journal Paper 1**

**McIntosh J.**, Trubka R., Kenworthy, J. and Newman, P. (2013) The Role of Urban Form and Transit in the Rise of Car Dependence: Analysis of 26 Global Cities from 1960 – 2000 *Transportation Research - Part D* Vol.33 Dec. 2014, 95–110

<http://www.sciencedirect.com/science/article/pii/S136192091400114X>

### **Journal Paper 2**

**McIntosh J.**, Newman P. and Glazebrook, G. (2013) Why Fast Trains Work: An assessment of a fast regional rail system in Perth, Australia, *Journal of Transportation Technologies* **2013, 3, 37-47** doi:10.4236/jtts.2013.32A005

Published Online May 2013 (<http://www.scirp.org/journal/jtts>)

### **Book Chapter 1**

Newman, P., Matan, A. and **McIntosh, J.** (2013) Urban Transport and Sustainable Development, *Routledge International Handbook on Sustainable Development* (Accepted for Publication - March, 2014)

### **Journal Paper 3**

**McIntosh J.**, Trubka R., Newman P. (2013) Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia. Published in *Transportation Research - Part A*, 67 (2014) 320-339

<http://www.sciencedirect.com/science/journal/09658564/67>

### **Journal Paper 4**

**McIntosh J.**, Trubka R., Newman P. (2013) Tax Increment Financing framework for integrated transit and urban renewal projects in car dependent cities. *Urban Policy and Research* (Accepted for Publication, September, 2014)

### **Journal Paper 5**

**McIntosh J.**, Kenworthy, J., Trubka R., Newman P. (2013) Framework for Land Value Capture from the investment in transit in car dependent cities. *Journal of Transport and Land Use* (Accepted for Publication - March, 2014)

## **LIST OF RESEARCH PUBLICATIONS BY THE CANDIDATE BUT EXCLUDED FROM THIS THESIS**

### **Research Paper 1**

**McIntosh, J.**, Newman, P., Crane, T. and Mouritz, M. (2011) Alternative Funding Mechanisms for Public Transport in Perth: the Potential Role of Value Capture, Committee for Perth. Downloadable from:

<http://www.committeeforperth.com.au/pdf/Advocacy/Report%20-%20AlternativeFundingforPublicTransportinPerthDecember2011.pdf>

### **Research Paper 2**

**McIntosh, J.**, Newman, P., Scheurer, J., Wisdom, A. (2012) Initial Assessment of the Accessibility & New Funding Opportunities for the Doncaster Rail Project, City of Manningham, Melbourne. Downloadable from

[http://www.manningham.vic.gov.au/maccwr/assets/main/lib90041/02%20-%20pdf%20files/appendix%20d%20-%20doncaster\\_rail\\_project\\_accessibility\\_and\\_new\\_funding\\_opportunities\\_report\\_final.pdf](http://www.manningham.vic.gov.au/maccwr/assets/main/lib90041/02%20-%20pdf%20files/appendix%20d%20-%20doncaster_rail_project_accessibility_and_new_funding_opportunities_report_final.pdf)

### **Research Paper 3**

Newman, P and **McIntosh, J.**, (2013) Australia Adjusting: Optimising national prosperity - Chapter 2.6 Delivering efficient public infrastructure: Some new trends, Committee for Economic Development of Australia (CEDA) Downloadable from:

[http://www.ceda.com.au/media/338287/cedaaustadjusting\\_web.pdf#](http://www.ceda.com.au/media/338287/cedaaustadjusting_web.pdf#)

## **ACADEMIC PEER REVIEWED CONFERENCE PUBLICATIONS**

### **Conference Paper 1**

**McIntosh J.**, Trubka R., Newman P., Kenworthy., J (2013) Framework for Land Value Capture from Transit in Car Dependent Cities - Planning Institute of Australia National Conference, 2013.

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## 1 INTRODUCTION

The fabric of urban areas has evolved over time, and its function and form is generally a result of the development of its culture, power, capital, technology, planning desiderata, environmental constraints, historical and geographical and importantly its transport system (Thomson, 1977; Cervero and Kockleman, 1997; Cervero and Duncan, 2002). Marchetti (1994) demonstrated that since 1800, any city's urban form has been constrained by its travel time budget such that all cities have grown to be 'one hour wide' (Zahavi and Ryan, 1980; Marchetti, 1994). The transport technology changes over time detailed by Marchetti, (1994) have led the city's urban fabric to evolve from 'walking city', to Transit City and subsequently to 'automobile city' urban fabric (Newman and Kenworthy, 1999), and notably all fabrics are generally present in all global cities.

In the post second world war period as passenger cars became the dominant urban transport mode in most cities, urban function and sprawling urban form became dependent on cars rather than trains, trams and buses. As many have pointed out (Thomson, 1977; Banister and Lichfield, 1995), this dependence on automobile-based transport in global cities has gone hand-in-hand with a dramatic increase in the impact of negative transport externalities, such as congestion, environmental emissions, and fossil fuel consumption. The rise of the car has also attended the decline in the demand and provision of transit provision per capita (service km per capita), as well as reduced investment in infrastructure for walking/cycling.

The first part of this thesis analyses the underlying causes of car dependence so that any investment to address car dependence in global cities addresses the causes rather than merely addressing the transport externalities in an uninformed manner (such as building more road capacity to address road congestion).

Contrary to the expectations of transport professionals and policy maker there has been a reduction in car use per capita since 2004, a phenomenon known as 'Peak Car' (Goodwin and Van Dender, 2013; Newman and Kenworthy, 2011). This decline in car use per capita has been matched by an increased demand for transit in recent

times as most global cities are looking to stem or reverse their car dependence by investing in modern transit systems (Newman et al. 2013). The transfer of urban trips from cars to transit in global cities has used any latent capacity available in the transit networks, and as such the networks are requiring a massive re-investment in transit infrastructure and service to meet current and future demand.

To match these changes in transport system demand, city planners are also reversing the car-dependent city paradigm of urban sprawl by promoting major urban consolidation and renewal, especially in locations where they can be integrated with transit facilities (Cervero, 1994; Calthorpe, 1993; Cervero, 1997; Kenworthy and Laube, 1999). The research into car dependence Newman and Kenworthy, 1989; Boarnet and Sarmiento, 1998; Coevering and Schwanen, 2006; Giuliano and Dargay, 2006; Hong et al., 2014) identified that both increasing transit and facilitating re-urbanisation in cities are key solutions to stemming care dependence. Indeed, there is significant “willingness to pay” (WTP) for this integrated transit oriented development in traditionally car-dependent cities (Bartik, 1988; Graham, 1992; Al-Moisand, et al. 1993; Cervero and Duncan, 2002; Bae, 2003; Debrezion, et al. 2007; Mohammad, et al. 2013).

One of the key constraints to meeting the demand for transit services is that public transit infrastructure has traditionally been funded by local, state and in some cases national governments from their already stretched consolidated tax revenue base. However, the focus of governments and transport agencies has moved in recent times to finding more long-term sustainable funding mechanisms that are outside of the cyclical political draw on consolidated revenue.

The focus of alternative funding mechanisms for transit infrastructure has been on capturing the value created in the infrastructure’s land and property market catchments. Alternative funding mechanisms have been used to cover the capital expenditure required for the investment in public transit infrastructure in a few cities (Allen, 1987; Batt, 2001; Iacono et al. 2009), and in some instances have been used to fund operational expenses as well (Zhao and Larson, 2011). However the approach is not mainstreamed in any way.

There is significant research that has examined the increased WTP for public transit infrastructure on land values in European, American and Asian cities with disparate results (Stopher, 1993; Rybeck, 2004; Zhao, and Larson, 2011; Yu-Hung and Alven, 1998; US EPA, 2013). However, little is understood of the Australian context and of car-dependent cities in particular (Allen Consulting Group, 2003).

The studies of value increases in the land and property markets have been focused on the resultant revenues that flow “passively” through to the private land owners and subsequently through to the public sector through induced increases in the existing taxes and charges (e.g. Land Tax and Capital Gains Tax). In addition to the passive benefits of increased taxes and charges, governments have actively sought to recoup some of the private sector windfall gains from the land and property markets by introducing new taxes and charges (e.g. in the form of transport levies) to actively recoup some of the additional private sector revenue from the transit investment.

In the US some local governments in traditionally car dependent cities have been using financial forecasting to determine the resultant net revenue return a transit investment would create, with these revenue streams to be captured and used to fund the investment in transit. Few, however, have actually used this means to fund a transit system, as the approach is much more common in funding urban regeneration projects.

Consequently, this thesis has developed a public transit value capture framework to enable car dependent global cities to have a reliable and practical approach to raise transit funding. The framework is needed, not just for infrastructure funding, but for integrated land development that can start to stem the drivers of car dependence.

The thesis demonstrates the WTP for transit using Perth, Western Australia, as a case study. This is an ideal city to examine as it was built around a completely car dependent model in the post second world war period, but is currently undergoing a dramatic revival in its rail transit system. Spatial and temporal econometric analysis of the land market value impact of the increased WTP for transit accessibility could be used as a model to build more transit in Perth and other car dependent cities.

Subsequently, this thesis is about how to use this WTP or transit accessibility as a mechanism to fund the investment required in public transit to meet the demand for service in car dependent cities around the world.

## **1.1 Research Aims**

The overarching question this research seeks to answer is:

*“Can land and property market value capture fund urban transit in car dependent cities globally?”*

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

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

- 1) develop an econometric model to determine the causes of car dependence in global cities and how car use per capita has changed in the post war car dominated period (1960-2000);
- 2) qualitatively assess the role of urban transit and urban redevelopment in policy and planning as means to reduce the causes of car dependence;
- 3) analyse the economic willingness to pay for urban transit accessibility and urban redevelopment in the land markets of car dependent cities;
- 4) quantify the financial value created by integrated urban transit and urban redevelopment in car dependent cities; and
- 5) develop a financial value capture framework for integrated urban transit and urban redevelopment to stem car dependence in global cities.

## **1.2 Research Scope to address the Research Aims**

Integrated urban transit and land redevelopment is not uncommon as an agenda in many global car dependent cities. However, the role of integrated urban transit and redevelopment to reduce car dependence in global cities is less well defined, as is the quantitative understanding of the land and property market benefits created by the

investment in transit, and how these can be captured to defray the cost of the project investment.

***Aim 1: Develop a universal econometric model to determine the causes of car dependence in global cities and how it has changed in the post war car dominated period (1960-2000)***

The research in this thesis begins with a comprehensive investigation to analyse the causes of car dependence in global cities, by econometrically modelling the factors that explain car use per capita across cities in Australia, Canada, the US and Western Europe, and how these variables changed over the period from 1960 to 2000. The research conducted in *Journal Paper 1* focuses on how metropolitan function (population, CBD employment, car ownership, etc.) and form (urban density, road and transit length's per capita, etc.) explains the city's car use per capita. The analysis formed the basis for an understanding of the role of public and private transport provision and urban density in explaining the city's Vehicle Kilometres Travelled (VKT) per capita, and as a result its dependence on car based transport. *Journal Paper 1* explains how the causes of car dependence can be overcome through investment in the alternatives of transit and urban renewal.

***Aim 2: Qualitatively assess the role of urban transit and urban redevelopment in policy and planning to reduce the causes of car dependence***

From the *Journal Paper 1* analysis of the causes of car dependence *Book Chapter 1* and *Journal Paper 2* addresses the second aim of the thesis by conducting qualitative policy analysis of the transit and land development planning factors that address how a city can seek to become less car dependent. This analysis within *Book Chapter 1* and *Journal Paper 2* gives focus to the quantitative analysis that follows.

***Aim 3: Analyse the economic willingness to pay for urban transit accessibility and urban redevelopment in the land markets of car dependent cities***

*Journal Paper 3* econometrically analyses the "Willingness to Pay" for urban transit and land development variables in land markets of Perth, Western Australia. The study presents a cross-sectional analysis of the city's land markets in a particular year

to determine the spatial distribution of the benefits of transit and different land and property development typologies. The temporal changes to the spatial distribution are then analysed in a panel data model to determine the WTP for the investment in a new fast rail line in the land markets of the city's most car dependent suburbs.

***Aim 4: Quantify the financial value created by integrated urban transit and urban redevelopment in car dependent cities***

Financial modelling and analysis of the value created by the WTP for transit accessibility in transit land market catchments using differing urban development typologies is undertaken in *Journal Paper 4* to determine the financial value created in the land and property markets by integrated urban transit and development in Perth, Western Australia. The analysis focusses on the financial impacts on the existing land and property *ad valorem* taxes and how they could be captured to fund the financing of the transit infrastructure investment.

***Aim 5: Develop a financial value capture framework for integrated urban transit and urban redevelopment to stem car dependence in global cities***

Finally, these separate analysis projects and methodologies are compiled into a quantitative framework in *Journal Paper 5* to analyse the value created by the investment in integrated urban transit and development and how they can be passively and actively captured as a means to fund transit infrastructure investment.

### **1.3 Research Objectives**

The first two aims provide the context for the thesis. The subsequent three aims are the core of the new research conducted for the PhD. Therefore the primary objectives of the research are:

- 1) To develop a methodology to assess the role and willingness to pay for integrated urban transit and development in car dependent cities
- 2) To develop a qualitative value capture framework that can be used to assess integrated urban transit and integrated development in car dependent cities
- 3) To develop a quantitative financial model and value proposition for urban transit and integrated development in car dependent cities.

The relationship between the research question, aims and objectives is illustrated in Figure 1.

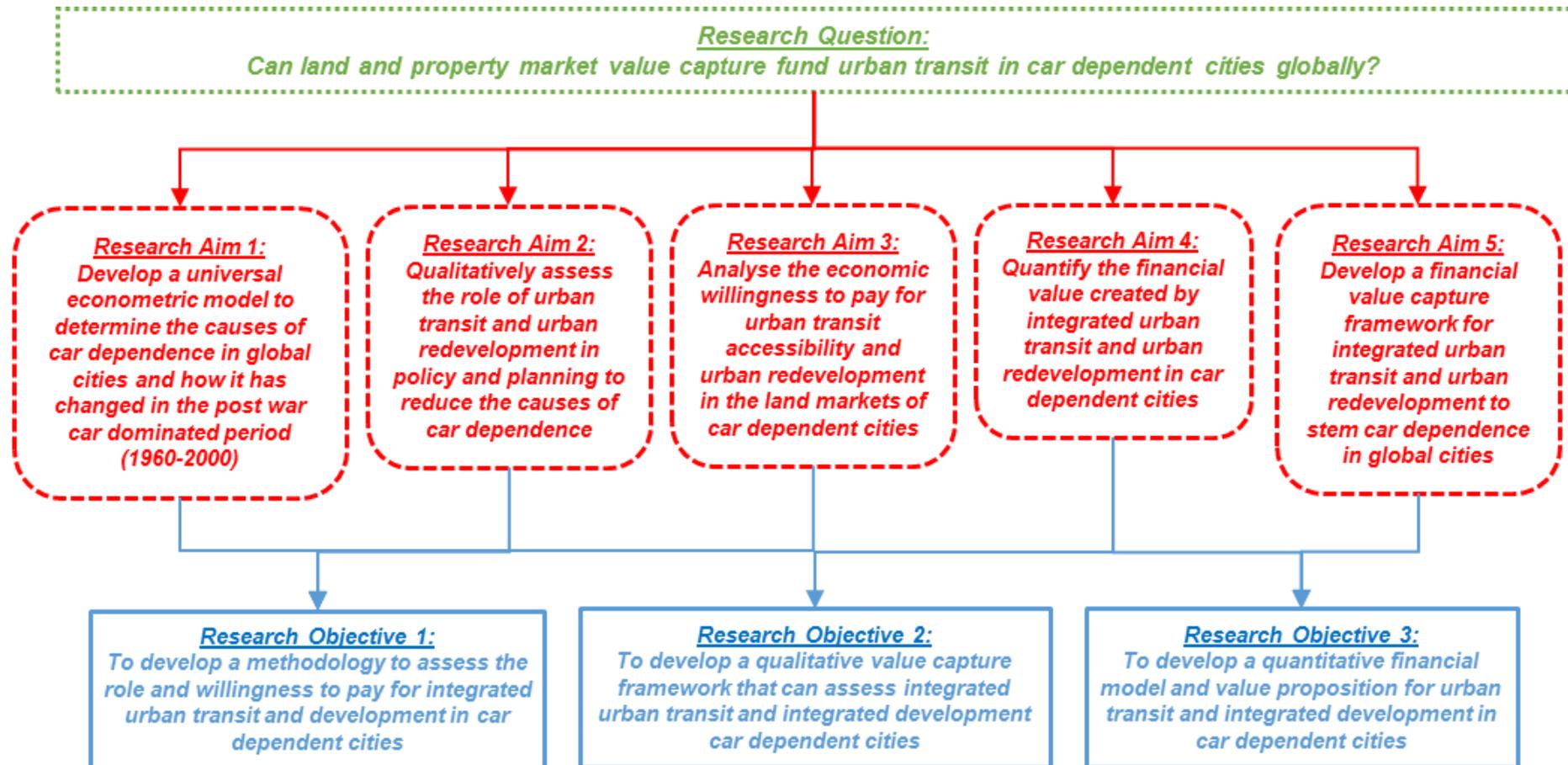


Figure 1 The relationship between research question, aims and objectives.

#### 1.4 Justification for this Research

The development of a universal quantitative urban transit value capture framework is one of the most important aspects lacking in the funding of transit systems in global cities (Iacono et al., 2009; US EPA, 2013; Cervero, 1997). This research demonstrates that provision of urban transit infrastructure integrated with modern land development is one of the most significant ways to stem and even reverse a city's car dependence. However, internationally all levels of government are under significant fiscal stress, and the cost of retro fitting urban transit into the existing car dependent urban fabric is expensive and challenging.

This historical lack of investment in transit and more sustainable urban development has led to increased negative public and private externalities, such as urban sprawl and transport externalities (for example, congestion, emissions, public transit crowding) and this effects the city's liveability and economy. One of the key reform recommendations of Infrastructure Australia in its 2012 report *Infrastructure Finance and Funding Reform* is that funding of infrastructure in Australia should be structured to:

*“...utilise appropriate models to drive revenue from the broader benefits delivered by major infrastructure projects, such as value capture for transport infrastructure...”* (Infrastructure Australia, 2012)

This call is echoed across the world in many reports on transport (e.g., see Salter et al. 2011; IPCC, 2007). There are many discrete forms of alternative funding mechanisms available, but their assessment methods are disparate (Iacono et al. 2009) and their international implementation is dispersed (Smith and Gihring, 2009) due to regional and historical differences in infrastructure funding. New urban transit funding mechanisms are needed to fund the integrated transit and dense urban land development they need. This thesis-by-publications addresses this requirement for new urban transit funding mechanisms. It does so by demonstrating that it is imperative that strong econometric and financial modelling underpin the economic

(benefit-cost ratio) and financial (project value proposition) assessment methodology for integrated transit and development projects.

### **1.5 Academic Significance**

The gap in the published literature that this research project seeks to fill is in the development of a globally-relevant assessment framework for alternative funding options for transit infrastructure projects in car-dependent cities, especially focused on capturing induced land and property market benefits.

#### ***Statement of Academic Significance***

*This PhD by publication demonstrates significant academic achievement by integrating the fields of public transport benefits, sustainable mobility, and land market performance through the contribution of six academic journal publication.*

*These publications further analytical and policy related research in the fields of the built environment and travel, price modelling of transit's capitalization effects, willingness-to-pay estimates of benefits, and the potential use of tax increment financing of transit investments.*

*This academic research make a significant contribution towards designing, implementing, and financing rail transit systems in rapidly growing and car dependent cities like Perth, Australia.*

### **1.6 Research Context**

To answer the research question, and research framework illustrated in Figure 1, I will first outline and critically review the existing alternative mechanisms that have been developed. Then I highlight key problems with the application and practice of these mechanisms notably, their failure to adequately capture and represent the increase in land value associated with transit, as well as their inability to take into account the complex urban transformations commonly associated with such investments.

### 1.6.1 The value created by transit

The transport accessibility benefits focussing on transit travel savings, as well as the reduction in road user travel times, accidents, fuel consumption and emissions (noise, particulate matter, greenhouse gases) are the primary rationale for the investment (Vuchic, 2005). These are also the only measures generally included in the project “Benefit Cost Analysis” (BCA) that is used as the economic measure of its success or failure (TCRP, 1998).

The increased accessibility, and saving in travel time created from the investment in transit is economically monetised into the infrastructure’s surrounding land and property catchments, and is deemed to be captured in the BCA through travel time savings. However, the standard BCA analysis is modally non-specific and does not capture the differences in the willingness to pay for access to different modes (Bus Rapid transit light rail transit, commuter rail, heavy rail) from the surrounding land and property markets (TCRP, 1998; Cervero and Duncan, 2002; Rodriguez and Targa, 2004; Du and Mulley, 2007).

Land and property market prices reflect the interaction between the buyers and sellers in the land market as costs (such as travel) are traded-off against land rents (and population densities) in a bid rent curve (Alonso, 1964; Muth, 1969). The willingness to pay for the access to transit can be developed through a unified framework (Rosen, 1974) that relates land value capitalization to the underlying concept of market equilibrium on which welfare measurement is based (Kuminoff et al, 2010), where the relative price of a land parcel is the summation of all its marginal or implicit prices that can be estimated through HPM regression analysis.

Therefore, temporal HPM analysis of the impact on land value from the investment in transit demonstrates the willingness to pay for transit in the surrounding land and property markets (Rodriguez and Mojica, 2008, Atkinson-Palombo, 2010; Mulley & Tsai, 2013), and can be used to calculate the financial value created in the surrounding land and property markets (as opposed to the economic monetisation of travel time savings covered in the BCA). This financial value creation from the

investment in transit forms the basis for suite of passive and active value capture mechanisms used to defray the cost of the investment in transit (Iacono et al., 2009).

#### 1.6.2 Value created by integrating land uses and development with transit

The integration of transit can also assist city planners in their furthering of key sustainability goals, such as of reducing a city's social, environmental and economic externalities. Research by Newman and Kenworthy (1999) and by Renne et al. (2009) has demonstrated that investment in integrated urban transit and development reduces the negative externalities of inefficient sprawling urban systems. This research into the integration of land use and transport demonstrates that Transit Oriented Developments (TODs) can stem cities car dependence (Newman et al, 2013) by reducing the need for residents and businesses to rely on cars for their accessibility, avoiding the cost of providing standard levels of car parking, and facilitating higher density development.

This high density development capacity due to the access to transit creates a significant willingness to pay in the land and property development markets, and can additionally drive the financial value created by the investment in transit.

#### 1.6.3 Capturing the value created by the investment in transit

There are many ways to capture the value created from the investment in transit including:

- Land owners: due to increases in underlying land values.
- Property developers: potential increase in developed real estate values, faster sales rates, reduced holding costs, and lower construction costs due to reduced parking requirements.
- Transport system users: a more efficient, less congested transport system results in less time spent in transit, allowing more time for other activities and better transit experience.

- Business owners: increased economic activity due to improved customer and employee accessibility to their business, with workers arriving less stressed and more productive.
- Federal/State and Local Governments: due to increases in land property based revenue from existing levies and taxes from increased land and property values.

The main source of revenue generated from the investment in transit that is included in the project BCA is from passengers paying at the fare box. The land and property market financial value is not captured as part of the project economic BCA, as these are seen as monetised travel time savings are already counted, and are not counted in the financial analysis as they are not seen to be ‘in project revenue streams’, and are seen as externalities, and hence not counted.

However, there are a range of existing passive mechanisms (receiving increased revenue through existing funding sources) and active mechanisms (new charges put in place generally seen as a cost recovery for the investment) used to capture the financial benefits created from the investment in transit.

#### 1.6.3.1 Passive Value Capture - Government Land and Property

An example is in Sydney, Australia where the state government rail operator, Railcorp sold the development rights over some of their stations to pay for the cost of their upgrade.

#### 1.6.3.2 Passive Value Capture – Non-Government Land and Property

US cities (most notably Chicago, and New York) have used ‘value capture’ for Tax Increment Financing (TIF) but mostly for urban regeneration projects. Its widespread use in the US as well as the use of other passive and active funding mechanisms could definitely be increased if a more comprehensive framework were developed to guide city planners in their search for funding (Zhao and Larson, 2011). However there is also a history of using dedicated land and property taxes for investment in

transit projects in the US. Some examples of the implementation of TIF for transit projects include:

- Chicago, Illinois - the Randolph/Washington station, the Dearborn subway, and various transit projects within central Chicago's Loop. The City of Chicago allocated \$42.4 million in TIF revenue to the Randolph/Washington station (US EPA, 2013).
- Atlanta, Georgia – Atlanta Belt Line is a comprehensive redevelopment and mobility project that will build a network of public parks, multi-use trails, and transit, including a 22-mile rail line that will serve 45 neighbourhoods and connect to existing MARTA service. The project will cost an estimated \$2.8 billion, with the Atlanta Belt Line TAD generating approximately \$1.7 billion of the total project cost over 25 years (Atlanta Belt Line, 2014).
- San Francisco, California - TIF financing is being used to support redevelopment of the Transbay Transit Center, a multimodal transportation hub that includes a 1,000-foot-tall office tower, a 5.4-acre rooftop park, and 2,600 new homes. Funding for the \$4.2 billion project will come from a variety of sources, including \$1.4 billion in TIF funds, of which \$171 million will be used to repay a federal TIFIA loan used for the transit centre's construction (USGAO, 2010).

Internationally there has been much less use of TIF for transit. The UK government amended the Local Government Finance Act (1992) in 2010 to allow for TIF in Scotland and now any proposal for a TIF project must demonstrate to Scottish Ministers that the enabling infrastructure will unlock regeneration, facilitate sustainable economic growth, and generate additional (or incremental) public sector revenues (net of a displacement effect). The Manchester City Deal included the "Earn Back Model", a commercial rates/taxes based TIF, which is expected to earn £1.20 Billion over a 30 year period and to repay or fund the finance for the investment in transport and other economic infrastructure (Greater Manchester Combined Authority, 2012).

### 1.6.3.3 Active Value Capture - Government Land and Property

The implementation of transport projects results in increases in land values and economic prosperity that increase the value of government land, and there a number of value capture mechanisms that can be used to capture these increases to offset the capital and operating costs of the infrastructure. These include the development of government property to maximize the transportation and revenue outcomes and joint development of government land with the private sector.

The benefits of government actively participating in development outcomes can increase financial return relative to sale of land/development rights, and can combine with project station procurement to reduce Project costs (e.g. station availability payments). This inturn reduces capital requirements relative to direct development, and creates the potential to capture future property related revenues to defray operating costs.

1.6.3.4 The joint development approach is best demonstrated by the Metropolitan Transit Railway Corporation (MRTC) in Hong Kong, which jointly develops its transit infrastructure with land development as part of the “Rail + Property” program (Cervero and Murakami, 2009) by selling the development rights around and over its stations. This program involving the private sector in land development around its stations covers the cost of transit investments (Hui and Lo, 2004; Zhao et al., 2009), thus making the strategic investment in transit a long-term cost-neutral decision for the government. Active Value Capture – Non-Government Land and Property

As stated previously, the implementation of transport projects and the resultant increases in land values and economic prosperity will be captured by non-government land and business owners unless mechanisms are put in place to return some component to government. The development of significant transport projects

creates a number of opportunities for potential implementation of a number of new value capture mechanisms. These include the introduction of:

- benefit area levies;
- region wide transport levy;
- developer contributions;
- parking levies; and
- density bonuses.

#### 1.6.3.5 Summary of the Value Capture Mechanisms Analysed

The alternative funding framework proposed in *Journal Paper 5* integrates all the mechanisms discussed into a single model which demonstrates the economic and financial benefits created from the implementation of a suite of value capture mechanisms.

The significance of the body of research is that it seeks to address one of societies ‘wicked problems’ (Van Bueren et al, 2003; Head, 2008) through the multidisciplinary analysis in the six papers that form this thesis is that they collectively integrate often separate fields of knowledge and professional practice, including establishing key relations amongst different types of planning (transport, land-use, and development), policy, and economic and finance modelling by:

- Quantitatively analysing the role of urban densification and urban transit infrastructure on stemming car dependence in global cities (*Journal Paper 1*);
- Qualitatively integrating land use/development (*Journal Paper 2*) and urban transit practice and policy (*Book Chapter 1*);
- Quantitatively analysing the willingness to pay for integrated transit and densification projects in car dependent cities (*Journal Paper 3*);
- Financially model the willingness to pay impacts for integrated transit and densification projects on the existing *ad valorem* taxes (*Journal Paper 4*); and

- Modelling the policy and financial implications of the previous research on the potential of passive and active value-capture mechanisms to fund the investment in integrated transit and densification projects (*Journal Paper 5*).

This integration of transport planning, land use planning and financial planning is rare in practice and is only outlined by a few academics such as Robert Cervero, Reid Ewing, David Banister, Kay Axhausen, Peter Newman, Jeff Kenworthy, Vukan Vuchic and the late Paul Mees. The key theoretical writings of these academics and the others that underpin this research thesis and the journal papers are presented in Table 1.

*Table 1 Key theoretical academic writings underpinning this research*

<p><b>Chapter 2</b> <i>(Journal Paper 1)</i></p>	<p>Alonso, W. (1964), Banister, D. and Lichtfield, N., (1995), Boarnet, M. and Crane, R. (2001), Boarnet, M. and Sarmiento S. (1998), Breheny, M. (1995), Brownstone, D. and Golob, T. (2009), Cameron, I., Kenworthy, J., and Lyons, T. J. (2003), Cao, X., Mokhtarian, P., and Handy, S. (2007), Cervero, R., and Murakami, J. (2010), Cervero, R., and Kockelman, K. (1997), Coevering, P. and Schwanen, T. (2006), Corpuz, G., McCabe, M., &amp; Ryszawa, K. (2006), Ewing R, Bartholomew K, Winkelman S, Walters J., and Chen, D. (2008), Fan, X., Thompson, B., and Wang, L., (1999), Giuliano, G. and Dargay, J. (2006), Goodwin, P. and Van Dender, K. (2013), Gordon, P and Richardson, H. (2007), Handy, S., and Clifton, K. (2001), Hooper, D., Coughlan, J. and Mullen, M. (2008), IBI Group (2000), Jacobs, J. (1961), Kenworthy, J. and Laube, F. (1999), Kenworthy, J., Laube, F., Newman, P., Barter, P., Raad, T., Poboan, C., Guia, B., (1999) Kenworthy, J. and Laube, F. (2001), Kenworthy, J. (2011), Kenworthy, J. (2014), Kirwan, R. (1992), Levinson, D. and Kumar, A. (1995), Litman, T. (2001), Marchetti, C., (1994), Mees, P. (2010), Metz, D. (2013), Mindali, O., Raveh, A., and Salomon, I. (2004), Mokhtarian, P., &amp; Cao, X. (2008), Muth, R. (1969), Newman, P., Kenworthy, J., (1989a), Newman, P., Kenworthy, J., (1989b), Newman, P., Kenworthy, J., and Vintila, P., (1995), Newman, P., and Kenworthy, J., (1999), Newman, P., and Kenworthy, J., (2000), Newman, P., Kenworthy, J., Camara, P. and Williams, B. (2001), Newman, P., and Kenworthy, J., (2011), Malpezzi, S., (1999), Samuelson, P., and Nordhaus, W., (2004), Thomson, J.M., (1977), Trubka, R., Newman, P., and Bilsborough, D., (2010), Vance, C., and Hedel, R. (2007), Zegras, C. (2010).</p>
<p><b>Chapter 3</b> <i>(Book Chapter 1 and Journal Paper 2)</i></p>	<p>Asian Development Bank, (2012), Australian Transport Council, (2006), Bachels, M., and Newman, P., (2011), Beatley, T., and Newman, P. (2009), Bottoms, G., (2003), Brookings Institution Metropolitan Program (2008), Burchard, J., (1957), City of New York, (2011), Crawford, J. (2002), Crozet, Y. (2005), Currie, G. (2009), Currie, G. (2009), Davis, B., Dutzik, T. and Baxandall, P. (2012), Delbosc, A. and Currie, G. (2013), Eddington, R. (2006), Ewing, R. and Cervero, R. (2010), Florida, R. (2002), Florida, R. (2010), Forsyth, A. and Krizek, K. (2010), Forsyth, A. and Southworth, M. (2008), Frank, L., Andresen, M. and Schmid, T. (2004), Gargett, D. (2012), Gehl, J. (2010), Gehl Architects, (2011), Gehl Architects, (2013), Glaeser, E. (2011), Goodwin, P. and Melia, S. (2011), Guo, Z. (2009), Handy, S., Cao, X. and Mokhtarian, P. (2005), Hensher, D. (1999), Hornweg, D., Sugar, L. and Gomez, C. (2011), Huy, C., Becker, S., Gomolinsky, U., Klein, T. and Thiel, A. (2008), Infrastructure Australia, (2012), Intergovernmental Panel On Climate Change, (2007), Jackson, L. (2003), Kane, M. (2010), Kaur, S., Nieuwenhuijsen, M. and Colville, R. (2007), Kostof, S. (1992), Larco, N., Steiner, B., Stockard, J. and West, A. (2011), Litman, T. (2012), Matan, A. (2011), Matan, A. and Newman, P. (2012), Matan, A., Trubka, R., Newman, P. and Vardoulakis, S. (2012), McIntosh, J., Newman, P., Crane, T. and Mouritz, M. (2011), McIntosh, J., Newman, P., Scheurer, J., and Wisdom, A. (2012), McIntosh, J., Newman, P. and Glazebrook, G. (2013), McIntosh, J., Newman, P., Trubka, R. and Kenworthy, J. (2014), Metz, D. (2013), New York City Department of Transport (2010), Newman, C. and Newman, P. (2006), Newman, P. (2003), Newman, P. (2006), Newman, P. and Kenworthy, J. (2011b), Newman, P., Kenworthy, J. and Glazebrook, G. (2013), Newman, P. and Matan, A. (2012), PATREC (2004), Papacostas, C. and Prevedouros, P. (2005), Pucher, J. and Buehler, R. (2010), Rabl, A. and De Nazelle, A. (2012), Renne, J. and Curtis, C. (2011), Saelens, B. and Handy, S. (2008), Saelens, B., Sallis, J. F. and Frank, L. (2003), Schiller, P. and Kenworthy, J. (2011), Sinclair Knight Merz and Pricewaterhouse Coopers, (2011), Sohn, D. W., Vernez Moudon, A. and Lee, J. (2012), Soltani, A. (2006), Stanley, J., Hensher, D., Stanley, J. and Vella-Brodrick, D. (2011), Stanley, J., Hensher, D. A., Currie, G., Greene, W. H. and Vella-Brodrick, D. (2011), Taddeo, L. (2010), Trubka, R. (2011), United Nations Human Settlements Programme (2013), Waldock, R., Martinovich, P., Cartledge, A., and Hamilton, R. (2008), Wunderlich, F. (2008), Vuchic (2005), Zahavi, Y. and Ryan, J. (1980)</p>

<p style="text-align: center;"><b>Chapter 4</b> <b>(Journal Paper 3)</b></p>	<p>Alonso, W., (1964), Atkinson-Palombo, C. (2010), Bae, W., Lee, Y., Kim, Y., Jang, Y., Maeng, D., and Lee, S. (2008), Banister, D., and Thurstain-Goodwin, M. (2011), Bloomquist, G. and Worley, L. (1981), Center for Transit-Oriented Development. (2008), Cervero, R., and Duncan, M. (2002), Cervero, R., and Kang, C. (2011), Chaney, H. (2005), Chin, T., and Chau, K., (2003), Debrezion, G., E. Pels, and P. Rietveld. (2007), Du, H., and Mulley, C. (2007), Golub, A., Guhathakurta, S., and Sollapuram, B. (2012), Garrett, T. (2004), Gatzlaff, D., and Smith, M. (1993), Gruen, A. (1997), Hannonen, M., (2009), Kuminoff, V., Parmeter, C. and Pope, J. (2010), Laakso, S. (1992), Lancaster, K. (1966), Löchl, M., and Axhausen, K. (2010), Mathur, S., and Ferrell, C. (2013), McCarthy, P. (2001), Mohammad, S., Graham, D., Melo, P. and Anderson, R. (2013), Mulley, C., and Tsai, C. (2013), O’Sullivan, A. (2012), Palmquist, (1992), Perk, V. and Catala, M. (2009), Rodriguez, R., and Targa, F. (2004), Rodríguez, D., and Mojica, C. (2009), Rosen, S. (1974), Scheurer, J. (2010), Sedway Group (1999), Tiebout, C. (1956), Voith, R. (1991), Yankaya, U., and Celik, H. (2004)</p>
<p style="text-align: center;"><b>Chapter 5</b> <b>(Journal Paper 4)</b></p>	<p>Batt, W. (2001), Brigham, E. (1965), Cervero, R. (1997), Cervero, R. and Duncan, M. (2002), Cervero, R. (2004), Duncan, M. (2010), Dye, R. and Sundberg, J. (1998), Fejarang, R. (1994), Giuliano, G., Gordon, P., Pan, Q. and Park J. (2010), Johnson, C., and Robinson &amp; Cole LLP. (2013), Kenworthy, J., (2008), Kilpatrick, J., Throupe, R., Carruthers, J., and Krause, A. (2007), Klinger, T., Kenworthy, J.R., Lanzendorf, M., (2013), Newman, P. and Kenworthy, J. (1989), Noland, R., and Lem L, (2002), O’Sullivan, A. (2012), Schneck and Diaz. (1999), Scheurer, J., Newman, P., Kenworthy, J., &amp; Gallagher, T. (2000), Steg, L., and Gifford, R. (2005), Sullivan, G., Johnson, S., and Soden, D., (2002), Weber, R. and Goddeeris, L. (2007), Zhao, Z., Das, K., and Larson, K. (2010), Zhao, Z., and Larson K. (2011)</p>
<p style="text-align: center;"><b>Chapter 6</b> <b>(Journal Paper 5)</b></p>	<p>Al-Mosaind, M., Dueker, K., and Strathman, J. (1993), Allen, B. (1987), Allen Consulting Group (2003), Armstrong, R. (1994), Ball, M. (1973), Bartholomew, K. and Ewing, R. (2011), Centre for International Economics (2010), Center for Transportation Studies, (2009), Cervero, R. (1994), Cervero, R., Ferrell, C., &amp; Murphy, S. (2002), Cervero, R., Hall, P., and Landis J. (1993), Day, P. (1992), Diaz, R. (1999), Duncan, M. (2008), Espada, I. (2010), Espada, I. and Luk J. (2011), Fujita M., Krugman, P. and Mori, T. (1999), Hanson, S. (1995), Hui, E., Ho, V. (2004), Iacono, M., Levinson, D., Zhao, J., &amp; Lari, A. (2009), Laakso, S. (1992), Mohammad, S., Graham, D., Melo, P. and Anderson, R. (2013), McCarthy, P. (2001), Mullins, J., Washington, E., and Stokes, R. (1990), PB, (2001), Perk, V., and Catala, M. (2009), Pucher, J., Korattyswaroopam, N., and Ittyerah, N. (2004), Punter, J. (2003), Renne, J., and Wells, J. (2005), Rybeck, W. (1981), Rybeck, R. (2004), Smith, J., and Gihring, T. (2009), Sharpe, C. (1977), Sherry, R. (1999), Small, K., A., and Verhoef, E., T. (2007), Stopher, P. (1993), TCRP 90, (2009), TCRP Report 129 (2009), Yiu, C., and Wong, S. (2005), Yu-Hung, H., and Alven H. (1998)</p>

## 1.7 Research Design

Figure 2 illustrates the research plan for the project, whereby the flow of the various analyses, the development of the project databases, econometric methods and analysis frameworks, are illustrated. The research plan shows how the individual papers analyses interact between the qualitative relationships and the quantitative processes designed to address the overarching research question

The research plan was developed around six academic papers, with each one focussing on discrete aspects of the overall research objectives. Subsequently, the outcomes of each paper were consecutive in nature and used in the development of the overarching transit value capture framework.

### 1.7.1 Structure of the Dissertation

*Journal Paper 1 (The urban transport problem and the rise of car dependence: Analysis of 26 Global Cities (1960 – 2000))* begins by qualitatively describing the causes of car dependence, and then subsequently uses this as the basis for the quantitative econometric analysis of the factors causing variable levels of car dependence in 26 global cities across the US, Canada, Western Europe and Australia. *Journal Paper 1* analyses the car dependence in cities in terms of the level of passenger car vehicle kilometres travelled per capita (VKT/Capita) as well as urban structure and form (see Table 2 for a full list of cities and variables). The car dependence analysis focusses on how VKT/Capita changed over time (1960-2000) and what transport and urban form factors were responsible for that change.

The key contribution of *Journal Paper 1* is the quantification of the role of city structure, form, and transit provision in the production of passenger car vehicle kilometres travelled. This enables an understanding of the level of dependence a city has on the car, in a global context over time. There has been considerable debate about the causes of growth in VKT/Capita, witness, for example, differences between Newman and Kenworth (1999) and Gardner and Abraham (2007). This paper provides the means to resolve this debate by compiling a detailed and relevant

data set of 26 cities from the Global Cities Database for a full 40-year comparison with the whole data set being available.

The econometric analysis of the variables that are used to explain the causes of car dependence in cities sets the basis for the econometric modelling of the WTP for urban transit accessibility in global cities land markets in *Journal Paper 3 (Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia)*. The WTP analysis was conducted on Perth, as Australia's most car dependent capital city (VKT/Capita of 8916 km/person in 2000), and also the second lowest Australian capital city urban density (11.2 dwellings per hectare) (Australian Bureau of Statistics, 2013).

The concepts of urban transit networks and sustainable urban land development systems are described in the role to stem car dependence in *Journal Paper 2 (Why Fast Trains Work: An assessment of a fast regional rail system in Perth, Australia)* and *Book Chapter 1 (Urban Transport and Sustainable Development)*. *Journal Paper 2* outlines a framework for optimising the role of modern mass transit in car dependent cities by demonstrating a qualitative assessment methodology and applying it to the implementation of the Mandurah Rail Line in Perth, Western Australia. The most significant contribution of *Journal Paper 2* is the discussion on the generalised cost (in terms of monetise time and financial cost of travel) model for a multi-modal transit system implemented in car dependent suburban catchments that were previously deemed to be too low-density for mass transit. The detailed analysis on the new Mandurah Rail system in Perth enables it to be used as the basis of the value capture work to come later.

*Book Chapter 1* clarifies the role of land development when integrating with urban transit. *Book Chapter 1* also reinforces the findings of *Journal Paper 1* regarding urban mass transit's role within car dependent cities. *Book Chapter 1* qualitatively describes the different transport induced city fabrics and sets the basis for the quantitative modelling of the impact of varying land use and development factors to describe and forecast scenarios to stem car dependence. The integration of land development and sustainable transport from the findings of *Journal Paper 2* and

*Book Chapter 1* directly input into the development of *Journal Paper 3* and form the qualitative basis for the quantitative research conducted for the rest of this thesis.

*Journal Paper 3 (Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia)* a mix of both spatial (cross sectional) and temporal (panel data) Hedonic Price Modelling on Perth's land markets is conducted using sixteen land use and transport variables that collectively describe Perth's land values. The cross-sectional analysis demonstrates that given differing land use and transport integration and variable city structure and forms of development, the WTP for transit accessibility results varies accordingly. The panel data analysis of these transport and urban form variables over time (2001-2012) clearly demonstrated large increases in the WTP for transit accessibility, where new infrastructure and services had been introduced during the study period. This increase in the WTP for transit accessibility was particularly noted for the Mandurah Line catchment (funded in 2003 and commenced operations in 2007).

The significant increase in the WTP for transit accessibility in the land catchments of the Mandurah Rail Line confirmed the hypothetical value curve proposed by the Center for Transit Oriented Development (2008), though this was the first documented example of this actually occurring within a car-dependent city. The results from the panel data analysis quantitatively confirmed the qualitative premise, proposed in *Journal Paper 1*, that high passenger demand for public transit service that successfully competes with the car in term of generalised cost would result in significant changes in the demand for access to these services.

In addition to the increase in the WTP for transit accessibility, *Journal Paper 3* also quantified the benefit of residential densification in the metropolitan Perth's land markets. This WTP for the increase in dwelling density quantitatively validated some of the urban consolidation recommendations from *Book Chapter 1*. The panel data land value uplift in the hedonic price within the Perth rail station's pedestrian catchments, as well as the quantified demand for dwelling density, formed the basis for the research into the financial impacts of the investment in transit.

*Journal 4 (Tax Increment Financing framework for integrated transit and urban renewal projects in car dependent cities)* introduces tax increment financing (TIF) as a method of capturing the passive taxation benefits created from the investment in infrastructure, and ties together the concepts of the benefits of integrated transit and development presented in previous research. *Journal Paper 4* uses financial modelling to determine the impact of the investment in urban transit and densification on car-dependent cities' land markets. This is demonstrated by using a case study (the Mandurah Rail Line) by forecasting the impact on the existing local, State and Commonwealth Government *ad valorem* taxes from the investment in the Mandurah Rail Line. As there has been limited intensification surrounding the stations along the Mandurah Rail Line, several potential future densification scenarios (to address the integration benefits proposed in *Journal Paper 1*) were conducted using the land value uplift factors developed in *Journal Paper 3* and the financial impact of these measures was demonstrated to be sufficient over a 30 year period to completely defray the cost of the investment

The resultant financial analysis of the potential future densification scenarios for the Mandurah Rail Line illustrates that the financial benefits of integrated transport and land use planning are significantly larger than if the transit project was undertaken in isolation of appropriate transit oriented development. To capture the passive financial benefit created by the integrated project, *Journal Paper 4* proposes a quantitative Tax Increment Financing (TIF) model within a West Australian context, with the forecasted revenue streams structured to be used to defray the cost of the investment in the Mandurah Rail Line project.

Neglecting to analyse and compile all the land use and transport infrastructure factors identified in the first five pieces of research has been a limitation of most of the studies into land value capture. *Journal Paper 5 (Framework for Land Value Capture from the investment in transit in car dependent cities)* proposes a comprehensive framework to capture all aspects of the analyses covered in *Papers 1-4*.

The integrated urban transit and development value capture framework proposed in *Journal Paper 5*, qualitatively and quantitatively analyses the land and property market economic and financial benefits gained from the investment in integrated transit projects. The framework is again demonstrated using the Mandurah Rail Line WTP analysis from *Journal Paper 3*, and the integrated transit and densification financial analysis from *Journal Paper 4* as a case study.

The universal value capture framework presented in *Journal Paper 5* shows that by developing an assessment around the WTP for transit and urban development an optimised value capture strategy can be developed to defray the cost of transit infrastructure projects.

In summary, all the research publications (the book chapter and five academic journal papers) selected for inclusion in this “*Thesis by Publication*” have all been published, or accepted for publication whilst enrolled as a PhD candidate. By qualitatively describing, then quantitatively analysing the role of integrated transit and development planning in car dependent cities, these papers when viewed as a whole, propose a coherent holistic approach to how enable the investment of transit to stem car dependence in cities internationally

All the papers maintain a focus on stemming car dependency in cities. All the papers progress the argument that the optimum path that can be taken to achieve reduced dependency is through investment in urban transit integrated with dense urban development. The linkages between the academic fields of transport planning, land use planning, land development planning and policy, econometric modelling and financial modelling are integrated into a single analysis framework to stem car dependency. The integration of these fields provides a quantitative basis for showing the real significance of value capture funding in car dependent cities. This is the major contribution of the research with the research findings providing the framework for implementation internationally in cities seeking to invest in transit infrastructure.

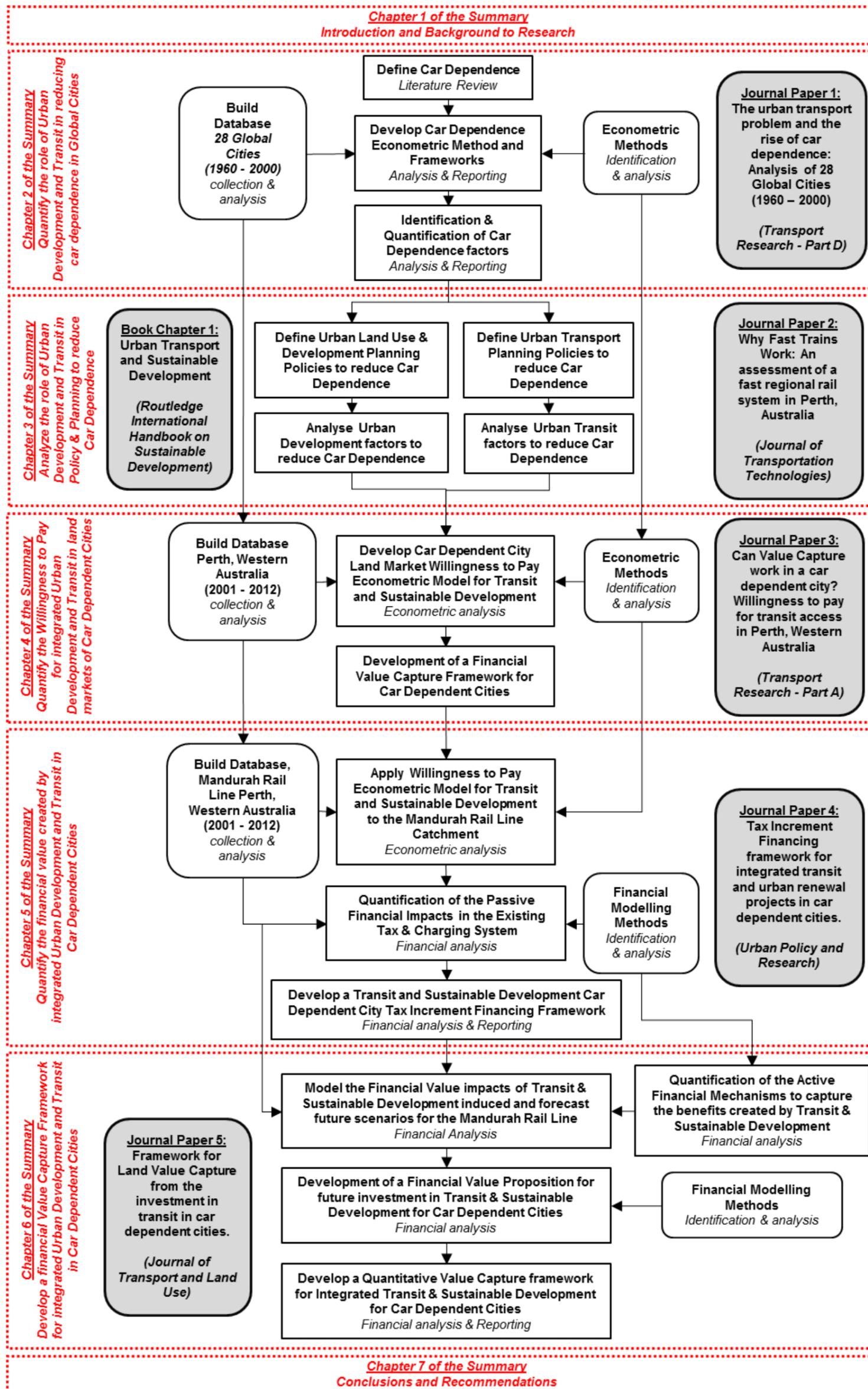


Figure 2 Schematic diagram illustrating the thesis by publication research structure, and development of each publication

## 1.8 Quantitative Study Areas and Datasets

As stated previously, Figure 2 presents the structure of the dissertation and illustrates the linkages between the research aims, the publications and the planning, policy and quantitative methods applied in the thesis. The quantitative analysis in *Journal Paper 1* starts at an international scale (analysing 26 cities across four regions) and then the analysis progressively the thesis moves to national and subsequently to a metropolitan level in Perth, West Australia, which is the focus in *Journal Papers 3, 4 and 5*.

Figure 3 provides an illustration of the data collection and econometric modelling process adopted for the quantitative research conducted in *Journal Papers 1, 3, 4 and 5* with particular emphasis on the selection of the econometric models datasets.

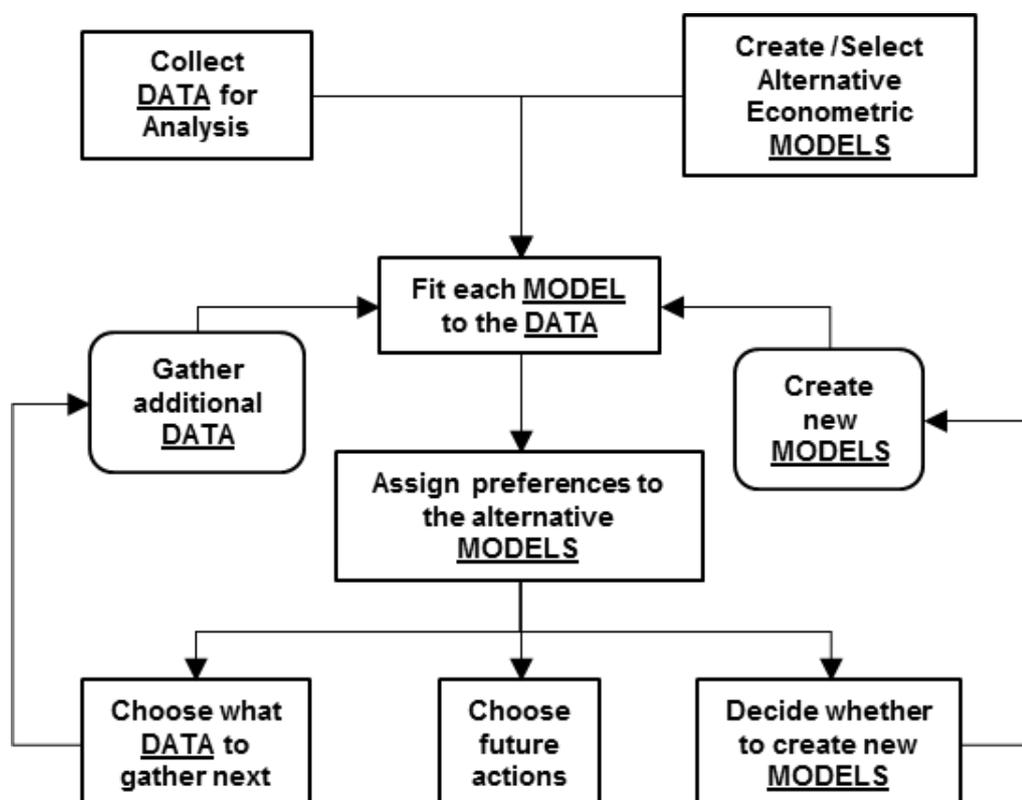


Figure 3 Abstraction of the Econometric Modelling Process (Adapted from Hannonen, 2009; Mackay, 1992)

The two main datasets utilised in this research were: (1) the adaption of the “Global Cities Database” first developed by Kenworthy et al. (1999) for *Journal Paper 1*; and (2) the development of the metropolitan Perth land and transport database for *Journal Papers 3, 4 and 5*.

#### 1.8.1 Global Cities Database (1960-2000)

The global scale analysis focussed on understanding the causes of car dependence in *Journal Paper 1*, analysing global cities over the period 1960 – 2000 by developing an understanding of 26 global cities’ function and form in explaining their varying levels of car dependence.

The global cities data for this research for 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 and Laube 2001) and 2005 updates of the database (Kenworthy, unpublished data set for UITP) created a set of observations for the year 2000 to ensure standardised time periods (10 years).

In addition to the core data collated from different versions of the global cities database in *Journal Paper 1*, Thomson’s (1977) five city ‘archetypes’ that describe basic differences in urban transport systems and in particular the relationship between transport systems and urban structure and form were adopted. These city archetypes were applied to the cities noted in Thomson, (1977), and where they cities in the database were not allocated by Thomson, the metrics in Tables 2, 3 and 4 were used to assign the archetypes to those cities.

Tables 2, 3, and 4 present a summary of the key variables from the Global Cities Database used for the research analysis in *Journal Paper 1*, where each city in the tables were ascribed one of the archetypes proposed by Thomson (1977) either by using Thomson’s classifications directly, or they were allocated on the basis of VKT per capita, transit passenger kilometres per capita, urban density, and percentage of jobs in the CBD for cases where no archetype was pre-allocated.

In addition to the variables pre-existing in the dataset, a series of dummy variables were created, including:

- five time period dummy variables for the data within the years 1960, 1970, 1980, 1990 and 2000, where 1960 became the model's base case;
- four region dummy variables for the cities within the US, Western Europe, Canada and Australia, with the US adopted as the regional base case; and
- four urban land use and transport archetypes (Full Motorisation Strategy, Weak Centre Strategy, Strong Centre Strategy, Traffic Limiting Strategy, with the Full Motorisation Strategy adopted as the regional base case).

The global cities database analysed in this research was compiled from two iterations of the database. There were a significant number of countries from the first database (1960-1990) that were not included in the second database (1995-2005), and the number and nature of metrics collected changed as well. The significant time required to rebuild the database from two disparate sources, the creation of the year 2000 data, as well as the addition of city archetypes to the model meant that the data used for *Journal Paper 1*, means that it is in effect a new Primary dataset for the research analysis in *Journal Paper 1*. This assertion is valid as the database compiled for analysis in *Journal Paper 1* was not previously available compiled in this form, and has not been structured for econometric analysis in this way elsewhere in the academic or broader literature.

The global cities database data collection has not been extended past 2005 at this stage, and given the limitation of only having continuous and consistent data for 26 cities, for 71 variables (including dummy variables) the data analysed in *Journal Paper 1* was the largest and most comprehensive available.

The key limitation for the dataset was the lack of consistent price data, (GDP, Transit and road costs and revenue, fare costs and revenue), and this limited the analysis of any willingness to pay for different modes, which would have been very useful

Table 2 City form summary data for 26 global cities for decades 1960-2000

City	Region	J.M. Thomson (1977) City Archetype	1960			1970			1980			1990			2000		
			City Population	Urban Density	% Total CBD Jobs												
Houston	USA	Full Motorisation *	1430394	10.2	10%	1999316	12.0	11%	2905353	8.9	12%	3462529	9.5	7%	4385643	9.2	6%
Washington	USA	Weak Centre *	1808423	20.5	27%	2481489	19.4	20%	2763105	13.2	17%	3363031	13.7	14%	4006346	13.5	12%
Denver	USA	Full Motorisation	803624	18.6	14%	1047311	13.8	13%	1352070	11.9	12%	1517977	12.8	11%	2120510	14.9	8%
San Francisco	USA	Weak Centre	2430663	16.5	20%	2987850	16.9	17%	3190690	15.5	17%	3629516	16	15%	3954824	20.2	13%
Los Angeles	USA	Full Motorisation	6488791	22.3	7%	8351266	25	5%	9479436	24.4	5%	11402946	23.9	5%	9418370	25.9	4%
Phoenix	USA	Full Motorisation *	552043	8.6	11%	863357	8.6	8%	1409279	8.5	4%	2006239	10.5	4%	3058459	10.6	4%
Chicago	USA	Weak Centre	5959213	24	13%	6714578	20.3	13%	6779799	17.5	12%	6792087	16.6	10%	7870265	16.8	9%
Perth	Australia	Weak Centre *	475398	15.6	40%	703199	12.2	31%	898918	10.8	24%	1142646	10.6	21%	1381510	11.1	18%
Brisbane	Australia	Weak Centre *	621550	21	26%	867784	11.3	-	1028527	10.2	14%	1333773	9.8	11%	1654342	9.7	12%
New York	USA	Strong Centre	16834500	22.5	30%	18731600	22.6	27%	17925200	19.8	23%	18409019	19.2	22%	19904078	18.6	19%
Calgary	Canada	Weak Centre *	249641	27	41%	403320	25	30%	592743	21.2	24%	710677	20.8	21%	877626	20.7	22%
Melbourne	Australia	Weak Centre	1984815	20.3	19%	2503450	18.1	17%	2722817	16.4	15%	3022910	14.9	11%	3440574	14.7	10%
Sydney	Australia	Strong Centre	2289747	21.3	20%	2807828	19.2	17%	3204696	17.6	13%	3539035	16.8	12%	4011645	19.2	13%
Vancouver	Canada	Weak Centre *	827335	24.9	-	1082185	21.6	22%	1268197	18.4	18%	1602502	20.8	13%	2007634	23.4	12%
Ottawa	Canada	Weak Centre *	-	-	-	633443	34.9	27%	735854	31.7	26%	907919	31.3	24%	1051609	31.1	20%
Frankfurt	W. Europe	Strong Centre *	670048	87.2	24%	669751	74.6	21%	631287	54.0	18%	634357	46.6	20%	652412	46.8	19%
Copenhagen	W. Europe	Weak Centre	1607526	40.1	26%	1752631	33.4	19%	1739860	30.4	16%	1711254	28.6	13%	1783349	28.9	13%
Montreal	Canada	Weak Centre *	2109509	57.6	-	2743208	39	26%	2835759	33.9	23%	3119570	33.8	20%	3355825	28.7	17%
Toronto	Canada	Strong Centre	1620861	36.8	18%	2089729	41.4	15%	2137395	39.6	13%	2275771	41.5	14%	5092398	26.2	6%
Zurich	W. Europe	Traffic Limiting *	697434	60	17%	791761	58.3	15%	780502	53.7	14%	787740	47.1	11%	808907	43.6	11%
Hamburg	W. Europe	Strong Centre *	1832346	68.3	20%	1793782	57.5	21%	1645095	41.7	20%	1652363	39.8	16%	1725764	38.2	17%
Stockholm	W. Europe	Traffic Limiting	808294	65.5	35%	740486	59.3	28%	647214	51.3	28%	674452	53.1	22%	1807851	27.4	13%
Munich	W. Europe	Traffic Limiting *	1046000	56.6	29%	1311798	68.2	26%	1298941	56.9	24%	1277576	53.6	25%	1306258	55.3	33%
London	W. Europe	Traffic Limiting	7992400	65.4	32%	7452300	61.6	31%	6713200	56.3	30%	6679699	42.3	31%	7259550	58.8	31%
Vienna	W. Europe	Traffic Limiting	1627566	91.4	17%	1614841	85.4	16%	1531346	72.1	15%	1539948	68.3	13%	1622017	70.3	12%
Brussels	W. Europe	Traffic Limiting *	1022795	100.3	-	1075136	91.1	-	1008715	82.3	25%	964285	74.9	24%	977436	74.3	23%

Note: \* denotes archetypes not allocated by Thomson (1977) and interpreted by authors

Table 3 Transport summary data for 26 global cities for decades 1960-2000

City	Region	J.M. Thomson (1977) City Archetype	1960			1970			1980			1990			2000		
			Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita
Houston	USA	Full Motorisation *	6829	20.6 (0%)	234.2	8257	12.6 (0%)	139.4	9918	9.1 (0%)	128.3	13016	16.7 (0%)	215	15807	19.3 (2%)	183.5
Washington	USA	Weak Centre *	-	32.7 (12%)	570.2	5671	26.7 (1%)	300.9	7939	39.9 (25%)	616.1	11182	37.3 (43%)	773.8	13050	49.1 (45%)	827
Denver	USA	Full Motorisation	5888	15.6 (0%)	245.3	6933	9.1 (0%)	92.7	8693	24.9 (0%)	217.6	10011	21.2 (0%)	198.6	12820	30.9 (5%)	260.4
San Francisco	USA	Weak Centre	5656	33.7 (13%)	596.7	7999	31.1 (10%)	532	9362	50.2 (26%)	925.8	11933	49.3 (42%)	899.3	12463	53.3 (47%)	856.2
Los Angeles	USA	Full Motorisation	7382	19.4 (0%)	244.3	7850	16.1 (0%)	159.7	9003	26.8 (0%)	383.6	11587	19.8 (0%)	351.6	12265	29.7 (8%)	408.9
Phoenix	USA	Full Motorisation *	7188	9.6 (0%)	101.7	8864	5 (0%)	35.9	9761	7.2 (0%)	66.0	11608	9.9 (0%)	123.7	11542	15 (0%)	108.4
Chicago	USA	Weak Centre	4091	52.1 (39%)	1015.3	5769	44.8 (42%)	855.5	7566	41.6 (44%)	971.1	9525	41.5 (47%)	805.3	10395	41.9 (46%)	723.4
Perth	Australia	Weak Centre *	3287	67.1 (17%)	907.8	5224	57.2 (12%)	732.0	6250	52.6 (10%)	591.5	7203	47 (10%)	544.4	8916	42.3 (27%)	694.9
Brisbane	Australia	Weak Centre *	2608	77.9 (65%)	1352.3	3788	57.2 (35%)	953.1	5861	48.3 (45%)	744.7	6467	55.1 (49%)	899.8	8572	63.1 (51%)	831.9
New York	USA	Strong Centre	4066	60.9 (54%)	1842.3	4864	66 (63%)	1395.3	5907	58.1 (58%)	1285.3	8317	62.8 (63%)	1334.3	8458	62.7 (63%)	1343
Calgary	Canada	Weak Centre *	2842	30 (0%)	242.4	3445	30.8 (0%)	319.7	6069	46 (4%)	875.4	7913	49.7 (18%)	774.6	8299	49.1 (19%)	1027.6
Melbourne	Australia	Weak Centre	2963	75.3 (72%)	1739.0	4228	57.3 (66%)	1221.7	5582	52.5 (66%)	778.5	6436	49.9 (57%)	843.8	7962	50.7 (58%)	1025.4
Sydney	Australia	Strong Centre	3757	104.7 (61%)	2158.0	5436	70.5 (47%)	1860.0	6442	76.9 (57%)	1510	7051	94 (58%)	1769	7249	76.5 (59%)	1530.5
Vancouver	Canada	Weak Centre *	-	36.6 (0%)	-	-	25.1 (0%)	-	6756	45.7 (0%)	839.1	8361	50.3 (24%)	871.3	6858	50.2 (30%)	847.7
Ottawa	Canada	Weak Centre *	3503	31.7 (0%)	426.9	-	23.8 (0%)	336.1	5776	65.3 (0%)	825.5	5883	55.9 (0%)	849.5	6470	45 (1%)	850.4
Frankfurt	W. Europe	Strong Centre *	2000	-	-	3500	-	-	4256	47 (69%)	1483.5	5893	47.9 (68%)	1148.9	5618	84.8 (69%)	1514.7
Copenhagen	W. Europe	Weak Centre	1263	72.3 (76%)	1547.7	3069	86.1 (60%)	1381.4	3462	109.5 (54%)	1658	4558	121.3 (56%)	1606.8	5402	115 (60%)	1623.8
Montreal	Canada	Weak Centre *	-	-	-	-	-	-	3267	63.4 (36%)	888	4746	60.2 (34%)	951.7	5380	52.9 (38%)	1057.5
Toronto	Canada	Strong Centre	-	48.2 (60%)	1335.7	-	57.9 (48%)	1369.5	4238	80.6 (48%)	1975.7	5019	98.4 (44%)	2172.8	5256	52.9 (37%)	1087.7
Zurich	W. Europe	Traffic Limiting *	-	102.7 (88%)	1944.9	-	92.9 (87%)	1560.3	4318	102.3 (84%)	1821	5197	148.1 (79%)	2459.4	5245	139.7 (75%)	2433.2
Hamburg	W. Europe	Strong Centre *	1560	60.1 (74%)	1958.7	3477	74.4 (67%)	1692.5	4409	71.7 (58%)	1501.6	5061	71 (62%)	1374.8	5187	83.9 (63%)	1577.1
Stockholm	W. Europe	Traffic Limiting	1804	87.5 (51%)	739.7	3525	93 (49%)	1294.5	4867	118.8 (51%)	2124.1	4638	133.2 (50%)	2351.3	4946	122.5 (58%)	2335.8
Munich	W. Europe	Traffic Limiting *	1516	-	-	2678	52.1 (60%)	806.2	3272	65.2 (76%)	1746	4202	91.4 (80%)	2462.5	4830	99.8 (72%)	2811.4
London	W. Europe	Traffic Limiting	1341	121.4 (58%)	2229.2	1855	114.8 (63%)	1995.2	2529	119.8 (65%)	1716.9	3892	138.4 (68%)	2405.1	4088	174.3 (69%)	2456.8
Vienna	W. Europe	Traffic Limiting	-	71.7 (93%)	1704.5	-	62.6 (86%)	1645.2	2664	69 (79%)	1828.2	3964	72.6 (72%)	2430.3	3909	100.8 (76%)	2333.6
Brussels	W. Europe	Traffic Limiting *	1793	64.1 (84%)	1787.7	2918	46.9 (61%)	1462.8	3891	53 (50%)	1400.3	4864	62.7 (48%)	1427.5	2648	92.8 (54%)	1780.9

Note: (%) signifies the % rail based transit (heavy rail and LRT/trams) operating in the city as part of the Total PT Service  
 \* denotes archetypes not allocated by Thomson (1977) and interpreted by authors

Table 4 Road based summary data for 26 global cities for decades 1960-2000

City	Region	J.M. Thomson (1977) City Archetype	1960			1970			1980			1990			2000		
			Car Park. Spaces /1000 CBD Workers	Cars /1000 People	Rd Length /Capita	Car Park. Spaces /1000 CBD Workers	Cars /1000 People	Rd Length /Capita	Car Park. Spaces /1000 CBD Workers	Cars/1000 People	Rd Length /Capita	Car Park. Spaces /1000 CBD Workers	Cars/1000 People	Rd Length /Capita	Car Park. Spaces /1000 CBD Workers	Cars/1000 People	Rd Length /Capita
Houston	USA	Full Motorisation *	497.2	388.1	-	363.1	647.9	11.7	369.9	602.6	10.6	612.3	607.7	11.7	721	714.1	9.1
Washington	USA	Weak Centre *	217.9	289.8	-	295	400.9	5.1	257.1	561.4	5.1	252.9	620.1	5.2	281	606.8	5.1
Denver	USA	Full Motorisation	595.2	479.1	8.8	578.3	522.7	11	497.6	666.2	9.4	605.6	752.6	7.6	542	693.8	8.7
San Francisco	USA	Weak Centre	135.1	407.4	4.7	154.5	487.9	4.7	145.2	543.4	4.9	136.6	603.5	4.6	182	629	4.5
Los Angeles	USA	Full Motorisation	372.8	459.1	4.9	534.8	521.2	4.8	523.6	541.5	4.5	520.4	543.6	3.8	674	563.4	3.6
Phoenix	USA	Full Motorisation *	619.2	367.8	15.4	836.3	499.1	12.7	1033	498.9	10.4	905.6	643.9	9.6	1106	533.5	8.1
Chicago	USA	Weak Centre	83	307.7	4.8	96.3	391	5	91.1	445	5	128.2	547.1	5.2	119	603.1	4.9
Perth	Australia	Weak Centre *	238.8	561.1	14.1	527.1	356.9	13.7	562.3	474.9	13.3	631.1	522.9	10.7	566	683.8	8.7
Brisbane	Australia	Weak Centre *	162.2	192.3	7.8	227.6	294.3	7.5	268.4	458.1	6.9	321.7	463	8.2	255	635.7	8.3
New York	USA	Strong Centre	-	270.6	4.3	348.2	-	4.1	69.1	411.9	4.7	59.9	483.5	4.6	64	444.8	4.8
Calgary	Canada	Weak Centre *	577.2	323.6	2.8	565.3	409.7	3.8	425.2	563.5	5	522	630.3	4.9	433	667.6	4.6
Melbourne	Australia	Weak Centre	155.6	224	8.1	295.3	192.1	6.8	270.4	445.8	7.9	337.3	518.3	7.7	308	621.2	8.4
Sydney	Australia	Strong Centre	-	268.1	4.7	86.6	366.4	5.1	156	489.3	6.2	222.2	530	6.2	201	534.6	6.9
Vancouver	Canada	Weak Centre *	-	285.3	7	341	401.7	6	342	453.9	6	443	564.5	5	417	513	4.9
Ottawa	Canada	Weak Centre *	-	279.8	-	-	369.7	-	-	473.9	8.4	230.3	510.2	7.1	340	536.7	8.3
Frankfurt	W. Europe	Strong Centre *	110.4	133.3	1.3	189.2	280	1.5	241.8	386.9	2	246.3	477.6	2	264	481.7	2
Copenhagen	W. Europe	Weak Centre	150.7	88.5	2.8	198.5	199.5	3.4	212.3	246.4	4.3	223.2	283	4.6	208	304.4	3.9
Montreal	Canada	Weak Centre *	-	192.5	-	-	248.9	-	313.3	326.5	-	346.8	420.2	4.5	377	437.5	4.5
Toronto	Canada	Strong Centre	191.8	297.8	1.7	198.2	358.2	2.3	197.6	462.5	2.7	175.8	606	2.6	206	474.7	4.4
Zurich	W. Europe	Traffic Limiting *	-	126	-	112.8	253.9	-	140.3	374.6	3.7	136.7	444.2	4	140	488.7	4.7
Hamburg	W. Europe	Strong Centre *	123.7	95.7	1.8	139.1	241.4	2	148.9	344.4	2.2	177.3	410.2	2.6	176	451.4	2.5
Stockholm	W. Europe	Traffic Limiting	99.7	143.2	1.5	130.4	274.7	1.8	153.3	346.5	2.3	193.2	408.9	2.2	162	424.9	4.8
Munich	W. Europe	Traffic Limiting *	-	130.9	1.5	-	261.8	1.5	248.7	359.9	1.7	266.2	468.2	1.8	275	500.2	1.8
London	W. Europe	Traffic Limiting	-	156.3	1.5	126.5	222.8	1.7	120.7	284.1	1.9	-	347.6	2	90	351.3	2
Vienna	W. Europe	Traffic Limiting	-	93.6	1.2	-	213.9	1.6	189.5	311.2	1.7	186.5	363.2	1.8	200	384	1.7
Brussels	W. Europe	Traffic Limiting *	-	157.3	1.4	-	262.3	1.4	185.5	357	1.6	314.1	428.2	2.1	394	468.7	1.9

Note: \* denotes archetypes not allocated by Thomson (1977) and interpreted by authors

### 1.8.2 Residential and Commercial Database for Perth, Western Australia

The quantitative input data for *Journal Papers 3, 4 and 5* were sourced from a variety of Western Australian government departments, including Landgate, Department of Planning and the Department of Transport.

The most important of the datasets was the government assessed land value data from the Western Australian Valuer General's Office in Landgate to act as the dependent variable in the hedonic price model of rail transit accessibility. These land valuation data from (2001-2012) for all metropolitan Perth residential and commercial zoned land parcels were excellent due to their comprehensive nature, the reliability of the assessment method, and in particular the uniform nature of the dataset when compared to property valuation data that include capital improvements.

Whilst there are some limitations in the dataset, such as a lack of responsiveness to market demand in particular, these were outweighed by its uniformity and its true representation of 'transit proximity benefit' without built form distortions. Included in the land valuation estimates, a percentage influence of scenic views was removed from the model, essentially controlling for this effect. Land value per square metre with the view percentage removed was modelled as the Hedonic Price Modelling (HPM) dependent variable using 462,476 residential land parcels across Metropolitan Perth with the aim of modelling the impact of rail transit infrastructure on land values per square metre. Due to significant data matching issues between the land valuations dataset and the rest of the cadastral level data, the preparation of this dataset into ArcGIS was one of the most time consuming parts of the PhD.

Public transport accessibility controls employed in the analyses included the Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) composite index, which is a;

“GIS-based tool that assesses the relationship between public transport network configuration, performance and service standards and the geographical distribution or clustering of land use activities across a metropolitan area” (Scheurer, 2010).

SNAMUTS provides an excellent supply side measure of public transport accessibility through the existing public transport network to not only the CBD, but to all other centres within the Metropolitan region. It does not however explain demand for services, and this would be a useful inclusion for the future.

The residential land database also included a range of control variables including residential density zoning (i.e. R-Codes), public high school district rating (using the NAPLAN Score), and the Australian Bureau of Statistics' (ABS) Socio Economic Index for Areas (SEIFA). In addition to these datasets, GIS was used to calculate the following spatial topographical attributes, including the proximity of a land parcel to:

- a major water body (i.e. river or ocean);
- major road infrastructure (highways and freeway on-ramps); and
- the CBD and other activity centres.

The dataset included 400m, 800m, and 1600m (5, 10 and 20 minute) pedestrian catchments to rail stations, calculated as road network service areas using Network Analyst in ESRI's ArcGIS. As well as the pedestrian catchments, the park and ride catchments for each of the rail lines were also calculated (10 minute drive to the station), and these formed the spatial extents for the region catchments for each of the lines. The spatial extents of all the regional and pedestrian catchments for the analysis are presented in Figure 4.

In addition to the variables pre-existing in the dataset a series of dummy variables were created, including:

- 12 time period dummy variables for the data within the years 2001-2012, where 2001 became the model's base case; and
- 6 region dummy variables for the rail station catchments for the 'all regions' model, the Fremantle line, the Armadale line, the Midland line, the Mandurah line and the Joondalup line.

The different time dummy variables demonstrated how the hedonic price for each of the attributes changed over time. This was particularly important for the analysis of

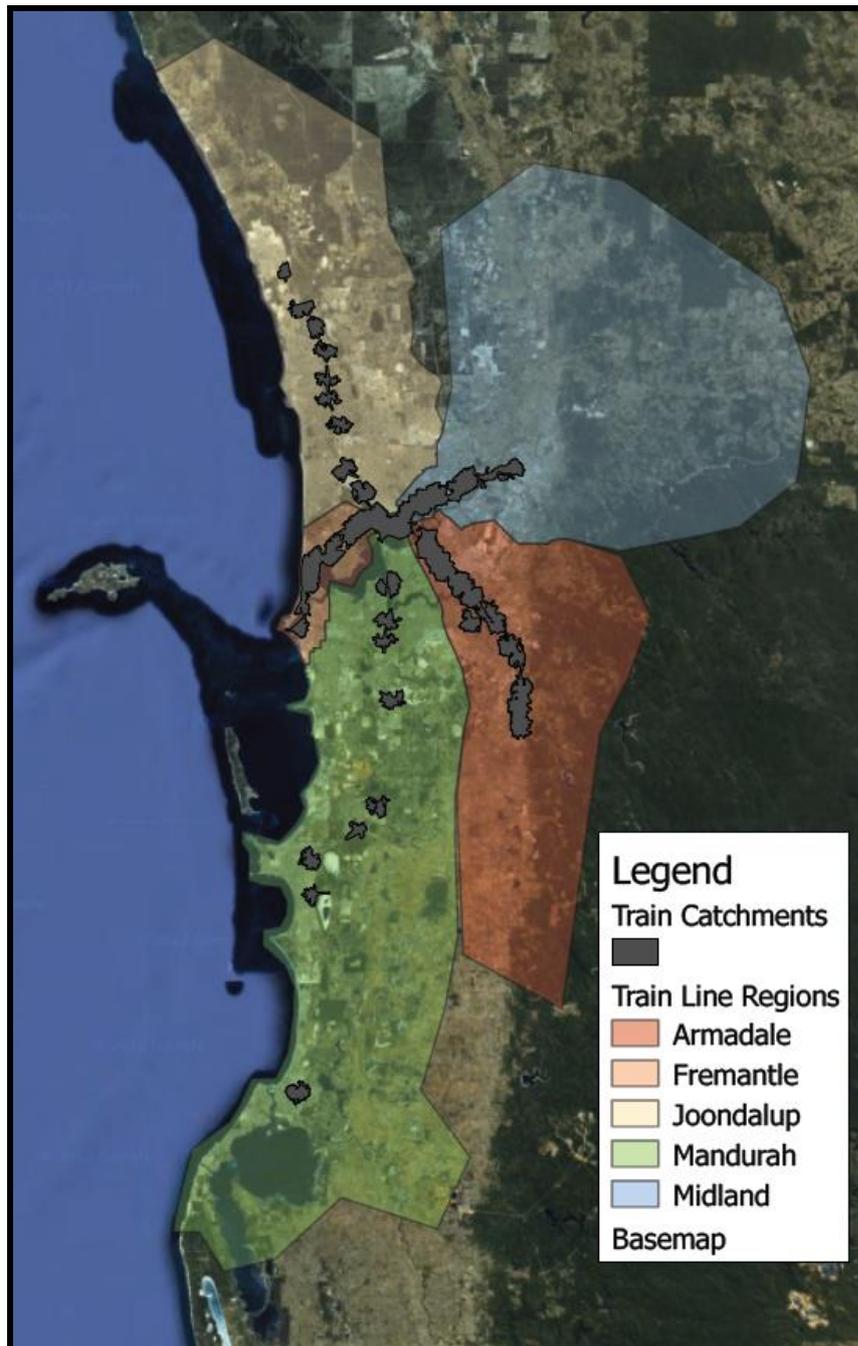
the impact of the investment in the Mandurah rail line, where funding commitment occurred in 2003, and operations commenced in 2007.

The regional dummy variables highlighted the differences in the hedonic price for each of the rail lines. This was important as the rail line speed, station accessibility models (pedestrian, park and ride, bus interchange), and physical surroundings (Mandurah and Joondalup lines are located in the middle of freeways), all differentially effect the willingness to pay for proximity and access to the rail services.

This database was subsequently used in the cross-sectional and panel data hedonic price modelling and willingness to pay for urban transit accessibility analysis for Metropolitan Perth. The dependent and explanatory variables descriptive statistics for both residential and commercial databases are presented in Tables 5 and 6.

Given the comprehensive nature of the metropolitan database, and its alignment with other willingness to pay for transit access literature (Rodriguez and Targa, 2004; Cervero and Kang, 2010; Cervero & Duncan, 2002; Golub, et al., 2012), the database was deemed to meet the requirements of the econometric and financial analysis undertaken in Journal Papers 3, 4 and 5.

Other primary data sources (modal interchange characteristics, rail line passenger volumes, and the proximity to other land uses) were collected, but were discounted as they dropped out of the analysis due to cross correlation with other variables, low significance values and a negative impact on the model's coefficient of determination ( $R^2$ ).



*Figure 4 Individual rail line catchments for the Perth metropolitan region, (with the individual station's 1600m pedestrian catchments shown in grey)*

*Table 5 Descriptive Statistics for the Perth Metropolitan Residential Cross-sectional HPM for 2011 (1) Fremantle Line, (2) Armadale Line, (3) Midland Line, (4) Mandurah Line and the (5) Joondalup Line*

Explanatory Variables	Mean or Percentage Values						Data Source (See Notes for source)
	All Regions	(1)	(2)	(3)	(4)	(5)	
Land Value/m <sup>2</sup> (no view) (AUD\$ 2011)	590.69	1646.59	366.95	425.29	542.88	632.00	(*)
Log Land Value/m <sup>2</sup> (no view)(AUD\$ 2011)	6.121	7.306	5.692	5.714	6.103	6.336	(**)
Number of Land Parcels	462476	28487	85108	67761	128136	152974	(*)
<b>Transportation Proximity</b>							
<b>400m train catchment</b> number of parcels (% of total catchment # of parcels) [Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011] {Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	5300 (1.2%) [1044.03] {6.65}	1913 (6.7%) [1885.62] {7.46}	1401 (1.6%) [473.19] {5.99}	1440 (2.1%) [701.85] {6.47}	224 (0.2%) [325.27] {5.67}	321 (0.2%) [556.69] {6.28}	(**)
<b>800m train catchment</b> number of parcels (% of total catchment # of parcels) [Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011] {Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	15998 (3.5%) [1002.33] {6.62}	4643 (16.3%) [1930.44] {7.50}	5068 (5.9%) [466.18] {5.96}	4000 (5.9%) [770.63] {6.57}	890 (0.7%) [588.45] {6.16}	1396 (0.9%) [789.61] {6.52}	(**)
<b>1600m train catchment</b> number of parcels (% of total catchment # of parcels) [Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011] {Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	51388 (11.1%) [768.32] {6.35}	6797 (23.9%) [1961.71] {7.48}	15749 (18.5%) [403.95] {5.84}	7424 (11.0%) [800.36] {6.55}	9238 (7.2%) [555.87] {6.09}	12179 (8.0%) [713.54] {6.47}	(**)
0 – 100m of a Hwy # of parcels (% total)	17811 (3.9%)	1306 (4.5%)	3746 (4.4%)	2585 (3.8%)	4753 (3.7%)	5420 (3.5%)	(**)
100 – 200m of a Hwy # of parcels (% total)	26215 (5.7%)	2355 (8.3%)	5365 (6.3%)	4566 (6.7%)	7108 (5.5%)	6820 (4.5%)	(**)
200 – 400m of a Hwy # of parcels (% total)	48942 (5.7%)	4105 (14.4%)	9643 (11.3%)	8106 (12.0%)	13784 (10.8%)	13302 (8.7%)	(**)
Distance to nearest freeway onramp	8.63	6.89	13.54	17.41	5.52	4.94	(**)
<b>Transportation Accessibility Measure</b>							
SNAMUTS score	6.62	11.02	7.34	5.58	6.98	5.56	(***)
# of Dwellings within 1600m of parcel	4680	5772	4228	3880	4404	5314	(**)
Distance to CBD (km)	17.422	12.16	17.97	18.37	18.76	16.56	(**)
Distance to secondary centre (km)	4.80	2.44	5.10	6.78	5.33	3.75	(**)
<b>Property and Locational Attributes</b>							
Area (m <sup>2</sup> )	1746	688	2067	4072	1488	942	(*)
R-Code	20.98	21.11	21.56	18.81	20.52	22.36	(*)
Senior public high school rating	5.52	17.34	7.33	2.80	4.88	7.05	*****
Socio Economic Index For Areas (SEIFA)	58.641	87.49	42.39	51.88	60.89	63.43	(****)
Distance to water (km)	3.17	1.15	5.01	4.08	2.13	3.00	(**)
Notes: Primary sources of data used for the analysis are noted as follows. (*) Sourced from the Department of Planning and the Valuer Generals Office at Landgate (**) Calculated by James McIntosh for the GIS model as a basis for econometric analysis in Journal Papers 3,4 and 5 (***) Unpublished SNAMUTS Model for Perth prepared by Dr Jan Scheurer. (****) Australian Bureau of Statistics (*****) School boundaries were digitised from Department of Education Plans, and school ratings came from NAPLAN scores							

*Table 6 Descriptive Statistics for the Perth Metropolitan Commercial Cross-sectional HPM for 2011 (1) Fremantle Line, (2) Armadale Line, (3) Midland Line, (4) Mandurah Line and (5) Joondalup Line*

Explanatory Variables	Mean or Percentage Values						Data Source (See Notes for source)
	All Regions	(1)	(2)	(3)	(4)	(5)	
Land Value/m <sup>2</sup> (no view) (AUD\$ 2012)	1302.03	2603.55	573.83	1008.46	1436.95	862.58	(*)
Log Land Value/m <sup>2</sup> (no view) (AUD\$ 2012)	6.580	7.675	5.88	6.36	6.61	6.36	(**)
Number of Land Parcels	6322	1270	1172	1428	1214	1237	(*)
<b>Transportation Proximity</b>							
<b>400m train catchment</b> number of parcels (% of total catchment number of parcels) [Ave. Catch. Land Val./m <sup>2</sup> AUD\$2012] {Ave. Catch. Log Land Val./m <sup>2</sup> AUD\$2012}	693 (11.0%) [2208.7] {7.29}	234 (18.5%) [2977.0] {7.83}	121 (10.3%) [562.9] {6.09}	228 (15.9%) [1358.8] {7.04}	60 (4.9%) [5902.7] {8.57}	50 (4.0%) [2038.9] {7.30}	(**)
<b>800m train catchment</b> number of parcels (% of total catchment number of parcels) [Ave. Catch. Land Val./m <sup>2</sup> AUD\$2012] {Ave. Catch. Log Land Val./m <sup>2</sup> AUD\$2012}	1072 (17.0%) [2153.6] {7.38}	433 (34.1%) [2926.1] {7.87}	189 (16.1%) [885.3] {6.45}	319 (22.3%) [1502.1] {7.12}	92 (7.5%) [3707.4] {8.01}	39 (3.2%) [1387.2] {7.04}	(**)
<b>1600m train catchment</b> number of parcels (% of total catchment number of parcels) [Ave. Catch. Land Val./m <sup>2</sup> AUD\$2012] {Ave. Catch. Log Land Val./m <sup>2</sup> AUD\$2012}	1285 (20.3%) [1604.3] {7.03}	326 (25.6%) [2955.8] {7.80}	322 (27.4%) [802.4] {6.41}	304 (21.2%) [1386.5] {7.06}	130 (10.7%) [1652.4] {7.06}	203 (16.4%) [1001.4] {6.74}	(**)
0 – 100m of a Hwy # of parcels (% of total)	1146 (18.1%)	189 (14.9%)	273 (23.3%)	278 (19.5%)	249 (20.5%)	156 (12.6%)	(**)
100 – 200m of a Hwy # of parcels (% of total)	382 (6.0%)	50 (3.9%)	108 (9.2%)	112 (7.8%)	62 (5.1%)	50 (4.0%)	(**)
200 – 400m of a Hwy # of parcels (% of total)	549 (8.7%)	56 (4.4%)	188 (16.0%)	124 (8.6%)	82 (6.8%)	206 (16.7%)	(**)
Distance to nearest freeway onramp	7.12	5.07	11.59	11.33	4.04	3.55	(**)
<b>Transportation Accessibility Measure</b>							
SNAMUTS score	11.096	13.57	9.90	11.53	11.68	8.61	(***)
Dwellings within 30mins	347647	343345	328278	360504	338956	364320	(**)
Effective job density	27325	30901	24145	27723	26469		(**)
<b>Property and Locational Attributes</b>							
Area (m <sup>2</sup> )	4565	1141	4309	5294	5079	6982	(*)
Socio Economic Index For Areas (SEIFA)	60.89	80.00	46.40	52.91	62.99	62.18	(****)
Distance to water	2.30	1.27	4.13	2.14	1.38	2.72	(**)
Notes: Primary sources of data used for the analysis are noted as follows. (*) Sourced from the Department of Planning and the Valuer Generals Office at Landgate (**) Calculated by James McIntosh for the GIS model as a basis for econometric analysis in Journal Papers 3,4 and 5 (***) Unpublished SNAMUTS Model for Perth prepared by Dr Jan Scheurer. (****) Australian Bureau of Statistics							

## 1.9 Econometric Modelling Techniques Applied in the Research

The data used for the econometric analyses in *Journal Papers 1, 3, 4 and 5* were generated from disparate sources and collected from various local, state and international government agencies, previous academic publications, as well as being created as part of this project. Such spatially and temporally variable datasets made analysis difficult, and to overcome these issues various econometric methods were employed.

Least squares regression based econometric analysis is useful in exploring and understanding the relationships between different explanatory variables and a dependent variable (Small and Verhoef, 2007). The analysis of these quantitative relationships between a city's function, form and (in the case of the *Journal Papers 3, 4 and 5*) the willingness to pay for urban transit, were extremely beneficial in illustrating the value residents and businesses place on locating within close proximity of a transit line.

In addition to the econometric methods applied in this research, a range of econometric methods were trialled throughout the research, including Multinomial Logit Modelling, Random and Fixed Effect Modelling and Geographically Weighted Regression. All had merit, but were eventually rejected due to the following reasons:

- Poor performance when used to analyse both the global cities database and Perth land valuation based dataset (Multinomial Logit Modelling);
- Difficulties in interpreting the results for making policy decisions (Geographically Weighted Regression);
- Difficulty in comparing the results of the analysis from these methods to those being achieved in the rest of the literature, thus influencing the choice of the methods selected.
- The use of Random and Fixed effect modelling was undertaken for Journal Paper 1, though it was eventually removed from the paper for brevity, and due to concerns that it was not adding anything to the analysis, that was not already covered by Structural Equation Modelling.

### 1.9.1 Spatial (Cross Sectional) Least Squares

Spatial (cross sectional) least squares generally involves the application of Ordinary Least Squares regression analysis, where the relationship between the dependent variable and explanatory variables is expected to be linear. Ordinary least squares was adopted for this analysis due to its ease of interpretation and its ubiquitous application internationally, therefore enabling direct comparisons between this research and others in the literature. The parametric equation for the observed land price (P) is shown in Equation 1.

*Equation 1 Parametric Land Price Equation*

$$P_i = f(X_i, \beta_i) + \varepsilon_i$$

Where:

- $P_i$  is the estimated land/property price of the  $i^{\text{th}}$  observation,
- $X_i$  is a vector of quantitative and qualitative land/property attributes,
- $\beta_i$  is the unknown hedonic, or implicit price, of the land and property for attribute j, and
- $\varepsilon_i$  is the stochastic error term.

An example of its application using the dataset illustrated in Table 4 and analysed in *Journal Paper 3* is presented in Equation 2, where the dependent variable is the natural log of a land parcel's value per square metre, with the government % uplift for the parcel's view removed from its value.

*Equation 2 Cross Sectional HPM - Log-Log form*

$$\begin{aligned} \text{Log}(vpsm\_no\_view) = & \text{Constant} + B_1 [\text{Log}(\text{Area})] + B_2 [\text{Log}(\text{R-Code})] + \\ & B_3 [400m \text{ Catchment}] + B_4 [800m \text{ Catchment}] + B_5 [1600m \text{ Catchment}] + \\ & B_6 [\text{Log}(\text{SNAMUTS})] + B_7 [\text{Log}(\text{SEIFA})] + B_8 [\text{Log}(\text{Schools})] + B_9 [\text{Log}(\text{Dist. to Water})] + \\ & B_{10} [\text{Log}(\text{Dwelling 1600})] + B_{11} [\text{Log}(\text{Dist. to CBD})] + B_{12} [\text{Log}(\text{Dist. 2nd Centre})] + \\ & B_{13} [100m \text{ Highway}] + B_{14} [200m \text{ Highway}] + B_{15} [\text{Log}(\text{Dist. To Fwy onramp})] \end{aligned}$$

### 1.9.2 Temporal (Panel Data) Least Squares

Panel data modelling of the temporal variation in land prices is important for understanding the behaviour of land prices over time. Many of the cross sectional variables are non-stationary in a temporal sense and can reflect a number of factors:

- economic changes;
- technology changes;
- political shifts; and
- cultural movements (gentrification for example.)

In addition to these factors, the most important reason for undertaking the panel data HPM analysis in this study was to determine the changes in a city or region's land market hedonic prices prior to and during construction as well as after the commencement of operations of new transit infrastructure. An example from *Journal Paper 3* of its application using the dataset illustrated in Table 4 is presented in Equation 3.

#### *Equation 3 Panel data HPM Log-Log*

$$\begin{aligned}
 \text{Log}(vpsm\_no\_view) = & \text{Constant} + B_1 [\text{Log}(\text{Area})] + B_2 [\text{Log}(\text{R-Code})] + \\
 & B_3[400m \text{ Catchment}] + B_4[800m \text{ Catchment}] + B_5[1600m \text{ Catchment}] + \\
 & B_6[\text{Log}(\text{SNAMUTS})] + B_7[\text{Log}(\text{SEIFA})] + B_8[\text{Log}(\text{Schools})] + B_9[\text{Log}(\text{Dist. to Water})] + \\
 & B_{10}[\text{Log}(\text{Dwelling 1600})] + B_{11}[\text{Log}(\text{Dist. to CBD})] + B_{12}[\text{Log}(\text{Dist. 2nd Centre})] + \\
 & B_{13}[100m \text{ Highway}] + B_{14}[200m \text{ Highway}] + B_{15}[\text{Log}(\text{Dist. To Freeway onramp})] + \\
 & B_{16}[dt\_2002] + B_{17}[dt\_2003] + B_{18}[dt\_2004] + B_{19}[dt\_2005] + B_{20}[dt\_2006] + \\
 & B_{21}[dt\_2007] + B_{22}[dt\_2008] + B_{23}[dt\_2009] + B_{24}[dt\_2010] + B_{25}[dt\_2011] + \\
 & B_{26}[t400(2001\_2002)] + B_{27}[t800(2001\_2002)] + B_{28}[t400(2001\_2002)] + \\
 & B_{29}[t800(2001\_2002)] + B_{30}[t1600(2001\_2002)] + B_{31}[t400(2001\_2003)] + \\
 & B_{32}[t800(2001\_2003)] + B_{33}[t1600(2001\_2003)] + B_{34}[t400(2001\_2004)] + \\
 & B_{35}[t800(2001\_2004)] + B_{36}[t1600(2001\_2004)] + B_{37}[t400(2001\_2005)] + \\
 & B_{38}[t800(2001\_2005)] + B_{39}[t1600(2001\_2005)] + B_{40}[t400(2001\_2006)] + \\
 & B_{41}[t800(2001\_2006)] + B_{42}[t1600(2001\_2006)] + B_{43}[t400(2001\_2007)] + \\
 & B_{44}[t800(2001\_2007)] + B_{45}[t1600(2001\_2007)] + B_{46}[t400(2001\_2008)] + \\
 & B_{47}[t800(2001\_2008)] + B_{48}[t1600(2001\_2008)] + B_{49}[t400(2001\_2009)] + \\
 & B_{50}[t800(2001\_2009)] + B_{51}[t1600(2001\_2009)] + B_{52}[t400(2001\_2010)] + \\
 & B_{53}[t800(2001\_2010)] + B_{54}[t1600(2001\_2010)] + B_{55}[t400(2001\_2011)] + \\
 & B_{56}[t800(2001\_2011)] + B_{57}[t1600(2001\_2011)]
 \end{aligned}$$

### 1.9.3 Willingness to Pay

The willingness to pay (WTP) for a parcel of land consisting of a range of site and neighbourhood characteristics can be calculated by evaluating the estimated regression variable and then taking the partial derivative of it with respect to a characteristic of choice (Rosen, 1974). In the case of an application of the log-log estimator where the coefficients are approximates of the expected percentage change in land value, the WTP for a one unit change of an attribute can be estimated as in Equation 2, and is applied to a variety of land characteristics including transit access.

*Equation 4 Willingness to Pay*

$$WTP_{i,t} = \frac{d(P_t)}{d(x_{i,t})} \cdot \bar{P}_t = \beta_{i,t} \cdot \bar{P}_t$$

Where:  $\bar{P}_t$  is the mean catchment land value in time period t

$\beta_{i,t}$  is the regression coefficient of attribute i at time period t

The use of the willingness to pay for access to differing location based utilities was a key tenet of the research and builds on its application in the literature.

### 1.9.4 Random and Fixed Effects Modelling

Random effects and fixed effects models were estimated in *Journal Paper 1* given the panel data structure of the global cities data. The fixed effect models were able to control for unobserved differences between archetypes, regions or cities, depending on the model being estimated. This is important when unobserved effects may be correlated with other model parameters. The random effects model assumes that unobserved differences are uncorrelated with the other model parameters but still controls for serial correlation within archetypes, regions or cities across time.

The individual fixed effect model removes the variation between cities and focuses on the variation within cities across time to control for potential influences of time-invariant unobserved heterogeneity on the other regressors; however it does so at the cost of efficiency due to less information being present in the data.

The random effects model applied in *Journal Paper 1* assumes any unobserved time-invariant effects to be orthogonal to the other regressors but must still control for serial correlation in the error term. The regressors were kept consistent across both models to enable a range of tests to be carried out comparing them with each other and with the panel model.

Though these methods were both applied in *Journal Paper 1*, they were finally removed at the request of the editor, due to concerns over the impact on the paper's brevity.

#### 1.9.5 Structural Equation Modelling

Structural equation modelling (SEM) is a statistical modelling technique that enables the exploration of complex relationships in datasets by combining statistical data analysis with qualitative assumptions of causality. The technique is carried out by simultaneously estimating a system of equations using Maximum Likelihood Estimation (MLE).

By estimating the covariance structures of the variables along designated paths, endogeneity biases can be statistically corrected (Cervero and Murakami, 2010). This modelling technique is useful in exploring urban transport matters where causality debates are common and two-way relationships among variables can lead to misleading statistical inferences in more conventional models.

### **1. 10 Financial Modelling Techniques Applied in the Research**

In addition to the econometric analysis applied in *Journal Papers 1 and 3*, *Journal Papers 4 and 5* used a variety of financial modelling methods to estimate the land and property market impacts of the increased ‘willingness to pay’ for transit accessibility. The research conducted in *Journal Papers 4 and 5*, applied several methods to determine the financial impacts on the land markets, and subsequently how these benefits flowed through to the existing land and property based taxes.

The financial analysis methods applied in *Journal Papers 4 and 5* were developed with the Western Australian Treasury Corporation. The analysis methods focussed on the case study of the introduction of the Mandurah rail line in Perth, Western Australia, and what the ‘real’ financial impacts on the existing ad valorem taxes would be for the rail stations’ pedestrian catchments if they were considered over an estimated thirty year funding period (if the rail line had been privately funded). In addition to modelling the transit accessibility benefits, there were some modelling assumptions made regarding the potential redevelopment of the corridor, and how this would occur. These redevelopment benefits were at the core of the modelling undertaken. The financial parameters used in modelling the increased accessibility impacts from the integrated transit and redevelopment investment are:

- Redevelopment rate, property turnover rate, urban intensification modelling
- Australian land and property tax modelling, including;
  - Commonwealth government taxes
    - Capital Gains Tax
    - Goods and Services Tax (on redeveloped property)
  - Western Australian state government taxes
    - Stamp Duty
    - Land Tax
    - Metropolitan Region Improvement Tax (MRIT)
  - Western Australian local government charges
    - Council rates
- Transit/Redevelopment project’s Present Value (PV) calculations

## 1.10.1 Land and Property Value Redevelopment Calculations

### 1.10.1.1 Land and Property Value

To model the land and property market impacts from the investment in transit and integrated redevelopment, land and property value had to be defined. For the purposes of the financial modelling conducted in *Journal Papers 4 and 5*, property value consists of the land value and the building value, the two elements are calculated separately as shown below:

$$\text{Total Land Value} = \text{Land parcel area} \times \text{Land Value per m}^2 \times (1 + \text{Compound Growth\%} + \text{transit uplift \%})$$

$$\text{Total Building Value} = \text{Land parcel area} \times \text{building to land ratio} \times \text{building value per GFA} \times (1 + \text{building value growth \%})$$

Where:

- The total land value divided by number of land titles provides an estimate of average land value per title.
- (Land parcel area) x (building to land ratio) provides an estimate of Gross Floor Area (GFA).
- Total property value is total land value + total building value.
- Total property value divided by number of property titles provides an estimate of average property value per title.

In addition to these calculations regarding the land and property value a critical component is making an assumption regarding what portion the residential land and property market are owner-occupiers, and what are leased for commercial purposes. This is important for the calculation of a number of the existing taxes, such as Land Tax, the MRIT which are not applicable to land and property used for owner occupiers. Capital Gains Tax and GST do not apply to the development and sale of primary and principle residence residential properties.

### 1.10.1.2 Redevelopment Rate

As part of the analysis of the redevelopment impacts on the property market, the redevelopment rate refers to:

- How much of the transit station catchment is redeveloped per year (i.e. 5%).
- The change in the number of properties per land title (one house on a parcel is converted to 5 townhouses on the same land title).
- How long the redevelopment of the property takes.

This rate of redevelopment is very important for the calculations on the ongoing taxes and charges, such as land tax, MRIT and council rates, as well as the calculation of GST on the redeveloped non-principle residence properties.

#### 1.10.1.3 Analysis of Catchment Redevelopment

The findings from *Journal Papers 4 and 5* demonstrate the rezoning and redevelopment impacts of land parcels increases the value of the underlying land, and shows that it also increases the amount of building stock within the catchments. This redevelopment process impacts all the taxes being used to assess the land and property value uplift, and a critical part of understanding the cost base and holding period implications. The average holding period (or turnover rate) has been used to assist with the calculation of the cost base (for transfer based taxes). For example, where a property is held without sale for a seven year period (the years 1 through to 7) and the Year 0 market value is used as the cost base. This methodology is indicatively illustrated in Table 7.

*Table 7 Cost Base & Holding Period (Existing Property)*

	Year								
	0	1	2	3	4	5	6	7	8
<b>Market Value</b>	X <sub>0</sub>	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>
<b>Cost Base</b>		Z <sub>1</sub>	Z <sub>2</sub>	Z <sub>3</sub>	Z <sub>4</sub>	Z <sub>5</sub>	Z <sub>6</sub>	Z <sub>7</sub>	Z <sub>8</sub>

The cost base and holding period are important for the calculation of the Australian Commonwealth Government capital gains tax generated on the non-primary principle residence properties.

## 1.10.2 Australian Commonwealth Government Land and Property Taxes

### 1.10.2.1 Capital Gains Tax

In the context of the value of the redevelopment of land and property in transit accessible catchment, Capital Gains Tax (CGT) occurs in two events: the initial sale of newly developed land, and the turnover sale of existing property. Therefore the calculation of the CGT needs to be viewed separately for newly developed properties and the existing property market turnover of non-primary and principle residence properties.

#### Newly Developed Properties (One-off events)

$$CGT = (Total\ Property\ Value - Cost\ Base) \times Tax\ Rate$$

Where:

- The cost base is assumed to be the property value 1 year before development.

#### Existing Property Turnover (Annually)

$$CGT = (Total\ Property\ Value - Cost\ Base) \times Turnover\% \times Tax\ Rate \times CGT\ Discount$$

Where:

- CGT applies to residential property when held for investment purposes, therefore  $CGT \times (1 - Owner\ Occupier\ Rate)$
- CGT Discount only applies to residential properties
- Average holding period is the period from the property value cost base to the turnover event

### 1.10.2.2 Goods and Services Tax

Similar to CGT, Goods and Services Tax (GST) applies to both the initial sale of newly developed land and the turnover of existing property. However, residential property is exempted from GST.

$$GST = (Total\ Property\ Value - Cost\ Base) \times Turnover\% \times GST\ Rate$$

Where:

- The same GST calculation applies to both initial sales and turnover sales; the cost base (input tax credit) is estimated similarly to CGT

- Turnover % is not included when calculating GST for first release of new developments

### 1.10.3 West Australian State Government Taxes

#### 1.10.3.1 Land Tax and Metropolitan Region Improvement Tax (MRIT)

Land tax is applied to both new developments and existing properties in the same fashion, where the average land value per title is applied to the Department of Finance's land tax table.<sup>1</sup> The tax payable on the average land value per title is multiplied by the total number of land titles to estimate total land tax. MRIT is calculated on average value per land title, where a flat MRIT rate is applied to the land value in excess of a threshold amount, where the threshold is \$300,000 and MRIT Rate is \$0.0014.<sup>2</sup>

$$MRIT = (Land\ Title\ Value - Threshold) \times MRIT\ Rate$$

Owner occupiers of residential land are excluded from paying land tax and MRIT, and the value per land title for land tax and MRIT calculation is capped to not be higher than 150% of the previous year's value.

#### 1.10.3.2 Stamp Duty

The average property value per title is passed through the Department of Finance's stamp duty tables, where separate rate tables exist for residential rate<sup>3</sup> and general rate.<sup>4</sup> The applicable tax rate per title is then multiplied by the number of transacting titles.

$$Stamp\ Duty\ per\ title = (\#\ of\ new\ titles + existing\ titles) \times Turnover\% \times \\ Stamp\ Duty\ Tax\ Rate\ per\ title$$

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<sup>1</sup> <http://www.finance.wa.gov.au/cms/content.aspx?id=239>

<sup>2</sup> <http://www.finance.wa.gov.au/cms/content.aspx?id=241>

<sup>3</sup> <http://www.finance.wa.gov.au/cms/content.aspx?id=2071>

<sup>4</sup> <http://www.finance.wa.gov.au/cms/content.aspx?id=2063>

#### 1.10.4 Western Australian Local Government Rates

Western Australian Local Government (council) rates are calculated by multiplying a property's Gross Rental Value (GRV) by the rate. Though a minimum council rate payable is implemented if the GRV calculation falls below the minimum council rate threshold. The GRV is estimated by multiplying the land value by a percentage.

$$\text{Council Rate} = (\text{Land Title Value} \times \text{GRV}) \times \text{Council Rate}$$

Under the existing structure of council rates in Western Australia, the rate applied is applied to meet budgetary needs of the council, though given the annual variability of the value of land, and the cross jurisdictional nature of the research these rates remained fixed and the rate revenue has been allowed to vary in accordance with the variation in land values.

#### 1.10.5 Present Value Calculations

The calculation of the present value of the forward induced project revenue streams (changes in the taxes and charges) are in terms of its current value (in real terms). In addition to this, the present value is also discounted for future uncertainty, or market risk premium using a 'discount rate', where the market risk premium for determining the discount rate was determined by taking the 20 day average of market yields on 10 year Australian Government Bonds (calculating a discount rate of 3.64%). Equation 5 expresses the discounted present value of the forecasted taxation cash flow:

*Equation 5 Discounted present value calculation*

$$DPV = \sum_{t=0}^n \frac{R_t}{(1+i)^t}$$

Where:

- $DPV$  Discounted present value of the future cash flow
- $R_t$  Nominal value of the cash flow at a future time  $t$
- $i$  Discount rate (rate of return that could be earned in financial markets with similar risk.); the capital opportunity cost
- $n$  is the total number of periods

The nominal present value cash flows are converted to real (adjusted for inflation) once they have been compiled to ensure consistency between the different taxes.

## 2 TRANSIT AND URBAN FORM'S ROLE IN REDUCING GLOBAL CITIES CAR DEPENDENCE

Newman and Kenworthy (1989) first coined the term 'automobile (car) dependence' in their book on 32 global cities, *Cities and Automobile Dependence*, and provided urban metrics to analyse cities that included:

- gasoline consumption;
- public and private transport system modal split;
- degree of infrastructure provision for the automobile (road supply and parking) relative to transit; and
- a measure of urban density and of urban centralisation.

The traditionally car dependent cities of North America and Australia are now investing in the introduction and extension of urban transit systems (especially rail) in their cities to meet the demand for transit (Newman et al., 2013) and to reverse the urban form and transport externalities created by the car dependence of their urban systems.

One of the key metrics used to define car dependence is *passenger car vehicle kilometres travelled per capita* (VKT/Capita). Figure 5 illustrates the growth in car based VKT/Capita from 1960 to 2000 for a sample of 26 global cities from the regions of USA, Canada, Western Europe and Australia. Figures 5 and 6 also illustrates the long term trends in VKT/Capita and urban density across the cities.

The differences in car and passenger VKT/Capita in absolute terms between the different regions presented in Figure 7 is probably most important, as it illustrates the relative differences, and the impact of the change in urban density and car use per capita since 1960. These Figures (5, 6 and 7) provide the context of historical increases in car use per capita that correspond with the reduction in residential density and provision of public transit per capita.

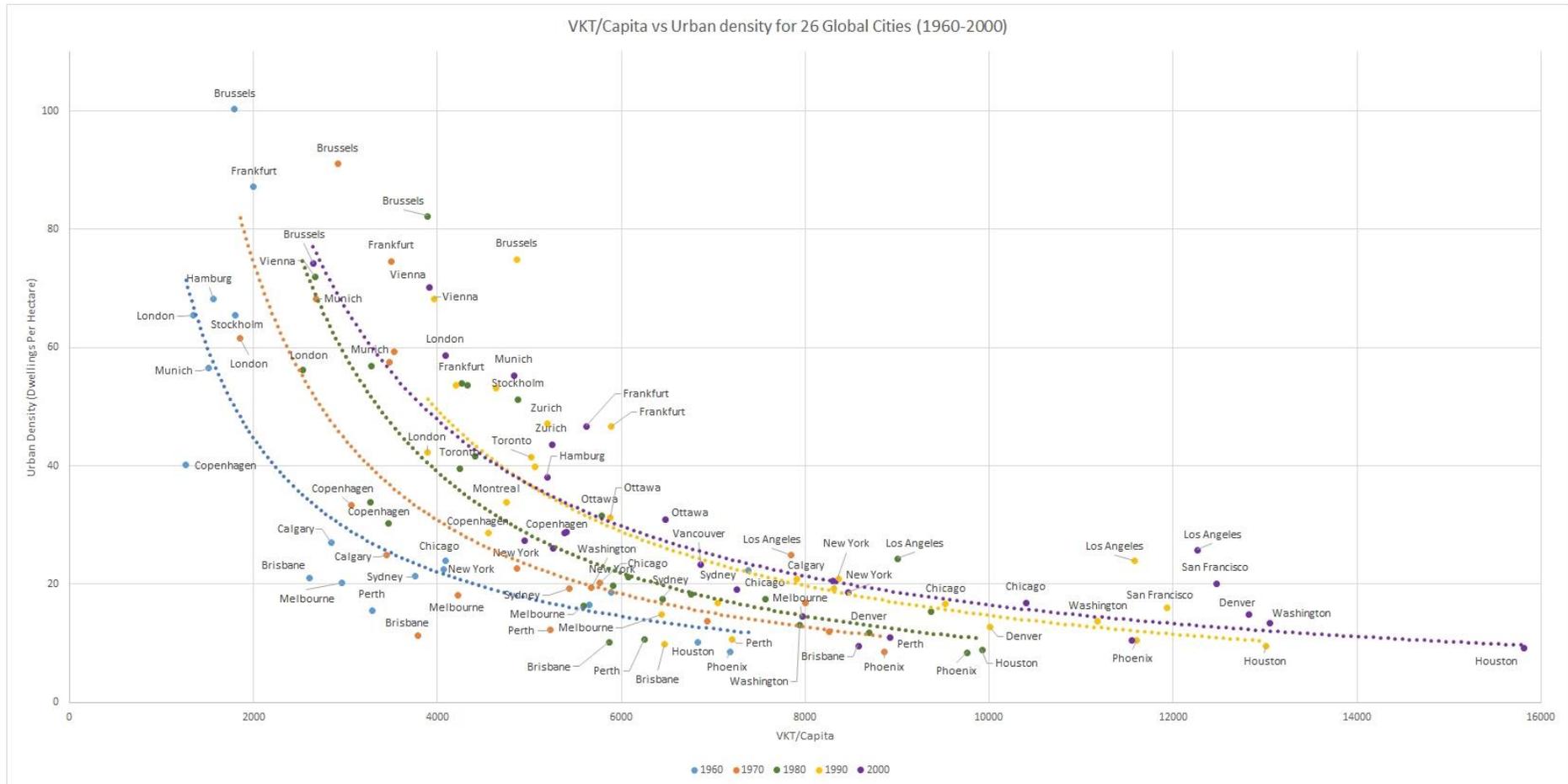


Figure 5 VKT/capita vs Urban Density for 26 global cities from 1960 to 2000. Trend lines for each of the datasets illustrate the changes in the increase in VKT/Capita across all the cities for decade

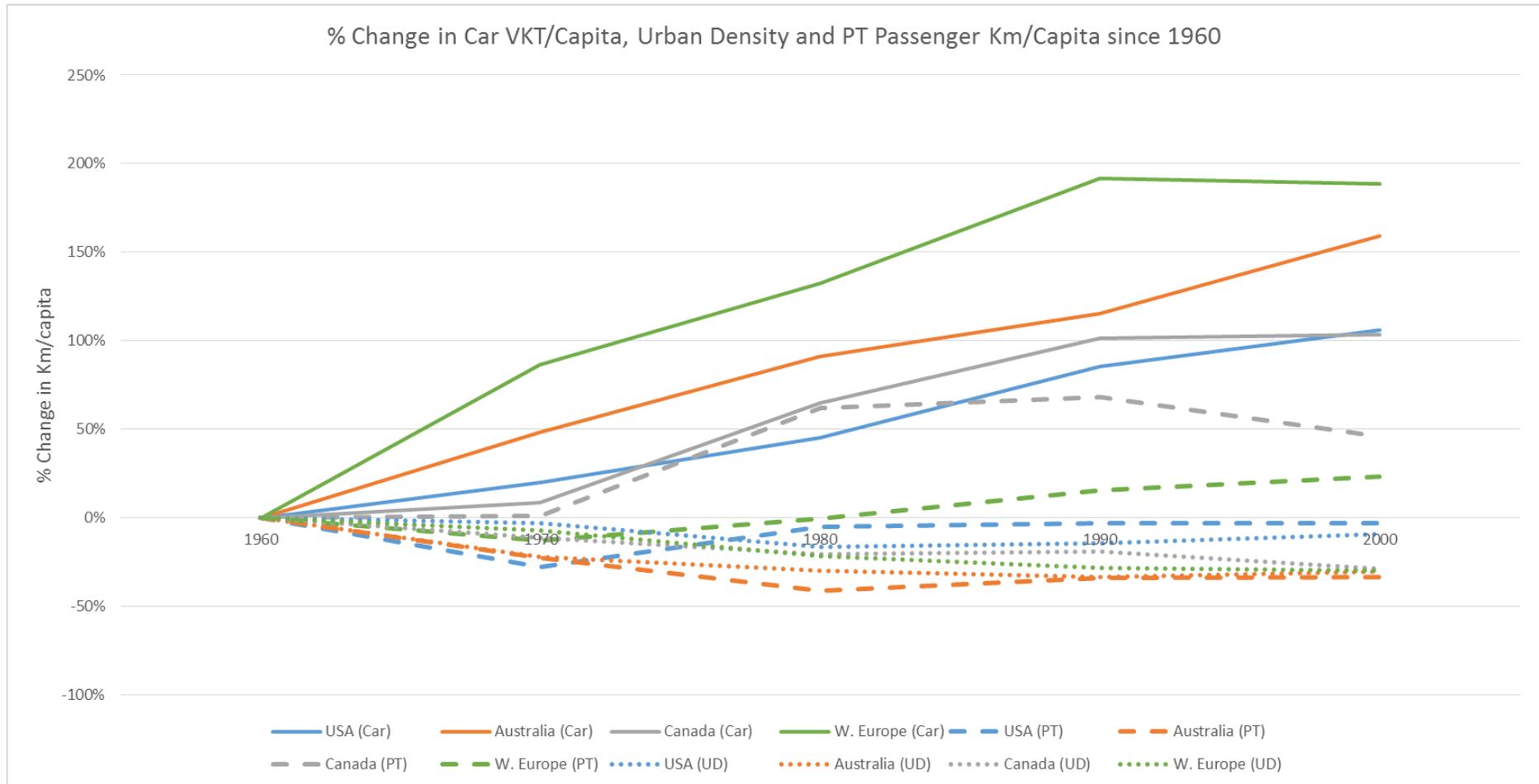


Figure 6 Percentage Change in Car VKT/Capita, Urban Density and PT Passenger Km/Capita since 1960

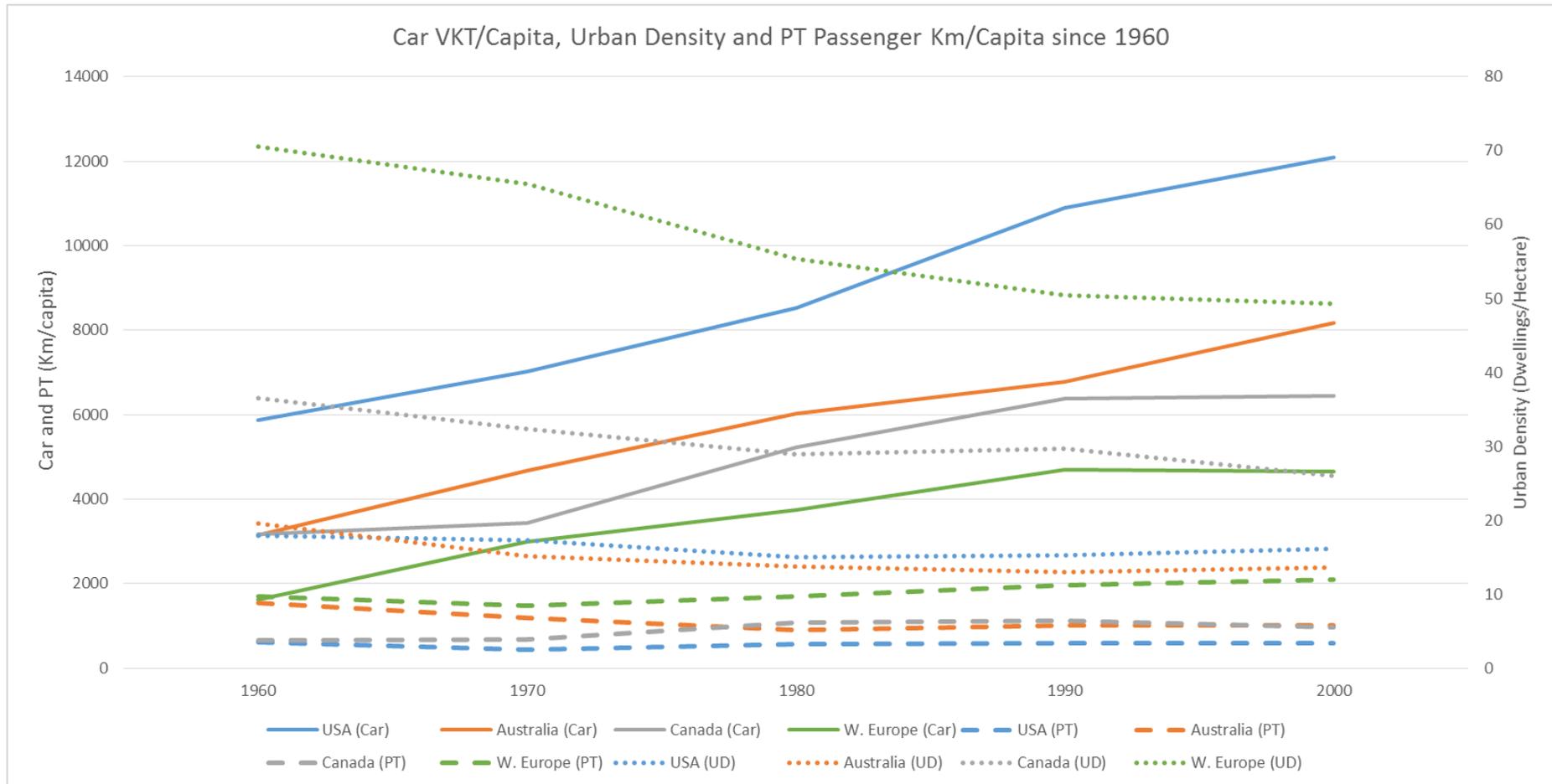


Figure 7 Car VKT/Capita, and PT Passenger Km/Capita and Urban Density (Dwelling/Hectare) since 1960

Table 8 presents a compilation of studies of the impact of a city's urban form, transit provision and socio economic factors on a city's VKT/Capita, which were again compiled for *Journal Paper 1* and provided the basis for the papers research design.

*Table 8 Selection of relevant international studies on car dependence*

<b>Author</b>	<b>Authors assessed causes of Car Dependence</b>	<b>Key Findings</b>
<i>Thomson (1977)</i>	<p><i>The transport and urban form archetypes adopted by the city</i></p> <ul style="list-style-type: none"> <li>• <i>Full Motorisation Strategy</i></li> <li>• <i>Weak Centre Strategy</i></li> <li>• <i>Strong Centre Strategy</i></li> <li>• <i>Low Cost Strategy</i></li> <li>• <i>Traffic Limiting Strategy</i></li> </ul>	<i>The nature of the urban form strategies respond to transport systems and is in effect predetermined by the transport system choices made by the city</i>
<i>Banister, and Lichtfield, (1995)</i>	<p><i>Large investment in urban roads</i>  <i>Suburbanisation of employment,</i>  <i>Low residential and job density</i>  <i>Low land use and transport integration</i></p>	<i>Questions causality issues with model specification</i>
<i>Newman, Kenworthy, Vintila,, 1995.</i>	<p><i>Urban planning,</i>  <i>Strategic planning vs ad hoc</i>  <i>Externality pricing strategies</i></p>	<i>Urban planning to overcome car dependence</i>
<i>Boarnet and Sarmiento (1998)</i>	<p><i>Neighbourhood level analysis</i>  <i>Socio economic variables</i>  <i>Residential location</i></p>	<p><i>Issues assessing causality at the neighbourhood level</i>  <i>Self-selecting choices regarding modal opportunities</i></p>
<i>Giuliano and Dargay, (2006)</i>	<p><i>Car ownership</i>  <i>Daily travel distances, and locational factors</i>  <i>Socio economic factors</i></p>	
<i>Cao, Mokhtarian, &amp; Handy (2007)</i>	<p><i>Socio economic factors</i>  <i>Comparing differing suburb dummy variables</i>  <i>Travel surveys used to collect choice data</i></p>	<p><i>Neighbourhood level analysis</i>  <i>SEM addresses self-selection through controlling for preferences, and use of longitudinal data</i>  <i>Changes in the built environment effect travel more than socio economic variables</i></p>
<i>Bartholomew and Ewing, (2008)</i>	<p><i>Meta data analysis</i>  <i>23 studies from 18 metropolitan areas</i></p>	<i>Compact growth can conservatively reduce VKT by 17% below trend</i>
<i>Brownstone and Golob, (2009)</i>	<p><i>Dwelling Density,</i>  <i>Socio Economic factors, income, race, # children, education rates...</i></p>	<p><i>Density is an important factor, though issues assessing causality at the neighbourhood level</i>  <i>Self-selecting choices regarding VKT</i>  <i>Data misspecification errors</i>  <i>Larger datasets are expected to bring model stability.</i></p>
<i>Litman, T. (2010)</i>	<p><i>Transit fares</i>  <i>Mode Choice</i></p>	<p><i>Cross elasticities short run and long run show long term change</i>  <i>Direct elasticities</i></p>

Public transport, mass transportation or urban transit cover the terms most commonly used for fixed route, fixed schedule urban passenger transit, covering modes such as bus, bus rapid transit (BRT), light rail transit (LRT), heavy rail and commuter rail (Vuchic, 2007). Figure 8, adapted from the National BRT Institute (2013), illustrates indicative urban transit modes operating speeds and capacity.

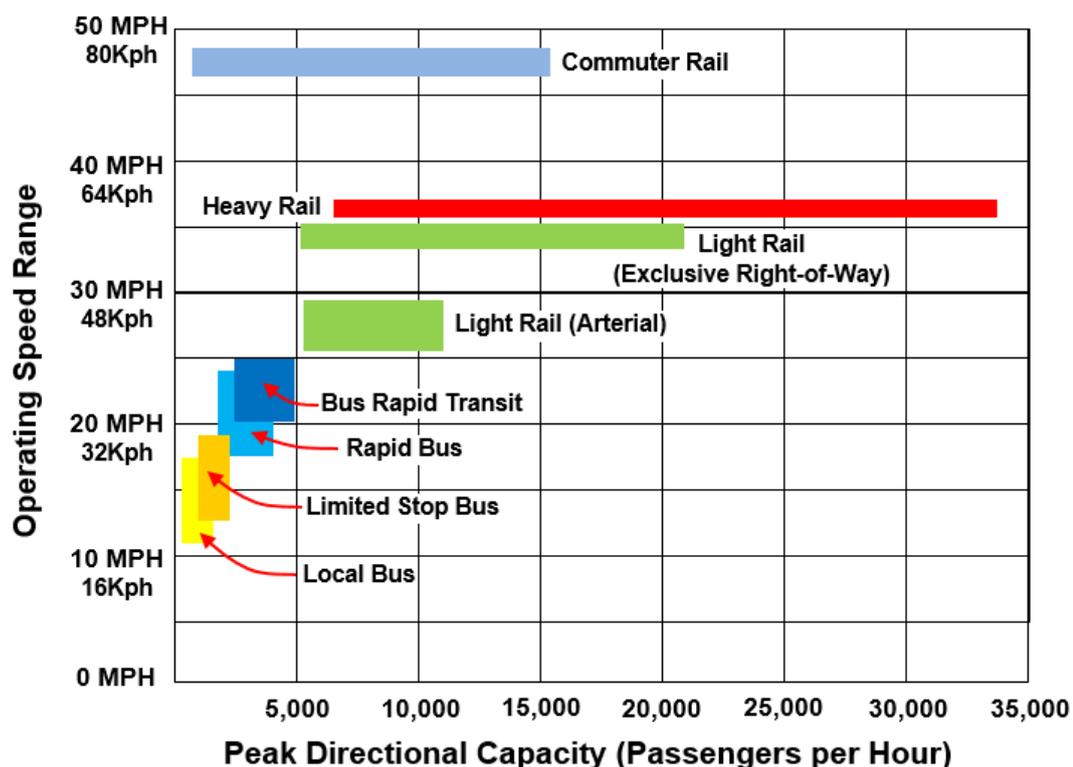


Figure 8 Operating capacities and speeds of different urban transit modes (Adapted from by the National BRT Institute, USA, 2013)

*Journal Paper 1* discusses the causes of car dependence, then econometrically analyses the factors that explain passenger car VKT/Capita using the Global Cities database. The econometric analysis was initially conducted using panel data random and fixed effect modelling methods, and then to address the issue of causation structural equation modelling was used to illustrate the underlying causes of VKT/Capita.

Thomson's (1977) Global city archetypes were used in the *Journal Paper 1* analysis to explain cities transport and urban systems by matching them to the typologies. Whilst Thomson's work is nearly forty years old, the key tenets of his analysis and the application of his city typologies stand virtually corrected today. Whilst there

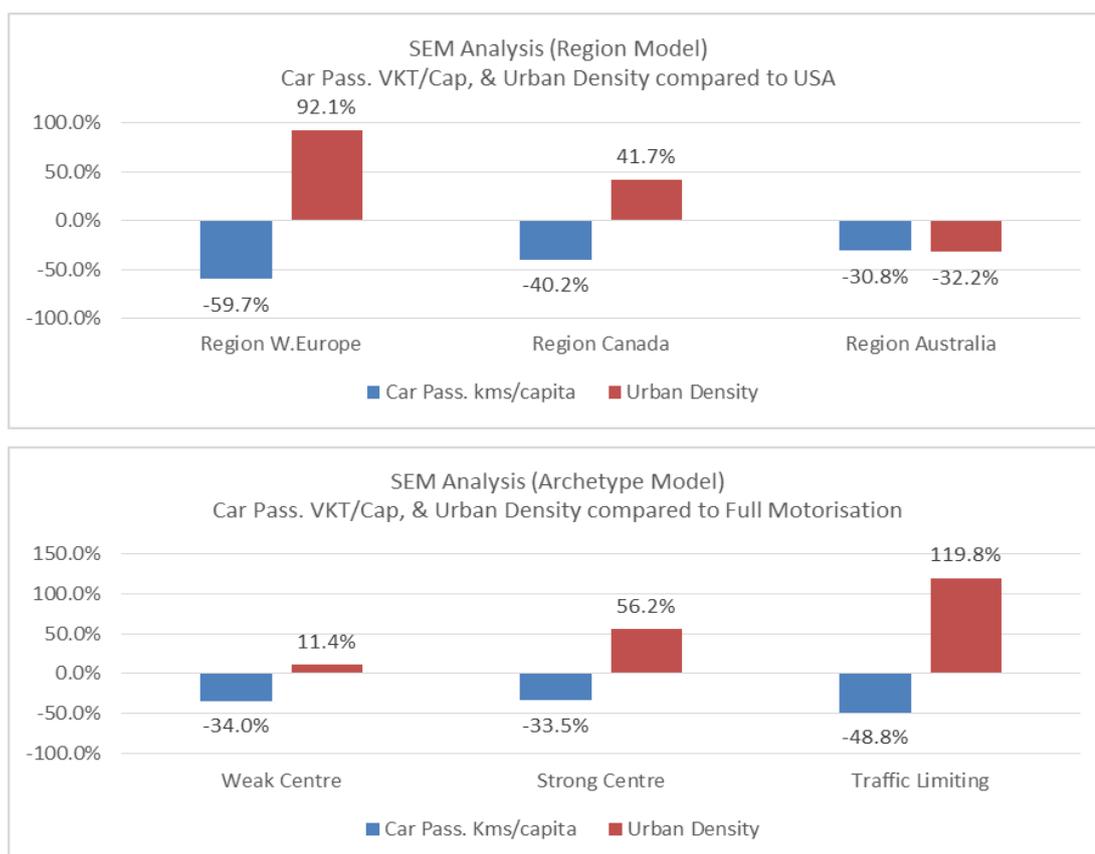
have been a number of individual studies into city function and form (Levinson and Kumar, 1995; Newman and Kenworthy, 1989; Malpezzi, 1999; Jacobs, 1961; Marchetti, 1994), Thomson's work is still unpanelled in its distribution of cities and scale of analysis, thus making it an ideal measure to be included into the analysis to attempt to account for a city's typology.

Thomson's (1977) city archetypes are specified in Table 9, and the results from the SEM modelling for region and archetype models are presented in Figure 9.

*Table 9 Global city archetypes, adapted from Thomson (1977)*

<b>Archetypes</b>	<b>Description</b>	<b>Example Cities</b>
<b>Full Motorisation Strategy</b>	<ul style="list-style-type: none"> <li>• Small to no city centre (&lt;120,000 Jobs) without a radial transport system</li> <li>• Employment in single storey building with extensive parking</li> <li>• Low density single storey dwelling suburbs</li> <li>• Large format shopping with extensive parking</li> <li>• Grid format freeways (4-10 lanes)</li> <li>• Buses on secondary highways, poor pedestrian environment</li> <li>• Car is dominant and cheaper in generalised cost than PT to centres</li> </ul>	<ul style="list-style-type: none"> <li>• Los Angeles</li> <li>• Detroit</li> <li>• Denver</li> <li>• Salt Lake City</li> </ul>
<b>Weak Centre Strategy</b>	<ul style="list-style-type: none"> <li>• City centre (&gt; 250,000 Jobs) with radial road network, and Transit</li> <li>• Significant peripheral and suburban employment served by car</li> <li>• Requires PT to attract passengers to limit intolerable congestion</li> <li>• Ring and radial freeways, commercial/industrial attracted to intersections</li> <li>• Strategy is unstable due to requirements for high transport accessibility to centre without full PT access</li> <li>• Car is marginally cheaper than PT in generalised cost of travel to centres</li> </ul>	<ul style="list-style-type: none"> <li>• Melbourne</li> <li>• Copenhagen</li> <li>• San Francisco</li> <li>• Chicago</li> <li>• Boston</li> </ul>
<b>Strong Centre Strategy</b>	<ul style="list-style-type: none"> <li>• Very High levels of CBD employment (&gt; 500,000 Jobs) with a radial transit network, and limited road accessibility to the centre</li> <li>• Ring Roads complement and interact with transit to provide centre access</li> <li>• Development outside the centre is focussed around the transit infrastructure</li> <li>• Transport investment to centres is equal road/transit</li> <li>• Transit is cheaper than car in generalised cost of travel to centres</li> </ul>	<ul style="list-style-type: none"> <li>• Paris</li> <li>• Tokyo</li> <li>• New York</li> <li>• Athens</li> <li>• Toronto</li> <li>• Sydney</li> <li>• Hamburg</li> </ul>
<b>Low Cost Strategy</b>	<ul style="list-style-type: none"> <li>• Large number of radial routes</li> <li>• BRT, Buses and trams carry the majority of passengers, with limited car use/capita</li> <li>• Very dense development at centres serviced by buses</li> </ul>	<ul style="list-style-type: none"> <li>• Bogota,</li> <li>• Lagos</li> <li>• Calcutta</li> <li>• Istanbul</li> <li>• Karachi</li> <li>• Manilla</li> <li>• Tehran</li> </ul>
<b>Traffic Limiting Strategy</b>	<ul style="list-style-type: none"> <li>• City centres hierarchy put in place; city centre, sector centres, suburban centres, neighbourhood centres, structured to minimise the need for travel</li> <li>• Radial rail and ring rail systems put in place, such that all centres accessible by transit, bus, cycling or walking as well as car</li> <li>• Limited access to the centre with car</li> <li>• High cost of car travel compared to transit (parking, congestion charging.)</li> </ul>	<ul style="list-style-type: none"> <li>• London</li> <li>• Singapore</li> <li>• Stockholm</li> <li>• Vienna</li> <li>• Bremen</li> <li>• Goteborg</li> </ul>

The results from the econometric Structural Equation Modelling (SEM) analysis into the causes of car dependence in *Journal Paper 1* are presented in Figure 9 and illustrate the direct impact of public transport accessibility and urban density on passenger car VKT/Capita in global cities.



*Figure 9 Results from the SEM Modelling for Region and Archetype Models when compared to the USA (Regional Model), or the Full Motorisation (Archetype model)*

The global distribution and the disparate nature of the cities analysed in *Journal Paper 1* address the self-selection issues raised by Boarnet and Sarmiento (1998), and enable the findings of the analysis to be applied to address car dependence internationally. Figure 9 illustrates the difference in VKT per capita and urban density between the region based models and the archetypal models in the amount of VKT/Capita, and the differences, and in particular the differences in urban density elasticities the changes to car based VKT/Capita are clear.

This lead to the discussion of the nature of the urban form and transport policy implications, which are addressed in *Book Chapter 1* and *Journal Paper 2*.

### **3 TRANSIT PLANNING AND URBAN DEVELOPMENT POLICY TO REDUCE CAR DEPENDENCE**

Building on the foundations of the sources and causes of car dependence outlined in the previous chapter and *Journal Paper 1*, this section analyses the urban form and transport policies required to respond to these global causes of car dependence as discussed in *Book Chapter 1 (Urban Transport and Sustainable Development)* and *Journal Paper 2 (Why Fast Trains Work: An assessment of a fast regional rail system in Perth, Australia)*.

The urban planning and policy discussion conducted in *Book Chapter 1* reinforces and builds on the findings from *Journal Paper 1* and develops the urban form policy response to address the causes of car dependence. The urban sustainable transport planning required for transit to make an impact in car dependent cities is comprehensively analysed in *Journal Paper 2*, and the results will be presented in this section to form the urban transit policy response to addressing and providing a transport alternative in car dependent cities.

*Book Chapter 1* traces the history of urban form and its interaction with its transport system, through a lens viewing cities as either ‘Walking cities’ (Central Melbourne and Central New York), ‘Transit Cities’ (Paris, London and Sydney) or ‘Automobile Cities’ (Houston, Denver and Phoenix), (Thomson, 1977; and Newman and Kenworthy, 1989). It also cites six public policy trends that enable the transformation of automobile cities to more transit city fabrics. *Book Chapter 1* proposes that planning and public policy positions should directly respond to the core issues identified in *Journal Paper 1* and discussed in Chapter 2. This leads onto the discussion in *Journal Paper 2* of why transit is needed in car dependent cities and how this issue can be dealt with in car dependent cities.

*Journal Paper 2* presents the land use planning, transport planning, urban economics and transport economics impacts of transit investment in car dependent cities focussing on the minimisation of the generalised cost of travel and proposes an assessment criterion of low generalised cost of travel. This criterion was then

analysed against the investment in the Mandurah rail line in Australia's most car dependent capital city, Perth. *Journal Paper 2* analyses the implementation of the Mandurah rail line, and whilst it has not yet integrated significantly with the surrounding land markets (due to its location in the median of the freeway) it has been very effective in achieving modal shift to transit due to its successful competition with the car in terms of generalised cost. The sustainable development implications for automobile fabrics to transition to transit city fabrics from *Book Chapter 1* and the optimum transit implementation generalised cost factors from *Journal Paper 2* are presented in Table 10.

*Table 10 Sustainable Development and Generalised Cost Factors*

<i>Book Chapter 1</i>	<i>Journal Paper 2</i>
<ol style="list-style-type: none"> <li>1. Integration of different modes</li> <li>2. Integration of different land uses</li> <li>3. Transit Speed compared to car based travel</li> <li>4. Assessment approaches for integrated development and transit projects to include: <ol style="list-style-type: none"> <li>a. agglomeration economies</li> <li>b. avoidable land development costs</li> </ol> </li> <li>5. Private-Public Partnership for integrated project procurement</li> <li>6. New approaches to funding transit through value capture</li> </ol>	<ol style="list-style-type: none"> <li>1. Transit mode time cost minimisation compared to cars <ol style="list-style-type: none"> <li>a. Access time</li> <li>b. Waiting time</li> <li>c. In vehicle time</li> <li>d. Egress time</li> </ol> </li> <li>2. Transit financial cost minimisation compared to cars <ol style="list-style-type: none"> <li>a. Fuel</li> <li>b. Wear and tear</li> <li>c. Parking costs</li> <li>d. Tolls</li> <li>e. Fares</li> <li>f. Transfer costs</li> </ol> </li> <li>3. Transit opportunity cost minimisation compared to cars <ol style="list-style-type: none"> <li>a. Road congestion</li> <li>b. Transit crowding</li> <li>c. Use travel productively</li> </ol> </li> </ol>

The impact of increased urban density and transit provision on the reduction of the production of VKT/Capita were demonstrated in *Journal Paper 1* through the regional and archetypal analysis performed.

*Book Chapter 1* and *Journal Paper 2* illustrated the policy and planning measures required to achieve these increases in urban density and provision of transit. These findings lead to the following key questions:

- How do you quantify the accessibility benefits created from a transit investment in the land markets it serves?
- Do the residents of these land markets value the investment in integrated transit accessibility and dense urban living?
- Can these benefits that are created by the transit investment be captured to assist in funding the infrastructure?

These questions lead to the development of an understanding of the ‘willingness to pay’ for transit accessibility and increased urban density in *Journal Paper 3* and will be further discussed in the next chapter.

## **4 LAND MARKET WILLINGNESS TO PAY FOR TRANSIT ACCESSIBILITY**

Batt (2001) and Ewing and Cervero (2010) (amongst a plethora of others) demonstrate that the increased transit accessibility due to an investment in fixed transit infrastructure is economically monetised into the land and property market catchment's values and reflects a reduction in the generalised cost of travel, representing a '*willingness to pay*' for a reduction in this economic cost.

### **4.1 Increased Willingness to Pay for Transit in Land and Property Markets**

Transport network accessibility is a critical aspect of metropolitan spatial and economic structures (Guiliano et al. 2010), and the role of public transport accessibility is vital for cities to overcome automobile dependence (Newman and Kenworthy, 1999; Newman, et al. 2013).

Cervero and Duncan (2002), Cervero (2004) and McIntosh et al. (2013) demonstrate that the increased accessibility due to the investment in transit is monetised into the value of the accessible land market catchments. As a consequence, transit can influence patterns of urban land use and development activity, which Batt (2001) argues is largely within a context based on a perception of economic costs incurred. The capitalisation of accessibility into land values reflects a '*willingness to pay*' and is a function of derived travel demand and a land parcel's location, reflecting the reduction in economic cost (Batt, 2001; Ewing and Cervero, 2010). This willingness to pay for access to transit reinforces Alonso's (1964) bid rent decay curve for an individual site's value (Figure 10).

The reduction in economic cost effectively moves a property closer to employment and other services (O'Sullivan, 2012). A selection of studies into the differences in the observed impacts in land and property markets from an investment in transit is shown in Tables 10-13. Although the studies presented in Tables 10-13 into the residential property market response to the investment in transit agree that proximity and accessibility to urban transit delivers a value uplift to properties, the identified

value of the uplift can vary depending on a number of factors (Ewing and Cervero, 2010), including the method used to assess the value uplift.

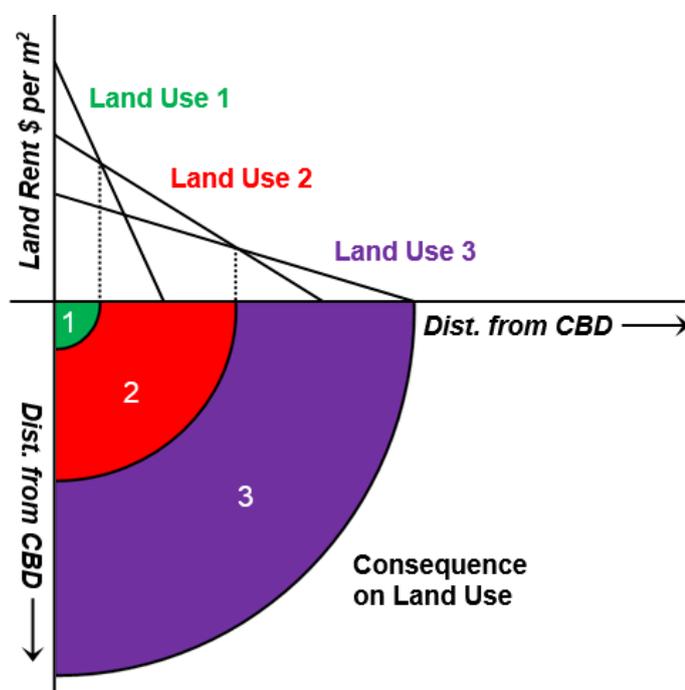


Figure 10 Bid rent curve for different Land Uses (Adapted from Alonso, 1964)

Other studies state that the variances in the premium rate recorded can include the type of property, type of transit service and its level of accessibility when compared to the car (Du and Mulley, 2006; Debrezion et al, 2007; Duncan, 2008; Pan and Zhang, 2008; Zhang, 2009; Mohammad et al, 2013). The variances in land value uplift can also be due to issues related to the operation of the service and its surrounds, namely increases in noise, pollution and crime levels within close proximity to the station (Diaz, 1999; Hui and Ho, 2004; PB, 2001), and the transit station precinct's '*Density, Diversity and Design*' (Cervero, 2004).

Mohammad et al. (2013) also noted a higher uplift premium due to transit in East Asian and European cities compared to North American and Australian cities, and this is suggested as being due to high dependence on transit in most of Europe and East Asia, and high car dependence in North American and Australian cities. This highlights the question as to whether land value capture is likely to be significant

enough to raise funding to enable rail systems to be built using this mechanism in car dependent cities.

Tables 10-14 demonstrate the potential for land value uplift premiums to occur for both BRT and rail based transit, with Cervero and Kang (2010) stating that it is not transit ‘hardware’ (steel-wheel trains or rubber-tire buses) that unlocks land use changes but rather the quality of service and the comparative travel-time savings of transit versus the private car. This is also found to be the case in the Perth case study undertaken in *Journal Paper 3* on the Mandurah rail line.

The variability of the value uplift between modes in different jurisdictions and contexts highlights the difficulty in using empirical studies for forecasting. The rail based transit modes have a greater uplift than the bus based rapid transit, with LRT, having the greatest level of uplift from the rail modes. The greatest land market ‘willingness to pay’ for transit accessibility found for LRT. This is no surprise as whilst it is not the fastest mode or has the highest capacity, it is the mode that highest level of integration with its surrounding land markets.

Table 11 Compilation of academic studies on BRT induced HPM value uplift on residential property and land markets

	Author	Location & Transit System	HPM Form	Dependent Variable	Explanatory Variables					
					Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Bus Rapid Transit	Rodriguez and Targa, (2004)	Bogota, Colombia TransMilenio BRT	OLS – Linear, Log, Log/Log	Linear, Log (Rental Cost)	5 min walk	6.8% to 9.3%	<ul style="list-style-type: none"> <li>Property Area,</li> <li># Beds,</li> <li>#Baths,</li> <li>Living Room,</li> <li>Age</li> </ul>	<ul style="list-style-type: none"> <li>Socio Econ.,</li> <li>Pop. Density,</li> <li>Employ. Density,</li> <li>%Diff. Land Uses,</li> <li>Crime, Poverty,</li> <li>400m Busway</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to BRT,</li> <li>Ped. Time to BRT,</li> <li>BRT Travel Time,</li> <li>Dist.to CBD</li> </ul>	-
	Rodriguez and Mojica, (2008)	Bogota, Colombia TransMilenio BRT	OLS – Log/Linear	Ln (Advert. Sale Price)	150m	13% to 15%	<ul style="list-style-type: none"> <li>House/Apt.,</li> <li>Age,</li> <li>#Bedroom,</li> <li>#Bath,</li> <li>#Garage,</li> <li>Area</li> </ul>	<ul style="list-style-type: none"> <li>Socio Econ.,</li> <li>Pop. Density,</li> <li>Employ. Density,</li> <li>%Diff. Land Uses,</li> <li>Crime</li> </ul>	<ul style="list-style-type: none"> <li>Prox.150m BRT,</li> <li>500m BRT</li> </ul>	<ul style="list-style-type: none"> <li>Year Dummies</li> <li>Interaction terms</li> </ul>
	Perk and Catala, (2009)	Pittsburgh, USA MLK, Jr East Busway	Robust LS - Linear	Appraised Property value	Dist. to BRT	Significant and +ve	<ul style="list-style-type: none"> <li>Lot Area,</li> <li>Living area size,</li> <li># Beds,</li> <li>#Bath,</li> <li>#1/2Bed,</li> <li>Age,</li> </ul>	<ul style="list-style-type: none"> <li>Income,</li> <li>Socio. Econ.,</li> <li>Pop. Density,</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to BRT</li> </ul>	-
	Cervero and Kang, (2010)	Seoul, South Korea Seoul BRT	Multi Level Logit	Land value	90m to 300m of BRT stop	5% to 10%	<ul style="list-style-type: none"> <li>Land use,</li> <li>Building coverage ratio,</li> <li>floor area ratio,</li> <li>%Age Demo.,</li> <li>%College degree</li> </ul>	<ul style="list-style-type: none"> <li>Pop. Density,</li> <li>Employment Density,</li> <li>Dist to River,</li> <li>%Park,</li> <li>%Land Developed,</li> <li>Road area ratio,</li> <li>%Res &amp; Comm. Develop. capacity</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to fwy ramp,</li> <li>Dist to BRT,</li> <li>Dist to CBD,</li> <li>Dist to Subway,</li> <li>Dist. to Major Rd.,</li> <li>Dist to Bus,</li> <li>Job Accessibility by Car</li> </ul>	-
	Mulley & Tsai, (2013)	Sydney Australia Liverpool-Parramatta BRT	ANOVA & OLS	Ln (Sale Price)	400m	-% to 3.3%	<ul style="list-style-type: none"> <li>#Bed.</li> <li>#Bath,</li> <li>#Parking,</li> <li>House/Apt</li> </ul>	<ul style="list-style-type: none"> <li>% Eng. Language,</li> <li>Unemployed,</li> <li>Income,</li> </ul>	<ul style="list-style-type: none"> <li>Within 50m of BRT stop</li> </ul>	<ul style="list-style-type: none"> <li>Time dummies;</li> <li>Pre-const,</li> <li>during const.</li> <li>operations</li> </ul>

Table 12 Compilation of academic studies on LRT induced HPM value uplift on residential property and land markets

	Author	Location & Transit System	HPM Form	Dependent Variable	Explanatory Variables					
					Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Light Rail Transit	Cervero & Duncan (2002)	San Diego, USA LRT	OLS - Linear	Sale Price	400m	3.8% to 17.3%	<ul style="list-style-type: none"> <li>• Size,</li> <li>• #Units</li> <li>• #Bath,</li> <li>• Bed,</li> <li>• Age</li> </ul>	<ul style="list-style-type: none"> <li>• Housing Density</li> <li>• Income</li> <li>• Race Profile</li> <li>• %Senior</li> <li>• % Vacant Land</li> </ul>	<ul style="list-style-type: none"> <li>• ½ Mile LRT</li> <li>• Dist. to Hwy/Fwy</li> <li>• Dist. to Fwy Ramp</li> </ul>	<ul style="list-style-type: none"> <li>• Time Dummies</li> <li>• Monthly to reflect different sale times</li> </ul>
	Garrett, (2004)	Missouri, USA St Louis Metrolink LRT	OLS Log/Linear	House Price	700m	32%	<ul style="list-style-type: none"> <li>• #Bed</li> <li>• #Bath</li> <li>• #Stories</li> <li>• Garage</li> <li>• Pool</li> <li>• Age</li> <li>• Lot Size</li> <li>• Living area size</li> </ul>	<ul style="list-style-type: none"> <li>• Dist. to Hwy interchg</li> <li>• %Res. With College Education</li> <li>• Income</li> <li>• Property Tax rate</li> <li>• School District Scores</li> <li>• LRT have P&amp;R?</li> </ul>	<ul style="list-style-type: none"> <li>• Dist. to nearest LRT Stn</li> <li>• Noise impact from LRT by Dist. to LRT</li> </ul>	-
	Du and Mulley (2007)	England, UK Tyne & Wear light rail	OLS & GWR	House Price	200m	17.1%	<ul style="list-style-type: none"> <li>• House Type,</li> <li>• #Bedroom,</li> </ul>	<ul style="list-style-type: none"> <li>• Local School Indicator,</li> <li>• % unemployed,</li> <li>• % Profession Occupn.</li> </ul>	<ul style="list-style-type: none"> <li>• PT Access</li> <li>• Car Access</li> <li>• Dist. to LRT</li> </ul>	-
	Hess and Almeida, (2007)	Buffalo, NY, USA LRT	OLS Linear	Assessed Property Value	1/4 mile	2 to 5%	<ul style="list-style-type: none"> <li>• Land Area</li> <li>• Age House</li> <li>• #Beds</li> <li>• #Bathrooms</li> <li>• Single Family</li> <li>• #Fire places</li> <li>• Basement</li> </ul>	-	<ul style="list-style-type: none"> <li>• Straight line Dist.</li> <li>• Ped. Dist.</li> </ul>	-
	Golub, et al., (2012)	Phoenix, USA Phoenix LRT	OLS – Log/Log	Ln (Adjusted Sale Price)	200ft	25%	<ul style="list-style-type: none"> <li>• Living size,</li> <li>• Lot size,</li> <li>• Age,</li> <li>• #Patios,</li> <li>• #Bath,</li> <li>• #Floors,</li> <li>• Pool,</li> <li>• TOD Zoning</li> </ul>	-	<ul style="list-style-type: none"> <li>• Dist. to LRT Stn.,</li> <li>• Dist. to LRT Alignment,</li> <li>• Dist. to CBD,</li> <li>• Dist. to Airport</li> </ul>	<ul style="list-style-type: none"> <li>• Time dummies</li> <li>• Prior NEPA,</li> <li>• During NEPA Review,</li> <li>• Planning &amp; Design,</li> <li>• Construction,</li> <li>• Operations</li> </ul>

Table 13 Compilation of academic studies on Metro/Heavy Rail induced HPM value uplift on residential property and land markets

	Author	Location & Transit System	HPM Form	HPM # Obs. (Model R <sup>2</sup> )	Dependent Variable	Explanatory Variables					
						Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Metro / Heavy Rail	Laakso (1992)	Helsinki, Finland Helsinki Metro	OLS Log/ Linear	6732 (0.940)	Ln (Sale price)	250m	3.5% to 6%	<ul style="list-style-type: none"> <li>Ln(Age)</li> <li>Ln(Area)</li> <li>Terrace House</li> <li>Pool</li> <li>Indoor Sports</li> <li>Health Stn</li> <li>Library, Day Care</li> </ul>	<ul style="list-style-type: none"> <li>Ln(%Park)</li> <li>Ln(Income quartile)</li> <li>Dist. to Coast</li> <li>Ln(Dist. to CBD)</li> </ul>	<ul style="list-style-type: none"> <li>Metro Station dummies</li> <li>Feeder Bus Dummies</li> <li>Commuter Rail Dummy</li> <li>Shopping centre Dummy</li> </ul>	<ul style="list-style-type: none"> <li>Transaction time dummies</li> </ul>
	Gatzlaff and Smith (1993)	Miami, USA Heavy Rail/Metro	OLS Linear Log/linear Log/Log	912 (0.72-0.84)	Sale Price	Dist. to metro	Mixed between stations	<ul style="list-style-type: none"> <li>House Area</li> <li>Lot Size</li> <li>Age</li> </ul>	<ul style="list-style-type: none"> <li>Est. House Price Index</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to Metro</li> </ul>	<ul style="list-style-type: none"> <li>Construction announcement dummy</li> </ul>
	Bae et al. (2003)	Seoul, South Korea Heavy Rail KoRail	GLS Log/ Linear	956 (0.9542)	Ln (Sales Price)	400m	0.3% to 2.6%	<ul style="list-style-type: none"> <li>Apart. Size, Age,</li> <li>#Houses block</li> <li>#Parking</li> <li>Heating Type</li> <li>Dist. to Park</li> </ul>	<ul style="list-style-type: none"> <li>Dist. from Han River</li> <li>School District</li> <li>Pop. Density</li> <li>Job Density</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to Subway</li> <li>Dist. to CBD</li> <li>Dist. to Sub centre</li> </ul>	<ul style="list-style-type: none"> <li>Time dummies</li> <li>Sales in 1995</li> <li>Sales in 1997</li> <li>Sales in 2000</li> </ul>
	Yankaya and Celik (2004)	Izmir, Turkey Izmir Metro	OLS Linear Log/linear Log/Log	360 (0.83)	Sale Price	500m	0.7% to 13.7%	<ul style="list-style-type: none"> <li>House size</li> <li>#Apt in Bldg.</li> <li>#Apts. in Floor</li> <li>Age, #Bed</li> <li>#Storey of Bldg.</li> <li>Corner location</li> <li>Parking, Heating</li> </ul>	<ul style="list-style-type: none"> <li>Location</li> <li>Type of ground</li> </ul>	<ul style="list-style-type: none"> <li>Dist to Subway</li> <li>Dist. to Bus</li> <li>Dist to Shop</li> </ul>	-
	Banister (2007)	London, UK , London Metro Jubilee Line	GWR	-	Land & Property Valuations	2000m Access to metro	75%	-	<ul style="list-style-type: none"> <li>Com. &amp; Enviro. amenity</li> <li>Car Ownership</li> <li>Socio. Economic</li> </ul>	<ul style="list-style-type: none"> <li>Access to shops</li> <li>Dist. to School</li> <li>Access to metro</li> </ul>	-
	Medda (2011)	Warsaw, Poland Warsaw Metro	OLS Log/ Linear	1130 (0.696)	Sale Price	1000m	6.7%-7.13%	<ul style="list-style-type: none"> <li>Area,</li> <li>#Rooms</li> <li>#Floors in Bldg.</li> <li>Age, Parking</li> </ul>	<ul style="list-style-type: none"> <li>School District</li> </ul>	<ul style="list-style-type: none"> <li>Dist to Hospital</li> <li>Dist. to Green</li> <li>Metro Catchmt. dummy</li> </ul>	<ul style="list-style-type: none"> <li>Time Dummy for year of sale</li> </ul>

Table 14 Compilation of academic studies on Commuter Rail induced HPM value uplift on residential property and land markets

	Author	Location & Transit System	HPM Form	HPM # Obs. (Model R <sup>2</sup> )	Dependent Variable	Explanatory Variables					
						Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Commuter Rail	Voith (1991)	Pennsylvania & New Jersey, USA Commuter Rail	OLS	571 (0.711)	Property Value	½ mile	6% to 10%	<ul style="list-style-type: none"> <li>• Size</li> <li>• Detached</li> <li>• Age</li> <li>• #Rooms</li> </ul>	<ul style="list-style-type: none"> <li>• %Black Neighbourhood</li> </ul>	<ul style="list-style-type: none"> <li>• Auto Commute</li> <li>• Station</li> <li>• Rail Commute</li> </ul>	-
	Gruen, (1997) Chaney (2005)	Chicago, USA METRA, Commuter Rail	OLS Log/linear	796	Property Value	400m	14.5 to 20%	<ul style="list-style-type: none"> <li>• House Size</li> <li>• Lot Size</li> <li>• #Bath</li> <li>• Age</li> <li>• Furnished</li> <li>• Garage</li> <li>• Fireplace</li> <li>• House Type</li> </ul>	-	<ul style="list-style-type: none"> <li>• Dist. from Station</li> <li>• Dist. from Hwy</li> <li>• Squared Dist. from Station</li> <li>• Squared Dist. from Hwy</li> </ul>	-
	Cervero and Duncan, (2002)	San Diego, USA Commuter Rail	OLS	25923 (0.7)	Sales Price	½ mile	-7.1% to 46.1%	<ul style="list-style-type: none"> <li>• House Size</li> <li>• Lot Size</li> <li>• #Bath</li> <li>• #Bed</li> <li>• Age</li> </ul>	<ul style="list-style-type: none"> <li>• Housing Density</li> <li>• Income</li> <li>• %White Neighbourhood</li> </ul>	<ul style="list-style-type: none"> <li>• ½ Mile Commuter Rail</li> <li>• Dist. to Hwy Ramp</li> <li>• Job Access Hwy</li> <li>• Job Access Transit</li> </ul>	Time Dummies <ul style="list-style-type: none"> <li>• Monthly to reflect different sale times</li> </ul>
	Lochl and Axhausen, (2010)	Zurich, Switzerland, Commuter Rail	OLS, Spatial Autoregressive model, GWR Log/Log	8592 (0.85)	Ln(Rent)	500m	4% to 8%	<ul style="list-style-type: none"> <li>• House Size</li> <li>• Lift</li> <li>• Balcony</li> <li>• #Bath</li> <li>• Age</li> <li>• Furnished</li> <li>• Garage</li> <li>• Fireplace</li> <li>• Single house</li> <li>• View</li> </ul>	<ul style="list-style-type: none"> <li>• Within 100m Autobahn</li> <li>• Air Noise</li> <li>• Job within 1km</li> <li>• Pop. Density per hectare</li> <li>• %Foreigners per Hectare</li> <li>• Local Tax level</li> <li>• Slope</li> </ul>	<ul style="list-style-type: none"> <li>• Dist. to CBD</li> <li>• Car Access time to employment</li> <li>• PT Access to employment</li> <li>• Rail stn. catchment</li> </ul>	Transaction time dummies

## 4.2 Land Market analysis of the Willingness to Pay for Transit Accessibility

Whilst the level of value uplift can differ depending on the nature of the project (as presented in Tables 10-14) among a number of other local factors, the significance of these can be determined by undertaking hedonic price analysis of the land values of commercial, industrial and residential properties with and without transit amenity (Small and Verhoef, 2007). In a meta-analysis of different studies into the impact of rail on land and property values Mohammad et al. (2013) discuss the use of a range of estimation methods to determine the impact of the investment in rail transit on property and land prices. They identified the following methods (with selected articles):

- *Hedonic price modelling (cross section, panel data) (Al-Mosaind et al. 1993)*
- *Geographically Weighted Regression (Du and Mulley, 2006)*
- *Comparison of average property/land values (Sherry, 1999; National Association of Realtors, 2013)*
- *Direct differencing of land values (Fejarang, 1994).*

While dependant on data availability, the use of the time variant panel data hedonic price modelling is likely to be the most effective method for illustrating the impact of transit investment as it changes over different stages of its planning, construction and operation (Agostini and Palmucci, 2008; Bae et al. 2003, Mohammad et al. 2013). If there is insufficient data, or a lack of a comparable investment that has been implemented within a similar region, cross sectional analysis of existing similar systems can demonstrate the value premium that the property and land markets place on in-situ infrastructure (Al-Mosaind et al. 1993; Du and Mulley, 2007; Laakso, 1992; Voith, 1991).

*Journal Paper 3* demonstrates the application of both cross sectional and panel data hedonic price modelling (HPM) methods and the results of this analysis are presented in Table 15. The real accessibility benefit from the investment occurs in the time period from funding commitment to commencement of operations.

*Table 15 Results of the Cross Sectional and Panel Data WTP Analysis from Journal Paper 3*

Relevant Explanatory Variables	Estimated Hedonic Price
<b>Cross Sectional HPM – Explanatory Variables</b>	
<b>R-Code (Elasticity)</b>	<b>0.112 (0.003)***</b>
<b>400m train catchment uplift %</b>	<b>-17.6% (0.017)***</b>
<b>800m train catchment uplift %</b>	<b>-5.1% (0.009)***</b>
<b>1600m train catchment uplift %</b>	<b>-3.2% (0.003)***</b>
<b>Adjusted R-Squared</b>	<b>0.863</b>
<b>Standard Error of Regression</b>	<b>0.254</b>
<b>Panel Data HPM – Explanatory Variables</b>	
<b>400m train catchment uplift %</b>	<b>28% (0.001)***</b>
<b>800m train catchment uplift %</b>	<b>13% (0.001)***</b>
<b>1600m train catchment uplift %</b>	<b>8% (0.001)***</b>
<b>Adjusted R-Squared</b>	<b>0.8720</b>
<b>Standard Error of Regression</b>	<b>0.280</b>
<p><b>Notes: Figures in brackets report parameter standard errors. Significance at the 0.01 level is indicated by three asterisks, significance at the 0.05 level is indicated by two asterisks, and significance at the 0.10 level is indicated by a single asterisk.</b></p>	

The determination of the price premium in property and land markets forms the basis for the alternative funding framework, and is critical for communicating the benefits to transit infrastructure stakeholders. It is necessary to set up a planning control area to facilitate a strategic assessment district to be established over the corridors and centres that are to receive transit investment and facilitate a re-urbanisation assessment. This is vital for integrated corridor planning and for the assessment of the value capture mechanisms to be geographically bounded and the financial analysis feasible.

The financial assessment of the economic monetisation of accessibility benefit into the catchment land markets and the methods to capture these benefits is undertaken in Journal Paper 4.

## **5 LAND MARKET FINANCIAL IMPACTS INDUCED BY THE INVESTMENT IN URBAN TRANSIT**

The increased economic ‘Willingness to Pay’ for transit accessibility demonstrated in *Journal Paper 3* has direct financial impacts on the value of the land and property markets it serves. These increases in land and property market values have financial impacts on the existing land and property market Commonwealth, state and local government taxes and charges.

### **5.1 The Use of Land and Property Taxes to Fund Transit**

The Australian Government Treasury stated in their 2010 review of the Australian tax system (AGT, 2009) that taxes affect the costs business and consumers must pay for their consumption or operation, and the efficiency cost of the individual tax depends on whether people and firms change their behaviour in response to a change in its price. The AGT (2009) state that land value based taxes are efficient, as the tax effectively reduces the value of land but does not affect how it is used or how much is used. Norregaard, in his 2013 report for the International Monetary Fund (IMF) states that the taxes on land and property are considered to be underutilised internationally, even though international treasuries and economists emphasise their virtues by suggesting that they are economically progressive due to their unavailability and immobility, long term revenue stability, fairness, low efficiency costs and benign impact on regional growth (by not affecting labour supply, investment and innovation for different regions).

Immovable property taxes are a central tenet to the overall revenue streams for government’s internationally (OECD GFS, 2013). The defining aspect of property taxes is their role in funding the lower levels of government, which is the case in Australia where local government is almost 100 percent funded through immovable property taxes (i.e. property rates). Norregaard (2013) suggests that this is a natural role for property taxes as property values to some degree reflect services supplied by local governments, strengthening the argument that it is reasonable for this stable and predictable revenue base to be tapped into to finance local activities such as the investment in transit and re-urbanisation.

Thus land taxes act as a price for local infrastructure and services, with individuals choosing locations that best offer the services and utilities they are willing to pay for (i.e. the Tiebout effect) (Tiebout, 1956).

Any transit project financial mechanism that seeks to utilise the induced tax benefits should take into account the tax's role in primarily funding regional and local government infrastructure, and support the self-selecting nature of property markets to optimise the use of the land for the highest and best purpose given the regional limits to willingness to pay for the utility created. *Journal Paper 4* presents the underlying theory and financial analysis methods required to understand the passive financial benefits generated in the land and property markets from the investment in transit and how to capture these benefits using Tax Increment Financing (TIF).

To demonstrate the TIF theory, the *Journal Paper 3* hedonic price modelling case study of the Mandurah Rail Line is extended in *Journal Paper 4* to demonstrate the calculation of the passive impacts on the existing land and property taxes, rates and charges. *Journal Paper 4* proposes a TIF framework to capture the increases in the existing taxes, rates and charges to defray the cost of the Mandurah rail line.

The analysis results from *Journal Paper 4* demonstrate that even in a country such as Australia that does not have a history of using TIF, it could adopt the TIF framework to use it to defray the cost of the investment in transit. The capture of the induced passive tax benefits from the investment in transit is however, only part of the suite of alternative funding mechanisms available. *Journal Paper 5* presents a framework to capture passive and active alternative funding mechanisms. These mechanisms are financially and economically assessed so that the induced active land and property market investment around the transit infrastructure can capture more funds to defray the cost of the investment in transit.

*Journal Paper 5* collates all the findings from all the research conducted as part of the thesis and synthesises it into a comprehensive alternative funding framework for the investment in integrated transit and urban development projects.

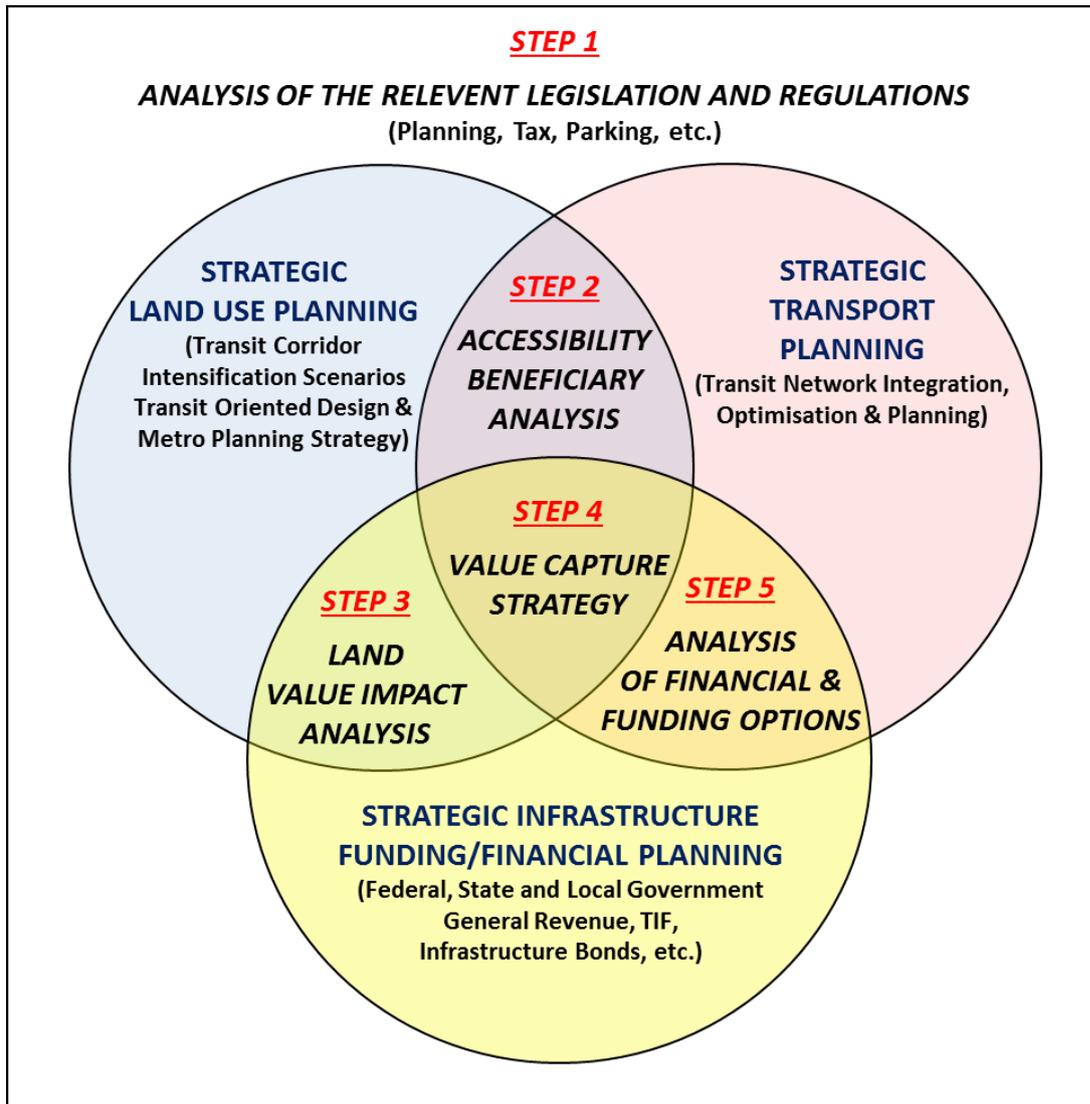
## **6 ALTERNATIVE FUNDING FRAMEWORK FOR INTEGRATED TRANSIT AND URBAN DEVELOPMENT PROJECTS IN CAR DEPENDENT CITIES**

*Journal Paper 5* proposes a theoretical framework to integrate all the city land use and transport policy and planning developed in *Book Chapter 1 and Journal Papers 2 and 3* and project beneficiary analysis (*Journal Paper 4*) with project funding into a single model.

This model is designed to deliver a value capture model to reduce the causes of car dependence in cities. The Value Capture (VC) framework is a five-step assessment process that integrates strategic transport planning, land use planning and infrastructure planning.

- Step 1. Assessment of the relevant alternative funding legislation and regulations*
- Step 2. Accessibility beneficiary analysis*
- Step 3. Land and property market analysis of 'willingness to pay' for transit accessibility*
- Step 4. Analysis of the transit project value capture mechanisms and preparation of the integrated land use and transit project value proposition*
- Step 5. Procurement and implementation strategy through hypothecated transit fund*

The VC framework can also be presented graphically. Figure 11 illustrates the interactions between framework's assessment steps and the associated disciplines required to analyse the value created by the investment in transit.



*Figure 11 Conceptual value capture analysis framework for the integration of strategic transit land use, transport and funding/financial planning*

A review of VC mechanisms implemented internationally is presented in Table 16. Whilst there is a broad array of mechanisms available, not all are suitable for all projects. The Mandurah Line case study from *Journal Papers 3 and 4* is further developed in *Journal Paper 5*, whereby the VC framework was applied to the rail line's pedestrian catchments.

*Journal Paper 5* discusses the benefits of costs of each method in Table 16 and presents the methodology applied for this research.

Table 16 Review of the international value capture mechanisms implementation

	Value Capture Mechanisms	Transit Project location (& transit mode)	Author	Notes
Government Property (Passive)	Sale of surplus property /development rights/air rights	<ul style="list-style-type: none"> <li>• Hong Kong, China (Metro)</li> <li>• Washington DC, USA (Metro)</li> <li>• Sydney, Australia (Heavy Rail)</li> </ul>	<ul style="list-style-type: none"> <li>• MTRC</li> <li>• WMATA</li> <li>• RailCorp</li> </ul>	Used when governments hold their property and receive a benefit when property values increase as improved transit accessibility is monetised
	Sale of naming rights to stations	<ul style="list-style-type: none"> <li>• New York, USA</li> <li>• Philadelphia, USA</li> </ul>	<ul style="list-style-type: none"> <li>• MTA</li> <li>• SEPTA</li> </ul>	
Government Property (Active)	Direct development of government property	<ul style="list-style-type: none"> <li>• Hong Kong, China (Metro)</li> </ul>	<ul style="list-style-type: none"> <li>• MTRC</li> </ul>	Mechanisms to capture increases in land values and economic prosperity that positively impact the value of State and Local Government property and land from transit
	Joint development	<ul style="list-style-type: none"> <li>• Tokyo, Japan (Metro)</li> <li>• Hong Kong, China (Metro)</li> <li>• London, UK (Metro)</li> </ul>	<ul style="list-style-type: none"> <li>• Tokyo Metro</li> <li>• MTRC</li> <li>• Crossrail Stns.- Canary Wharf &amp; Heathrow Airport</li> </ul>	
	Returns on government parking	<ul style="list-style-type: none"> <li>• Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• Portland Streetcar Inc.</li> </ul>	
	Government property leasing	<ul style="list-style-type: none"> <li>• Philadelphia (USA)</li> </ul>	<ul style="list-style-type: none"> <li>• SEPTA</li> </ul>	
	Advertising revenue	International implementation		
Non-Government (Passive)	Tax Increment Financing & additional taxes hypothecated to transit			Primarily focussed on increases in existing ad valorem taxes that result from increases in property and land value
	<ul style="list-style-type: none"> <li>• State Transfer Duty/Sales Taxes</li> </ul>	<ul style="list-style-type: none"> <li>• Atlanta, USA (Heavy Rail)</li> <li>• Dallas, USA (LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• MARTA</li> <li>• DART</li> </ul>	
	<ul style="list-style-type: none"> <li>• State Land / Property Tax</li> </ul>	<ul style="list-style-type: none"> <li>• Dallas, USA (LRT)</li> <li>• Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• DART</li> <li>• Portland Streetcar Inc.</li> </ul>	
	<ul style="list-style-type: none"> <li>• Local Government Rates/Taxes</li> </ul>	<ul style="list-style-type: none"> <li>• Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• Portland Streetcar Inc.</li> </ul>	
Non-Government (Active)	Benefit Area levies (or Special Assessment Districts) through State or Local Government Infrastructure cost recovery	<ul style="list-style-type: none"> <li>• London, UK (Metro)</li> <li>• Seattle, USA (Streetcar/LRT)</li> <li>• Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• Crossrail Business Rate Supplement</li> <li>• Seattle Streetcar Inc.</li> <li>• Portland Streetcar Inc.</li> </ul>	Mechanisms to capture all or part of the increases in property and land values and economic prosperity that benefit non-government land and business owners
	Differential Rates, Specified Area Rates, Service charges	<ul style="list-style-type: none"> <li>• Atlanta, USA (Heavy Rail)</li> <li>• Dallas, USA (LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• MARTA</li> <li>• DART</li> </ul>	
	Region wide transport levy	<ul style="list-style-type: none"> <li>• Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• Portland Streetcar Inc.</li> </ul>	
	Existing Infrastructure Tax Hypothecation	<ul style="list-style-type: none"> <li>• London, UK (Metro)</li> <li>• Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>• Crossrail Community Infrastructure Levy</li> <li>• Portland Streetcar Inc.</li> </ul>	
	Developer contributions	International implementation		
	Parking Levies / Bonds			
	<ul style="list-style-type: none"> <li>• Localised development Parking levies</li> <li>• Increased cash in lieu</li> <li>• Metropolitan Wide Parking Levy</li> </ul>	<ul style="list-style-type: none"> <li>• Portland, USA (Streetcar/LRT)</li> <li>• San Francisco, USA</li> </ul>	<ul style="list-style-type: none"> <li>• Portland Streetcar Inc.</li> <li>• SFMTA</li> </ul>	
	<ul style="list-style-type: none"> <li>• Density bonuses</li> </ul>	<ul style="list-style-type: none"> <li>• New York, USA (metro)</li> <li>• Curitiba, Brazil</li> </ul>	<ul style="list-style-type: none"> <li>• NYC Department of Planning</li> <li>• Rede Integrada de Transporte</li> </ul>	

Prior to the implementation of the value capture mechanisms into a transit project's quantitative Value Proposition, each mechanism should be evaluated against a qualitative policy evaluation framework (such as the one presented in Table 17). Externalities from poorly implemented funding mechanisms arise where there are divergences between social and private costs and are an example of a circumstance where the market acting alone will deliver poor outcomes (Allen Consulting Group, 2003). Funding options that allow the full economic, social and environmental costs to be accurately reflected in prices will, in general, be those that least distort economic activity and lead to the best community outcomes (Allen Consulting Group, 2003; TCRP, 2009; Litman, 2013).

*Table 17 Value Capture Mechanism Evaluation Criteria (Center for Transportation Studies, 2009, Allen Consulting Group, 2003; TCRP Report 129, 2009)*

Evaluation Criteria	Explanatory notes
<b>Revenue Yield</b>	Whether the mechanism generates adequate yield for the cost of implementation, and if the mechanism is stable over time.
<b>Cost Effectiveness</b>	Effectiveness is the central requirement of a funding approach to mobilise sufficient funds for investment in infrastructure, and to do so in a timely manner.
<b>Economic Efficiency</b>	Allocative efficiency is a longstanding concern of governments and measures which distort economic decision making with regard to investment or consumption patterns can lead to outcomes that shrink overall wellbeing.
<b>Equity</b>	Social justice concerns about sharing the burden of revenue raising fairly between individuals who have differing abilities to pay: it is generally deemed fair if people in similar economic circumstances are treated similarly (horizontal equity) and the amount paid varies in relation to the individual's economic circumstances (vertical equity).
<b>Compliance Costs, Certainty &amp; Transparency</b>	Low compliance costs, and certainty is crucial in effective planning for businesses, with transparency being a key means of reducing uncertainty as it facilitates an understanding of the process and issues that need to be dealt with.
<b>Stakeholder Support</b>	Ultimately every funding approach requires making someone pay and governments are well aware this inevitably involves discontent from some quarter in the community, though this does not automatically preclude widespread support for a measure with the question of support often more about reasonableness and the outcome of a fair process, or trust in a fair decision maker and a 'level playing field' or perception thereof on the part of the development community is critical. Any suggestion that one group or project can avoid such costs while another has to pay will be rejected.
<b>Technical Feasibility</b>	New technology is used in the collection of transport related taxes and revenue handling, and whilst these can be effective and accurate in allocation and collection of costs they can add another layer of complexity to traditional methods of funding collection.

The financial and economic analysis was entered into an evaluation matrix that allowed the financial revenue streams of each of the mechanisms, as well as the economic evaluation of their performance, to be analysed in the same table. This is presented in Table 18 and forms the key analysis method for the VC framework.

*Table 18 Unweighted Transit Project Value Capture Mechanism Analysis Matrix for the Mandurah Rail Line Value Capture Analysis*

	Value Capture Mechanisms	Revenue Yield Present Value (\$M AUD2013) for 2001-2031				Qualitative Indicators (Evaluation Criteria -3 to 3)						
		Federal Govt \$(M)	State Govt \$(M)	Local Govt \$(M)	Revenue Certainty	Cost Effectiveness	Economic Efficiency	Equity	Compliance costs, & transparency	Stakeholder support	Technical Feasibility	Total Qualitative Score
<i>Govt. Property (Passive)</i>	Sale of surplus property /development air rights	-	-	-	1	1	3	3	3	3	2	<b>16</b>
	Sale of naming rights to stations	-	-	-	1	3	3	3	2	3	3	<b>18</b>
<i>Govt. Property (Active)</i>	Direct development of Govt. property	-	-	-	2	1	1	2	1	3	1	<b>11</b>
	Joint development	-	-	-	2	3	3	3	1	3	3	<b>18</b>
	Returns on government parking	-	-	-	3	3	3	1	1	2	2	<b>15</b>
	Government property leasing	-	-	-	2	2	2	0	1	3	0	<b>10</b>
	Advertising revenue	-	-	-	2	3	3	3	3	3	3	<b>20</b>
<i>Non-Govt. (Passive)</i>	Federal Govt. Capital Gains Tax	\$102	-	-	2	3	3	0	-3	0	-3	<b>2</b>
	Federal Govt. Goods & Services Tax	\$36	-	-	2	3	3	0	-3	0	-3	<b>2</b>
	State Transfer Duty/Sales Taxes	-	\$106	-	2	3	2	1	2	1	2	<b>13</b>
	State Land / Property Tax	-	\$150	-	2	3	3	2	2	2	2	<b>16</b>
	Metropolitan Region Improvement Tax		\$12	-	3	2	2	2	3	2	2	<b>15</b>
	Local Government Rates/Taxes	-	-	\$36	2	3	3	2	2	2	2	<b>16</b>
<i>Non-Govt. (Active)</i>	Benefit Area levies State or Local Government Infrastructure cost recovery • Differential Rates, Specified Area Rates, Service charges	-	-	\$218	3	3	-1	1	0	-2	2	<b>6</b>
	Corridor transit levy	-	-	\$3	3	3	2	1	1	1	1	<b>12</b>
	Developer contributions	-	-	\$0	3	2	-3	0	1	1	2	<b>7</b>
	Parking Levies / Bonds • Development Parking levies, Increased cash in lieu, Regional Parking Levy	-	-	\$65	2	3	3	2	2	2	2	<b>16</b>
	Density bonuses	-	-	\$29	2	3	3	3	2	2	2	<b>17</b>
<b>Total Revenue for each tier of government \$(M)</b>		<b>\$138</b>	<b>\$268</b>	<b>\$351</b>								
<b>Notes:</b>												
1. Not all the mechanisms were applicable to the Mandurah rail line and hence were not financially assessed, though they were all qualitatively assessed for application suitability. Lack of information on the nature and amount of Government property in the corridor inhibited this assessment, though this could be rectified for future assessments of the corridor.												
2. Qualitative Indicators Evaluation Criteria 3 (Strong Performance), 1 (Modest Performance), 0 (Marginal Performance), -1 (Moderately Poor Performance), -3 (Very Poor Performance)												

Table 18 highlights not only the financial revenue generated by a range of passive and active value capture mechanisms, but it analyses all the non-monetary benefits and costs incurred from each of the mechanisms. This monetary and non-monetary evaluation matrix enables the evaluation of all the potential sources of revenue, and assists in the design of an optimal value capture strategy.

In the case of the Mandurah rail line, there was limited government property development potential included in the analysis presented in Table 18, but if there were some appropriate government land holdings, the qualitative evaluation highlights that these are desirable to deliver the optimum land use and transit integration outcomes.

Table 18 illustrates the multijurisdictional nature of the passive value created in the private sector land markets from the investment in transit, with the most significant revenue streams attributed to the commonwealth and state governments, with only a small amount going to local government. The non-monetary evaluation highlights the technical issues with the securing the commonwealth tax revenue, and the relative ease of securing the state and local government taxes and charges. Viewing these passive revenue streams in this light enables the government jurisdictions to understand their net benefit position from the investment in transit and facilitates a more open discussion regarding the level of contribution to the project.

The active mechanisms, and revenue streams presented in Table 18, highlight the potential role of local government in partially defraying some of the land side the costs from the investment in transit. This achieved by focussing on understanding the uplift benefits the investment will bring to the surrounding land markets and explaining them in such a way such that the active mechanisms design is supported by both the existing residents and business and the development community. The levy and charges directed at developers were rated lower in the qualitative evaluations compared to the incentive based mechanisms as they can drive key development away from the station precincts if they are not designed and presents appropriately to the development market.

## 7 SUMMARY OF RESULTS

This thesis by publication present the importance and the benefits of bringing metropolitan region strategic land use and transit planning together with strategic funding mechanisms to enable implementation of transit infrastructure and re-urbanisation. This section summarises the key findings of research thesis and its publications.

*Journal Paper 1* demonstrates that transit service kms/capita and urban densification are the main measures to reduce car use per capita. The Structural Equation Modelling (SEM) elasticities for the impact of transit urban density as well as the provision of additional road capacity on car use per capita for 26 global cities is presented in Table 19.

*Table 19 Log-log structural equation models: direct and indirect coefficient estimates*

	<i>Regions SEM</i>		
<i>Independent Variable</i>	<i>Direct Coefficient</i>	<i>Indirect Coefficient</i>	<i>Total Coefficient</i>
<b>Ln PT passenger km/cap</b>	-0.1	-	-0.1
<b>Ln PT Service Km/Capita</b>	-	-0.157	-0.157
<b>Ln Rd Length/Capita</b>	-	0.023	0.023
<b>Ln Urban Density</b>	-0.151	-0.046	-0.197

These elasticities demonstrate that economically the investment in transit and urban densification are the main measures to reduce car use per capita in cities, whereas the investment in road length per capita actually increases it. These results formed the quantitative basis and justification for policy discussions in *Book Chapter 1* and *Journal Paper 2*.

*Journal Paper 3* analyses the ‘willingness to pay’ for transit and urban densification in a car dependent city. This panel data analysis demonstrates the increases in the willingness to pay for transit over the period of the investment in the Mandurah rail line. The land market uplift for the 400m, 800m and 1600m pedestrian catchments around the stations over a 10-year period is illustrated in Figure 12. In addition to the increased willingness to pay for transit accessibility, the hedonic price modelling analysis in *Journal Paper 3*

produced a land market price elasticity for urban density of 0.112, which correlates to a 0.112 increase in land value for each percentage increase in urban density. This is presented in Table 20.

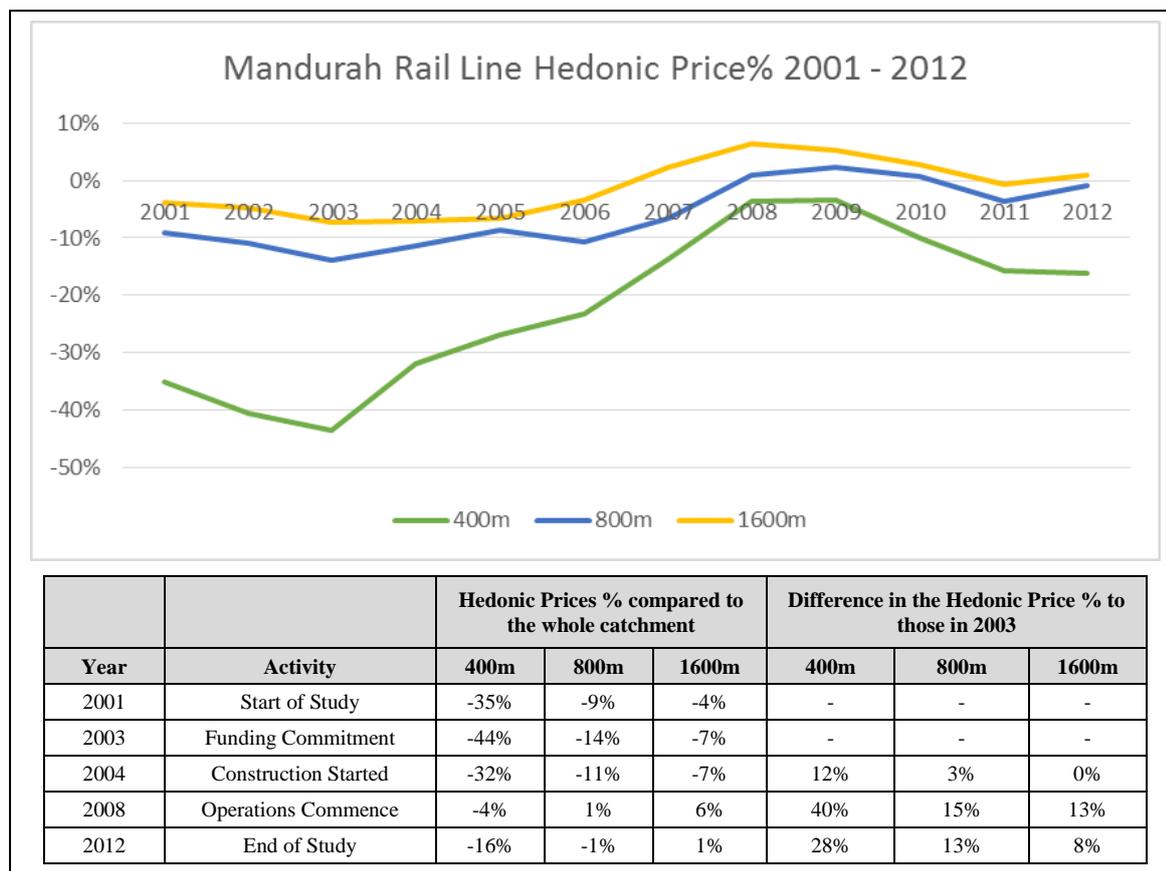


Figure 12 (Top) Mandurah Rail line residential panel data hedonic price (2001-2012)  
(Bottom) Absolute and relative Hedonic price difference for the Mandurah Rail line's catchments (2001-2012)

Table 20 Possible future residential density increase scenario - Mandurah Rail Line

Existing R-Code	Possible future R-Code Scenario	% Change in R-Code	Catchment R-Code Elasticity	R-Code Scenario Uplift impact on the land value
20	40	100%	0.112	11.2%
20	60	200%	0.112	22.4%
20	80	300%	0.112	33.6%
20	100	400%	0.112	44.8%

*Journal Paper 4* financially analysed the impacts of these increases in the land and property markets in Perth, Western Australia from the investment in the Mandurah rail transit line and the potential for intensification of the catchments surrounding the transit stations. The focus of the analysis was on the impacts of the existing land and property market taxes and charges, and to propose a transit tax increment financing framework. The results of this analysis are presented in Table 21.

*Table 21 Potential impacts on the total tax revenue and a potential State Government based TTIF (Land Tax, MRIT, Stamp duty) with scenario for increases in catchment densities.*

Possible R-Code Scenario	% Change in R-Code	R-Code Scenario Uplift & Transit impact in brackets	Combined Transit & R-Code Uplift factor	Net Total tax increase over <u>No Transit Base Case</u> (\$AUD 2007)	Net tax increase as % Capex (\$1,184M AUD 2007)	TTIF revenue over <u>No Transit Base Case</u> (\$AUD 2007)	TTIF revenue as % Capex (\$1,184M AUD 2007)
20 (current)	0%	0% (+28%)	28%	\$506M	43%	\$227M	19%
40	100%	11.2% (+28%)	39%	\$616M	52%	\$304M	26%
60	200%	22.4% (+28%)	50%	\$739M	62%	\$390M	33%
80	300%	33.6% (+28%)	62%	\$866M	73%	\$476M	40%
100	400%	44.8% (+28%)	73%	\$1005M	85%	\$563M	48%

*Journal Paper 5* proposed a value capture framework that in five steps can determine the value capture revenue to fund a new transit system. The Mandurah rail line case study demonstrated that substantial funds could have been generated to defray the cost of the investment using the government mechanisms currently available. The reality is that most, if not all, of the funding could have been obtained by value capture mechanisms if appropriate transit oriented development had been enabled within the station precincts, with many more people therefore having easy access to the transit line.

The results of the econometric and financial analysis conducted in *Journal Paper 5* on car dependent cities and value capture using the case study of the introduction of transit into a car dependent city can be summarised as follows:

- The value uplift from the investment in the Mandurah rail line in the residential land markets surrounding the stations was 28% to 40% when compared to non-transit areas.

- The passive value capture results from the analysis of the Mandurah rail line show that around 20% of the cost of the rail line could have been covered by passive increases in State based taxes (which increases to 34% when including taxes from all tiers of government). However, this state based increase in revenue stream increases to 44% of the cost of the project if the station land uses were intensified (or 78% with all taxes).
- The active value capture results for the Mandurah line show an additional 24% of revenue could have been captured with active mechanisms using existing land market conditions, though if the land market densities were increased this could have been over 50% of the cost of the project.

The results from *Journal Paper 5* show that a significant proportion of the funding could have been raised from value capture on the Mandurah rail line. This is higher than has been expected in the past by transport planners in car dependent cities. The revenue generated from these mechanisms highlights the importance of integration of land uses and transport systems, as the base case without increased development generated less than half that of the intensification scenario.

## **8 CONCLUSIONS AND RECOMMENDATIONS**

This ‘thesis by publication’ has been generated through six publications, with each one developing key parts of the overall framework to capture the value created by integrated transit and urban development in car dependent cities.

As a basis for the research, *Journal Paper 1* econometrically analysed the causes of car dependence in 26 global cities in the post war period (1960-2000). The levels of urban density and public transport provision and patronage were revealed to be key causes of car dependence, with the direct implication that they stem or reduce car dependence in global cities. Therefore, these key urban characteristics have to be addressed by city planners and policies contemplating a reduction in automobile dependence.

The next step in the thesis was to understand the urban development and transport planning/policies that need to be put in place to enable the changes in urban development (*Book Chapter 1*) and urban transit provision in car dependent cities (*Journal Paper 2*). *Journal Paper 3* quantitatively modelled the economic willingness to pay for the provision of urban density and transit accessibility, and this formed the basis for the research’s quantitative financial analysis.

The financial benefits of increased urban density and transit accessibility in car dependent cities land and property markets were analysed in *Journal Paper 4*, and developed into a Tax Increment Financing (TIF) model for implementation in car dependent cities internationally.

All the research conducted to this stage was collated and modelled in *Journal Paper 5*, which proposes a Value Capture Framework to quantify and develop mechanisms to capture the benefit of integrated urban densification and transit.

### **8.1 Revisiting the Research Questions, Aims and Objectives**

The overarching research question this research ‘PhD by publication’ was seeking to address was:

***“Can land and property market value capture fund urban transit in car dependent cities globally?”***

The culmination of all the research throughout the PhD is documented in *Journal Paper 5* which is designed to address the overarching research question, by developing a quantitative and qualitative research framework for transit and urban densification. The case study of the Mandurah rail line illustrates that when transit and urban densification are integrated around transit stations the passive and active value capture mechanism revenues are sufficient (over a 30-year period in real terms) to pay for the infrastructure investment. This is an unexpected result with great significance for cities seeking to invest in transit to reduce the dependence on cars for their urban mobility.

Table 22 illustrates how each of the research aims is addressed by the research publications.

*Table 22 Correlation between the research aims and the individual publications*

	<b>Research Aim</b>	<b>Publication</b>
<i>Research Aim 1</i>	Develop a universal econometric model to determine the causes of car dependence in global cities & how it has changed in the post war car dominated period (1960-2000)	<i>Journal Paper 1</i> The urban transport problem and the rise of car dependence: Analysis of 26 Global Cities (1960 – 2000)
<i>Research Aim 2</i>	Qualitatively assess the role of urban transit and urban redevelopment in policy and planning to reduce the causes of car dependence	<i>Journal Paper 2</i> Why Fast Trains Work: An assessment of a fast regional rail system in Perth, Australia <i>Book Chapter 1</i> Urban Transport and Sustainable Development
<i>Research Aim 3</i>	Analyse the economic willingness to pay for urban transit accessibility and urban redevelopment in the land markets of car dependent cities	<i>Journal 3</i> Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia
<i>Research Aim 4</i>	quantify the financial value created by integrated urban transit and urban redevelopment in car dependent cities	<i>Journal 4</i> Tax Increment Financing framework for integrated transit and urban renewal projects in car dependent cities
<i>Research Aim 5</i>	develop a financial value capture framework for integrated urban transit and urban redevelopment to stem car dependence in global cities	<i>Journal 5</i> Framework for Land Value Capture from the investment in transit in car dependent cities

The research objectives were addressed by each of the publications in a more broadly, whereby each research objective is answered by components of several papers. The connections between research objectives and publications is illustrated in Figure 11 below.

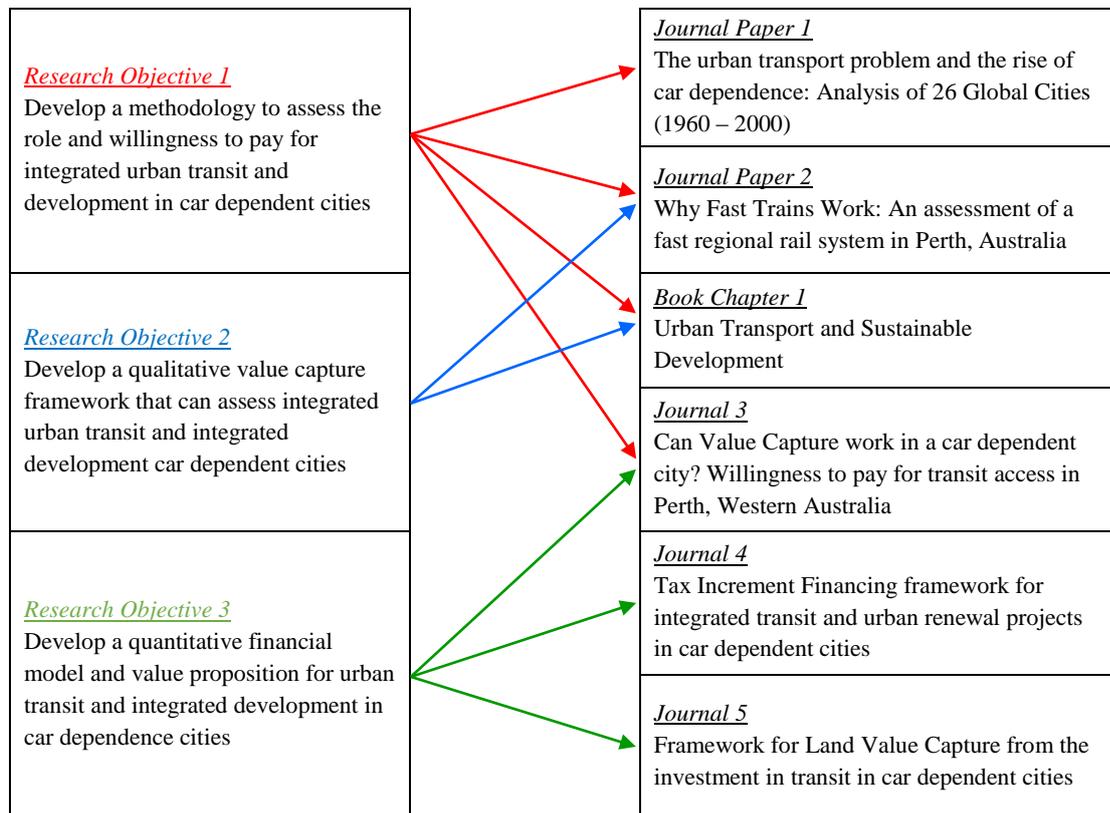


Figure 13 Connections between research objectives and publications

## 8.2 Implications for Integrated Land Use and Transport Project Assessment

### 8.2.1 Project Economic Assessment

The key economic method that needs to be applied to the assessment of integrated transit and land development projects is to undertake ‘Willingness to Pay’ analysis of the existing land markets. This facilitates an understanding of the land market response to increases in urban density and the provision of transit. This analysis forms the basis for the project beneficiary modelling, and alternative funding modelling.

### 8.2.2 Project Funding Assessment

The financial analysis of the land and property market impacts from the investment in integrated urban development and transit are vital for partially (or in some cases wholly) capturing the benefits created so they can be entered into the project value proposition.

The value capture framework has significant implications for governments seeking to fund projects as it has been demonstrated that the different tiers of government (commonwealth, state and local) and the private sector (land and property owners as well as developers) can both passively and actively make a large contribution to transit project funding, even in car dependent cities like Perth.

## 8.3 Recommendations for Further Work

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 build on the existing research and datasets collected throughout the PhD. Suggested future research includes the following topics:

### Future Research Question 1

What is the impact of freeway investment on residential, commercial, and industrial land markets in car dependent cities? A case study of Perth, Western Australia from 2001-2012?

- This research into the land market benefits of residential, commercial, and industrial land markets from non-transit infrastructure investment builds on the analysis conducted in *Journal Paper 3*. This research enables the analysis of the alternative ‘non-user based charging’ funding models for economically generative investments in freight-based corridors and freeways.

### Future Research Question 2

What are the opportunities, costs and potential value of viewing rail transit park-and-ride for urban redevelopment?

- Park-and-ride has long been one of the key inhibiting factors stopping transit oriented development occurring near transit stations as outlined in *Book Chapter 1*. This research would quantify all the costs and benefits of park-and-ride to develop a true

integration benefit analysis model for transit oriented development to replace park-and-ride bays.

*Future Research Question 3*

What is the willingness to pay for differing levels of transit accessibility in the world's largest tram city, Melbourne, Australia?

- This analysis builds on the 'willingness to pay' for transit access in *Journal Paper 3* and would form the basis for other Australian and international cities to use as the basis for their LRT/Tramways funding modelling.

*Future Research Question 4*

What is causing 'Peak Car Use' in car dependent cities? Econometric analysis of Australian city's urban and transport systems since 1970.

- This analysis of Australia's car dependent cities would analyse the causes of peaking of car use per capita using Structural Equation Modelling (as applied in *Journal Paper 1*), and look at the effect of peak car use on the city's transport and land use investment opportunities.

*Future Research Question 4*

What are the implications of 'Peak Car Use' and the rise of car fuel efficiency on traditional funding models of Australian national transport infrastructure?

- This research would analyse the impact of peak car use on the existing national traditional funding for transport infrastructure (fuel excise, for example), and how this funding gap can be filled with land based alternative funding methods (building on the analysis in *Journal Paper 5*).

There would also be a lot of value in using the framework to analyse the potential for value capture in many other cities, especially car dependent cities similar to Perth. One such study is proposed for Melbourne which as well as substantial areas of car dependent suburbs has a large urban rail network and the world's largest tram system; thus the potential for value capture funding of extensions to these transit systems can be estimated from the land value differences in the existing transit corridors.

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**THE ROLE OF URBAN FORM AND TRANSIT IN CITY CAR DEPENDENCE:  
ANALYSIS OF 26 GLOBAL CITIES FROM 1960 - 2000**

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**Keywords:** Transit Planning, Urban Density, Car Dependence

**Abstract**

Car dependence is in decline in most developed cities, but its cause is still unclear as cities struggle with priorities in urban form and transport infrastructure. This paper draws conclusions from analysis of data in 26 cities over the last 40 years of the 20<sup>th</sup> century. Statistical modelling techniques are applied to urban transport and urban form data, while examining the influence of region, city archetype and individual fixed effects. Structural equation modelling is employed to address causation and understand the direct and indirect effects of selected parameters on per capita vehicle kilometres travelled (VKT). Findings suggest that, while location effects are important, transit service levels and urban density play a significant part in determining urban car use per capita, and causality does flow from these factors towards a city's levels of private vehicle travel as well as the level of the provision of road capacity.

**1. Introduction**

Increases in passenger car traffic per capita have major and well-documented environmental, social and economic impacts on urban function, form and liveability (Boarnet and Sarmiento, 1998; Coevering and Schwanen, 2006; Giuliano and Dargay, 2006; Hong et al., 2014), and this has global significance (IPCC, 2013). Reducing car dependence requires an understanding of its causes.

'Car dependence', or automobile dependence, was first coined as a term by Newman and Kenworthy (1989) based on a range of transport and land use parameters from 32 cities in their

Global Cities Database. The historical evolution of this was explained by Newman and Kenworthy (1999) in terms of the 'Walking City' (pre-history to 1850s), the 'Transit City' (1850s to 1950s) and the 'Automobile City' (from 1950s). Extensions to the Global Cities Database (Kenworthy and Laube, 1999; 2003) documented significant differences in car use between cities and suggested that factors like transit services and urban density were critical to the control of growth in car use (Kenworthy, 2010). However, the historical analysis of car use trends in the Global Cities Database did not distinguish directions of causality and the magnitudes of effect, and hence there is considerable dissension about the role of factors such as culture, economics, climate, transport infrastructure and urban form (Kirwan, 1992; Breheny, 1995; Boarnet and Crane, 2001; Mindali, et al, 2004; Coevering and Schwanen, 2006; Gordon and Richardson, 2007; Mees, 2010;).

This paper seeks to resolve many of these issues by analysing a reliable set of data in the Global Cities Database for 26 cities covering the period 1960 to 2000. Data on cities worldwide since 2000 suggests that VKT per capita has peaked, especially in developed cities (Goodwin and Van Dender, 2013; Metz, 2013; Newman and Kenworthy, 2011). If the causes of car dependence, and of peak car use, can be better understood, this will help cities – particularly those in the developing world – to reduce their traffic (IPCC, 2013; Metz, 2013; Zegras, 2010).

This paper examines transport and urban form parameters, as well as regional, archetypal and city fixed effects, in order to explain car dependence and investigate whether there is association, or causation between parameters related to private vehicle travel. This is achieved by defining the changes in the level of urban car dependence from the Global Cities Database, and then econometrically modelling the impact of urban density, transit service levels and other factors on the generation of passenger VKT per capita from 1960 to 2000, using data on 26 cities in the USA, Canada, Western Europe and Australia. In addition to investigating temporal and regional differences, the impact of different city typologies or "archetypes" developed by

Thomson (1977) is examined. The global cities database is unique for this task as there is nowhere else that one can find such a time series of data to work with which has been developed using the same definitions and methods spanning 40 years from 1960 to 2000. If a researcher tried to develop these data today for 1960, 1970 or even 1980 there is a very large probability that it would simply be impossible because the data have long since ceased to exist in government repositories.

The city-scale level of the data employed and their geographical and temporal variation removes the possibility of the assessment being susceptible to residential self-selection in the analysis as raised by the work of Cao et al., (2007) and Mokhtarian and Cao, (2008). This paper also presents a structural equation model as a series of equations to represent the complex relationships between the urban form and transport parameters used.

## **2. Research Theory**

### ***2.1. Econometric studies into drivers of VKT***

Consistent with traditional urban location theory, access to basic employment prompts the formation of households and increases dwelling densities, and this increased demand for access to employment in dense city fabrics is associated with lower VKT per capita (Alonso, 1964; Muth, 1969). Traditional transport theory also suggests that the provision of transport at lowest generalised cost (including time savings) establishes the city form and function (Levinson and Kumar, 1997; Newman and Kenworthy, 1989; Malpezzi, 1999; Jacobs, 1961; Marchetti, 1994). Both urban form and transport are important and linked, but understanding these linkages requires statistical analysis.

Table 1 presents a selection of nine econometric and policy research papers investigating VKT in cities, identifying the explanatory variables used and the econometric methods applied to analyse how urban structure and urban form generate VKT per capita. The main econometric

methods applied in these papers are ordinary least squares (OLS) regression, multinomial logit and probit modelling (MNL and probit), structural equation modelling (SEM), and mobility equations.

The analysis of Sydney, Australia by Corpuz, McCabe and Ryszawa (2006) found that the car ownership rate was the most important factor increasing car use per capita, whereas the locational land use mix was the most important factor decreasing car use. Cameron, Kenworthy and Lyons (2003) added that, as well as these factors, city structure was critical in determining car use. The analysis by Boarnet and Crane (2001) showed mixed results, noting some urban design factors that could explain car use, while cautioning against using the findings to infer causality.

Cervero and Kockelman's (1997) study of San Francisco again found a positive relationship between car ownership and car use and a large negative relationship between car use and both transit provision and land use diversity, which is consistent with the findings of Corpuz, McCabe and Ryszawa (2006) and Vance and Hedel (2007) from their study in Germany. In their structural equation modelling study of 370 American cities, Cervero and Murakami (2010) found that population density did have a small negative impact on car use per capita though the extent of this is likely to be limited by the small variations among American urban densities compared to other global cities.

IBI (2000) found that although neighbourhood design influenced travel decisions, it was less important than changes to locational factors or the socioeconomic make-up of the neighbourhood, suggesting that the "macro" urban structure is more important than the "micro" neighbourhood design. Interestingly, Zegras (2010) found that the most important factor predicting increased car use in Santiago, Chile, was higher household income, but the reverse was found in Australian cities (Trubka et al 2011).

Hong et al. (2014) demonstrated that while at the city scale travel attitude could lead to self-selection in travel behaviour, transit system integration and transferability are more important than travel attitude. The study also demonstrated that built-environment factors still show significant effects while urban density and land use mix along with employment are the key criteria for reducing VKT.

Table 1 Studies of the impact of urban form, transit provision and socio-economic factors on urban VKT per capita

	<i>Corpuz, McCabe &amp; Ryszawa (2006)</i>	<i>Boarnet and Crane (2001)</i>	<i>Cervero and Murakami (2010)</i>	<i>Cervero and Kockelman (1997)</i>	<i>Vance and Hedel (2007)</i>	<i>IBI (2000)</i>	<i>Zegras (2010)</i>	<i>Cameron, Kenworthy and Lyons (2003)</i>	<i>Litman (2001)</i>	<i>Hong et al (2014)</i>
<b>Study location</b>	Sydney, Australia	Orange County Los Angeles, USA	370 USA Cities	San Francisco, USA	Germany	Toronto, Canada	Santiago, Chile	45 Global Cities	-	Seattle, USA
<b>Model Type</b>	Linear Regression	Multi-variant Probit regression	Log-Log Regression & structural equation Model	Bi-nomial Logit regression,	2 stage regression model.	OLS	OLS & MNL regression	Mobility Equations	Policy Discussion of indicators	OLS and Multi-Level Modelling
<b>Dependent Variable</b>	Sqrt (Car VKT)	Non-work car trips	Log (VMT/Capita)	VMT/Household	VKT	Automobile VKT	VMT	Total annual car VKT	-	Log VMT
<b>Explanatory Variables</b>										
<b>Travel related variables</b>	<ul style="list-style-type: none"> <li># of vehicles per household</li> <li># of persons of driving age</li> <li># of licence holders</li> </ul>	<ul style="list-style-type: none"> <li>Median non-work trip speed</li> <li>Median non-work trip distance</li> <li>Long Commute</li> <li>Work day dummy</li> <li>Interaction term (Long commute) x (work day)</li> </ul>	<ul style="list-style-type: none"> <li>% Auto commute</li> <li>Rail passenger miles/cap</li> </ul>	<ul style="list-style-type: none"> <li>Transport Intensity Factor</li> <li>Accessibility Index</li> </ul>	<ul style="list-style-type: none"> <li>Walking to PT (Minutes)</li> <li># Cars per licensed driver</li> </ul>	<ul style="list-style-type: none"> <li>Dist. To CBD</li> <li>Av. vehicles per household</li> <li>Dist. to transit</li> <li>Road type</li> <li>Daily bus service hours</li> <li>Ln (jobs in 1km)</li> </ul>	<ul style="list-style-type: none"> <li>Income</li> <li>Bus access</li> </ul>	<ul style="list-style-type: none"> <li>Average car occupancy</li> <li>annual VKT by motor cycles</li> <li>Average MC occupancy</li> <li>Total annual VKT by taxis</li> <li>Total annual PT Pass. Boardings</li> <li>Total annual PT seat km</li> <li>Total annual PT kilometres</li> <li>Average PT trip length</li> <li>Total annual # walking trips</li> <li>Average length of walking trip</li> <li>Total annual # of cycling trips</li> <li>Average length of cycling trip</li> </ul>	<ul style="list-style-type: none"> <li>Motor vehicle ownership</li> <li>Vehicle use</li> <li>Walking</li> <li>Traffic speeds</li> </ul>	<ul style="list-style-type: none"> <li># of vehicles</li> <li>Pro-Transit</li> <li>Ease and convenience of transit</li> <li>Distance to bus stop</li> </ul>

<p><i>Transport infrastructure &amp; vehicle related variables</i></p>	<ul style="list-style-type: none"> <li>• Accessibility to nearest non-road PT</li> <li>• Accessibility to nearest bus service</li> <li>• # persons in the household</li> </ul>	<ul style="list-style-type: none"> <li>• Cars per drivers in household</li> </ul>	<ul style="list-style-type: none"> <li>• Roadway infrastructure density</li> <li>• Urban passenger rail infra. density</li> </ul>	<ul style="list-style-type: none"> <li>• Walking quality factor</li> <li>• % intersections of four way</li> <li>• % Quadrilateral shaped blocks</li> <li>• Sidewalk width</li> <li>• Lot side / front on street parking</li> </ul>	<ul style="list-style-type: none"> <li>• Distance to work</li> </ul>	<ul style="list-style-type: none"> <li>• % street bike routes /rd. length</li> <li>• Bike route dummy</li> <li>• 3 lane arterial rds. – dummy</li> <li>• % 3 lane rd. to other rd lengths</li> <li>• Intersections per rd. km</li> <li>• % wide arterial rd. to total rd.</li> </ul>	<ul style="list-style-type: none"> <li>• 4-way intersection</li> <li>• 3-way intersection</li> <li>• Plaza density</li> <li>• Distance to metro</li> <li>• Distance to CBD</li> </ul>	<ul style="list-style-type: none"> <li>• Total (urbanised) area of the metropolitan area</li> <li>• Total length of metropolitan road network</li> <li>• Total length of metropolitan rail network</li> <li>• # passenger cars on register</li> <li>• # motor cycles on register</li> <li>• # taxis on register</li> </ul>	<ul style="list-style-type: none"> <li>• Land for transport</li> <li>• Road design</li> <li>• Street scale</li> <li>• Signage</li> <li>• Parking</li> </ul>	<ul style="list-style-type: none"> <li>• Transport accessibility</li> <li>• Intersection density</li> <li>• Distance from CBD</li> </ul>
<p><i>Land use &amp; built-environment related variable</i></p>	<ul style="list-style-type: none"> <li>• % local social &amp; commercial services</li> <li>• Land-use mix</li> <li>• Urban form / neighbourhood design variables</li> <li>• Dwelling structure</li> <li>• Housing density</li> </ul>	<ul style="list-style-type: none"> <li>• % Grid lot layout</li> <li>• Population density</li> <li>• Retail density</li> <li>• Service job density</li> </ul>	<ul style="list-style-type: none"> <li>• Population density</li> <li>• Employment density</li> <li>• Local-serving retail employment density</li> <li>• Basic-employment accessibility index</li> <li>• Local retail accessibility index</li> </ul>	<ul style="list-style-type: none"> <li>• Land use mixing</li> <li>• Vertical mixing</li> <li>• % residential acres within ¼ mile of store</li> </ul>	<ul style="list-style-type: none"> <li>• Commercial density</li> <li>• Street density</li> <li>• Commercial diversity</li> </ul>	<ul style="list-style-type: none"> <li>• % detached housing</li> <li>• Ln (# jobs within 5km Radius)</li> <li>• Land use mix within 1km radius</li> </ul>	<ul style="list-style-type: none"> <li>• Dwelling unit density</li> <li>• Diversity index</li> </ul>		<ul style="list-style-type: none"> <li>• Land use density</li> <li>• Land use mix</li> <li>• Site design</li> </ul>	<ul style="list-style-type: none"> <li>• Residential Density</li> <li>• Non-residential density</li> </ul>
<p><i>Demographic &amp; economic variables</i></p>	<ul style="list-style-type: none"> <li>• Level of local employment</li> <li>• Income</li> </ul>	<ul style="list-style-type: none"> <li>• Female</li> <li>• Age</li> <li>• Non-white</li> <li>• No high school</li> <li>• College</li> <li>• Income</li> <li>• (Income)<sup>2</sup></li> <li>• #Children &lt;16yr</li> </ul>	<ul style="list-style-type: none"> <li>• Urbanized area</li> <li>• Household income</li> </ul>		<ul style="list-style-type: none"> <li>• Female</li> <li>• Advanced school degree</li> <li>• # under 18 in household</li> <li>• # over 64 in household</li> <li>• # employed in household</li> <li>• Average zip code Income</li> <li>• Employed</li> <li>• Age</li> </ul>	<ul style="list-style-type: none"> <li>• Ln (average # of people/household)</li> <li>• Average income</li> </ul>		<ul style="list-style-type: none"> <li>• Metropolitan area population</li> <li>• # jobs in the metropolitan area</li> <li>• Metropolitan area GDP per capita</li> <li>• Annual per capita expenditure on road investment</li> <li>• Annual per capita expenditure on PT investment</li> </ul>		<ul style="list-style-type: none"> <li>• Household size</li> <li>• # of workers</li> <li>• Gender</li> <li>• Age</li> <li>• Education level</li> <li>• Household income</li> </ul>

## 2.2. Classification of city archetypes

None of the above studies (apart from the Cameron, Kenworthy and Lyons work that uses the Global Cities Database) were comparisons of different cities from across the world. The significance of a global comparison is that different types of cities can be brought together to enable statistical analysis on a larger variation in the parameters that may be making a difference in VKT. In his 1977 book, *“Great Cities and Their Traffic”*, Thomson developed five city “archetypes” that describe differences in urban transport systems across the world’s cities and in particular the relationship between such systems and urban structure and form. Table 2 summarises each archetype and cities selected by Thomson that exemplify them.

Table 2 *Global city archetypes, adapted from Thomson (1977)*

<b>Archetypes</b>	<b>Description</b>	<b>Example Cities</b>
<b>Full Motorisation</b>	<ul style="list-style-type: none"> <li>• Small to no city centre (&lt;120,000 Jobs) without a radial transport system</li> <li>• Employment in single storey buildings with extensive parking</li> <li>• Low density single storey suburbs</li> <li>• Large format shopping with extensive parking</li> <li>• Grid format freeways (4-10 lanes)</li> <li>• Buses on secondary highways, poor pedestrian environment</li> <li>• Car is dominant and cheaper in generalised cost than PT to centres</li> </ul>	<ul style="list-style-type: none"> <li>• Los Angeles</li> <li>• Detroit</li> <li>• Denver</li> <li>• Salt Lake City</li> </ul>
<b>Weak Centre Strategy</b>	<ul style="list-style-type: none"> <li>• City centre (&gt; 250,000 Jobs) with radial road and transit network,</li> <li>• Significant peripheral and suburban employment served by car</li> <li>• Requires PT to attract passengers to limit intolerable congestion</li> <li>• Ring and radial freeways, commercial/industrial attracted to intersections</li> <li>• Strategy is unstable due to requirements for high transport accessibility to centre without full PT access</li> <li>• Car is marginally cheaper than PT in generalised cost of travel to centres</li> </ul>	<ul style="list-style-type: none"> <li>• Melbourne</li> <li>• Copenhagen</li> <li>• San Francisco</li> <li>• Chicago</li> <li>• Boston</li> </ul>

<p><b>Strong Centre Strategy</b></p>	<ul style="list-style-type: none"> <li>• Very high levels of CBD employment (&gt; 500,000 Jobs) with a radial transit network, and limited road accessibility to the centre</li> <li>• Ring roads complement and interact with transit to provide centre access</li> <li>• Development outside the centre is focussed around transit infrastructure</li> <li>• Transport investment to centres is equal between road and transit</li> <li>• Transit is cheaper than car in generalised cost of travel to centres</li> </ul>	<ul style="list-style-type: none"> <li>• Paris</li> <li>• Tokyo</li> <li>• New York</li> <li>• Athens</li> <li>• Toronto</li> <li>• Sydney</li> <li>• Hamburg</li> </ul>
<p><b>Low Cost Strategy</b></p>	<ul style="list-style-type: none"> <li>• Large number of radial routes</li> <li>• BRT, buses and trams carry the majority of passengers, with limited car use/capita</li> <li>• Very dense development at centres serviced by buses</li> </ul>	<ul style="list-style-type: none"> <li>• Bogota,</li> <li>• Lagos</li> <li>• Calcutta,</li> <li>• Istanbul</li> <li>• Karachi,</li> <li>• Manilla,</li> <li>• Tehran</li> </ul>
<p><b>Traffic Limiting Strategy</b></p>	<ul style="list-style-type: none"> <li>• City centres hierarchy put in place: city centre, sector centres, suburban centres, neighbourhood centres, structured to minimise the need for travel</li> <li>• Radial rail and ring rail systems put in place, such that all centres accessible by transit, bus, cycling or walking as well as car</li> <li>• Limited access to the centre by car</li> <li>• High cost of car travel compared to transit (parking, congestion charging.)</li> </ul>	<ul style="list-style-type: none"> <li>• London</li> <li>• Singapore</li> <li>• Stockholm</li> <li>• Vienna</li> <li>• Bremen</li> <li>• Goteborg</li> </ul>

Based on Table 2, all 26 cities in this study were placed in one of the above archetypes. Thomson's analysis was not conducted on the basis comparative data but more on a qualitative understanding of their differences based on experience as a transport planner familiar with the cities. They are consistent with the kind of clusters of city types determined by Newman and Kenworthy, (1989; 1999), Kenworthy (2005) and Priester et al., (2013).

### 3. Research Method

In order to understand how factors like transit service levels and urban density help to explain VKT per capita, structural equation modelling (SEM) methods were applied to the global cities data on 26 cities from the US, Europe, Canada and Australia for the years 1960, 1970, 1980, 1990 and 2000. Each city was assigned to one of the Full Motorisation Strategy, Weak Centre Strategy, Strong Centre Strategy or Traffic Limiting Strategy archetypes using the criteria specified in Table 2. The following expression depicts the general model used:

$$\text{Per capita car VKT} = f(X, R, T)$$

where per capita VKT can be explained as a function of a location's time variant attributes (X), its time-invariant attributes (R) and the decade of examination (T). The selection of time periods, regions and archetypes was determined by data availability and the focus on the growth of car dependence in global cities in the post-war period (since 1950).

#### **3.1. Global Cities Database (1960-2000)**

The choice of cities for the analysis dates back to the original study by Newman and Kenworthy (1989) that selected a set of the 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 and Laube 2001) 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.

The historical and more current urban data from these sources are a unique source of consistent data on so many cities over such a long timeframe. They have never before been brought together in this way to explore the causal factors that lie behind the use of cars in cities. As a

general rule though, the data are patchier for the 1960 and 1970 periods. For this reason our paper, which focuses on cities with the most data over the longest period, uses only 26 cities out of the 46 cities in this longitudinal database. In this sense the data alone in Tables 4a, 4b and 4c are a rich resource from which trends and patterns can be observed.

The cities selected needed to have observations in as many of the time periods as possible. A summary of the cities, the continuous variables and the dummy variables available in the database and considered in the modelling process are presented in Table 3.

The high degree of correlation among the variables in the dataset was evidence of the complex relationships among many of the urban form, structure and transport variables employed in analyses of VKT. Urban density and job density are examples of variables in the dataset that display near perfect correlation, which meant including both in a regression model would produce inefficient parameter estimates. The correlation between public transit service kilometres and passenger kilometres is another such example, where the former reflects the supply of public transit and the latter its uptake. Whilst many of these relationships have been documented previously (Kenworthy and Laube, 1999), the econometric modelling of these relationships across 26 global cities over a four-decade period has not been done before; it therefore has the potential to add to the base of knowledge and the policy platform for future urban policy in a world where reducing VKT is firmly on the policy agenda (eg IPCC, 2014).

Tables 4a, 4b and 4c present a summary of the key variables from the global cities database to be applied in the research analysis. Each city was assigned one of Thompson's archetypes either by using his classifications directly or, for cases where no archetype had been assigned, on the basis of VKT per capita, transit passenger kilometres per capita, urban density, and percentage of jobs

in the CBD along with the other criteria in Table 2. In addition to pre-existing dataset variables a series of dummy variables were created, including:

- five time period dummy variables for the data within the years 1960, 1970, 1980, 1990 and 2000, where 1960 became the reference case in the econometric models;
- four region dummy variables for the cities within the US, Western Europe, Canada and Australia, with the US adopted as the region reference case; and
- four urban land use and transport archetypes (Full Motorisation Strategy, Weak Centre Strategy, Strong Centre Strategy, and the Traffic Limiting Strategy).

*Table 3 All the initial global cities, database variables (1960-2000), and derived dummy variables initially included in the research database for modelling, where the variables in italics were used in the final econometric analysis*

<b>Cities</b>	<b>Urban Transport Variables</b>	<b>Urban Development Variables</b>	<b>Model Dummy Variables</b>
<i>Brisbane</i>	<i>Pass. car km/capita</i>	City population	<i>Region Europe</i>
<i>Brussels</i>	<i>Rd length/capita</i>	Urbanised area	<i>Region Australia</i>
<i>Calgary</i>	<i>Pass. Car km/km of road</i>	Number of jobs in the CBD	<i>Region USA</i>
<i>Chicago</i>	<i>Cars/1000 people</i>	<i>Urban density</i>	<i>Region Canada</i>
<i>Copenhagen</i>	<i>Parking spaces/1000 CBD jobs</i>	Job density	
<i>Denver</i>		<i>Proportion of jobs in CBD</i>	<i>Year 1960</i>
<i>Frankfurt</i>	<i>Total PT pass km/capita</i>		<i>Year 1970</i>
<i>Hamburg</i>	Bus passenger km/capita		<i>Year 1980</i>
<i>Houston</i>	Rail passenger km/capita		<i>Year 1990</i>
<i>London</i>	Tram/LRT pass. km/capita		<i>Year 2000</i>
<i>Los Angeles</i>			
<i>Melbourne</i>	<i>Total PT service km/capita</i>		<i>Archetype Full Motorisation</i>
<i>Montreal</i>	Bus km/capita		<i>Archetype Weak City Strategy</i>
<i>Munich</i>	Rail km/capita		<i>Archetype Strong Centre Strategy</i>
<i>New York</i>	Tram/LRT km/capita		<i>Archetype Traffic Limiting Strategy</i>
<i>Ottawa</i>	Total PT boardings/capita		
<i>Perth</i>	Rail boardings/capita		Rail dummy
<i>Phoenix</i>	Trams/LRT boardings/capita		Bus dummy
<i>San Francisco</i>			LRT/Tram dummy
<i>Stockholm</i>	Overall ave. PT speed		Ferry dummy
<i>Sydney</i>	Bus ave. speed		
<i>Toronto</i>	Trams/LRT ave speed		
<i>Vancouver</i>	Rail ave. speed		
<i>Vienna</i>	Ferries ave. speed		
<i>Washington</i>	Speed ratio bus to rail		
<i>Zurich</i>			

While all the global cities database variables (1960-2000), and derived dummy variables presented in Table 3 were initially included in the research database for modelling. The majority of the variables fell out of the modelling due to multi-collinearity between each other. An example of this multi-collinearity is where the population and land area variables were effectively perfectly controlled for by urban density, and therefore had high p-values and were step-wise removed from the modelling dataset.

Table 4a City form summary data for 26 global cities for decades 1960-2000 (\* denotes archetypes not allocated by Thomson (1977) and interpreted by authors)

City	Region	J.M. Thomson (1977) City Archetype	1960			1970			1980			1990			2000		
			City Population	Urban Density	% Total Jobs in CBD	City Population	Urban Density	% Total Jobs in CBD	City Population	Urban Density	% Total Jobs in CBD	City Population	Urban Density	% Total Jobs in CBD	City Population	Urban Density	% Total Jobs in CBD
Houston	USA	Full Motorisation *	1430394	10.2	10%	1999316	12.0	11%	2905353	8.9	12%	3462529	9.5	7%	4385643	9.2	6%
Washington	USA	Weak Centre *	1808423	20.5	27%	2481489	19.4	20%	2763105	13.2	17%	3363031	13.7	14%	4006346	13.5	12%
Denver	USA	Full Motorisation	803624	18.6	14%	1047311	13.8	13%	1352070	11.9	12%	1517977	12.8	11%	2120510	14.9	8%
San Francisco	USA	Weak Centre	2430663	16.5	20%	2987850	16.9	17%	3190690	15.5	17%	3629516	16	15%	3954824	20.2	13%
Los Angeles	USA	Full Motorisation	6488791	22.3	7%	8351266	25	5%	9479436	24.4	5%	11402946	23.9	5%	9418370	25.9	4%
Phoenix	USA	Full Motorisation *	552043	8.6	11%	863357	8.6	8%	1409279	8.5	4%	2006239	10.5	4%	3058459	10.6	4%
Chicago	USA	Weak Centre	5959213	24	13%	6714578	20.3	13%	6779799	17.5	12%	6792087	16.6	10%	7870265	16.8	9%
Perth	Australia	Weak Centre *	475398	15.6	40%	703199	12.2	31%	898918	10.8	24%	1142646	10.6	21%	1381510	11.1	18%
Brisbane	Australia	Weak Centre *	621550	21	26%	867784	11.3	-	1028527	10.2	14%	1333773	9.8	11%	1654342	9.7	12%
New York	USA	Strong Centre	16834500	22.5	30%	18731600	22.6	27%	17925200	19.8	23%	18409019	19.2	22%	19904078	18.6	19%
Calgary	Canada	Weak Centre *	249641	27	41%	403320	25	30%	592743	21.2	24%	710677	20.8	21%	877626	20.7	22%
Melbourne	Australia	Weak Centre	1984815	20.3	19%	2503450	18.1	17%	2722817	16.4	15%	3022910	14.9	11%	3440574	14.7	10%
Sydney	Australia	Strong Centre	2289747	21.3	20%	2807828	19.2	17%	3204696	17.6	13%	3539035	16.8	12%	4011645	19.2	13%
Vancouver	Canada	Weak Centre *	827335	24.9	-	1082185	21.6	22%	1268197	18.4	18%	1602502	20.8	13%	2007634	23.4	12%
Ottawa	Canada	Weak Centre *	-	-	-	633443	34.9	27%	735854	31.7	26%	907919	31.3	24%	1051609	31.1	20%
Frankfurt	W. Europe	Strong Centre *	670048	87.2	24%	669751	74.6	21%	631287	54.0	18%	634357	46.6	20%	652412	46.8	19%
Copenhagen	W. Europe	Weak Centre	1607526	40.1	26%	1752631	33.4	19%	1739860	30.4	16%	1711254	28.6	13%	1783349	28.9	13%
Montreal	Canada	Weak Centre *	2109509	57.6	-	2743208	39	26%	2835759	33.9	23%	3119570	33.8	20%	3355825	28.7	17%
Toronto	Canada	Strong Centre	1620861	36.8	18%	2089729	41.4	15%	2137395	39.6	13%	2275771	41.5	14%	5092398	26.2	6%
Zurich	W. Europe	Traffic Limiting *	697434	60	17%	791761	58.3	15%	780502	53.7	14%	787740	47.1	11%	808907	43.6	11%
Hamburg	W. Europe	Strong Centre *	1832346	68.3	20%	1793782	57.5	21%	1645095	41.7	20%	1652363	39.8	16%	1725764	38.2	17%
Stockholm	W. Europe	Traffic Limiting	808294	65.5	35%	740486	59.3	28%	647214	51.3	28%	674452	53.1	22%	1807851	27.4	13%
Munich	W. Europe	Traffic Limiting *	1046000	56.6	29%	1311798	68.2	26%	1298941	56.9	24%	1277576	53.6	25%	1306258	55.3	33%
London	W. Europe	Traffic Limiting	7992400	65.4	32%	7452300	61.6	31%	6713200	56.3	30%	6679699	42.3	31%	7259550	58.8	31%
Vienna	W. Europe	Traffic Limiting	1627566	91.4	17%	1614841	85.4	16%	1531346	72.1	15%	1539948	68.3	13%	1622017	70.3	12%
Brussels	W. Europe	Traffic Limiting *	1022795	100.3	-	1075136	91.1	-	1008715	82.3	25%	964285	74.9	24%	977436	74.3	23%

Table 4b Transport summary data for 26 global cities for decades 1960-2000 (\* denotes archetypes not allocated by Thomson (1977) and interpreted by authors)

City	Region	J.M. Thomson (1977) City Archetype	1960			1970			1980			1990			2000		
			Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita	Car VKT/Capita	PT Service Km/Capita (% rail)	PT Pass. Km/capita
Houston	USA	Full Motorisation *	6829	20.6 (0%)	234.2	8257	12.6 (0%)	139.4	9918	9.1 (0%)	128.3	13016	16.7 (0%)	215	15807	19.3 (2%)	183.5
Washington	USA	Weak Centre *	-	32.7 (12%)	570.2	5671	26.7 (1%)	300.9	7939	39.9 (25%)	616.1	11182	37.3 (43%)	773.8	13050	49.1 (45%)	827
Denver	USA	Full Motorisation	5888	15.6 (0%)	245.3	6933	9.1 (0%)	92.7	8693	24.9 (0%)	217.6	10011	21.2 (0%)	198.6	12820	30.9 (5%)	260.4
San Francisco	USA	Weak Centre	5656	33.7 (13%)	596.7	7999	31.1 (10%)	532	9362	50.2 (26%)	925.8	11933	49.3 (42%)	899.3	12463	53.3 (47%)	856.2
Los Angeles	USA	Full Motorisation	7382	19.4 (0%)	244.3	7850	16.1 (0%)	159.7	9003	26.8 (0%)	383.6	11587	19.8 (0%)	351.6	12265	29.7 (8%)	408.9
Phoenix	USA	Full Motorisation *	7188	9.6 (0%)	101.7	8864	5 (0%)	35.9	9761	7.2 (0%)	66.0	11608	9.9 (0%)	123.7	11542	15 (0%)	108.4
Chicago	USA	Weak Centre	4091	52.1 (39%)	1015.3	5769	44.8 (42%)	855.5	7566	41.6 (44%)	971.1	9525	41.5 (47%)	805.3	10395	41.9 (46%)	723.4
Perth	Australia	Weak Centre *	3287	67.1 (17%)	907.8	5224	57.2 (12%)	732.0	6250	52.6 (10%)	591.5	7203	47 (10%)	544.4	8916	42.3 (27%)	694.9
Brisbane	Australia	Weak Centre *	2608	77.9 (65%)	1352.3	3788	57.2 (35%)	953.1	5861	48.3 (45%)	744.7	6467	55.1 (49%)	899.8	8572	63.1 (51%)	831.9
New York	USA	Strong Centre	4066	60.9 (54%)	1842.3	4864	66 (63%)	1395.3	5907	58.1 (58%)	1285.3	8317	62.8 (63%)	1334.3	8458	62.7 (63%)	1343
Calgary	Canada	Weak Centre *	2842	30 (0%)	242.4	3445	30.8 (0%)	319.7	6069	46 (4%)	875.4	7913	49.7 (18%)	774.6	8299	49.1 (19%)	1027.6
Melbourne	Australia	Weak Centre	2963	75.3 (72%)	1739.0	4228	57.3 (66%)	1221.7	5582	52.5 (66%)	778.5	6436	49.9 (57%)	843.8	7962	50.7 (58%)	1025.4
Sydney	Australia	Strong Centre	3757	104.7 (61%)	2158.0	5436	70.5 (47%)	1860.0	6442	76.9 (57%)	1510	7051	94 (58%)	1769	7249	76.5 (59%)	1530.5
Vancouver	Canada	Weak Centre *	-	36.6 (0%)	-	-	25.1 (0%)	-	6756	45.7 (0%)	839.1	8361	50.3 (24%)	871.3	6858	50.2 (30%)	847.7
Ottawa	Canada	Weak Centre *	3503	31.7 (0%)	426.9	-	23.8 (0%)	336.1	5776	65.3 (0%)	825.5	5883	55.9 (0%)	849.5	6470	45 (1%)	850.4
Frankfurt	W. Europe	Strong Centre *	2000	-	-	3500	-	-	4256	47 (69%)	1483.5	5893	47.9 (68%)	1148.9	5618	84.8 (69%)	1514.7
Copenhagen	W. Europe	Weak Centre	1263	72.3 (76%)	1547.7	3069	86.1 (60%)	1381.4	3462	109.5 (54%)	1658	4558	121.3 (56%)	1606.8	5402	115 (60%)	1623.8
Montreal	Canada	Weak Centre *	-	-	-	-	-	-	3267	63.4 (36%)	888	4746	60.2 (34%)	951.7	5380	52.9 (38%)	1057.5
Toronto	Canada	Strong Centre	-	48.2 (60%)	1335.7	-	57.9 (48%)	1369.5	4238	80.6 (48%)	1975.7	5019	98.4 (44%)	2172.8	5256	52.9 (37%)	1087.7
Zurich	W. Europe	Traffic Limiting *	-	102.7 (88%)	1944.9	-	92.9 (87%)	1560.3	4318	102.3 (84%)	1821	5197	148.1 (79%)	2459.4	5245	139.7 (75%)	2433.2
Hamburg	W. Europe	Strong Centre *	1560	60.1 (74%)	1958.7	3477	74.4 (67%)	1692.5	4409	71.7 (58%)	1501.6	5061	71 (62%)	1374.8	5187	83.9 (63%)	1577.1
Stockholm	W. Europe	Traffic Limiting	1804	87.5 (51%)	739.7	3525	93 (49%)	1294.5	4867	118.8 (51%)	2124.1	4638	133.2 (50%)	2351.3	4946	122.5 (58%)	2335.8
Munich	W. Europe	Traffic Limiting *	1516	-	-	2678	52.1 (60%)	806.2	3272	65.2 (76%)	1746	4202	91.4 (80%)	2462.5	4830	99.8 (72%)	2811.4
London	W. Europe	Traffic Limiting	1341	121.4 (58%)	2229.2	1855	114.8 (63%)	1995.2	2529	119.8 (65%)	1716.9	3892	138.4 (68%)	2405.1	4088	174.3 (69%)	2456.8
Vienna	W. Europe	Traffic Limiting	-	71.7 (93%)	1704.5	-	62.6 (86%)	1645.2	2664	69 (79%)	1828.2	3964	72.6 (72%)	2430.3	3909	100.8 (76%)	2333.6
Brussels	W. Europe	Traffic Limiting *	1793	64.1 (84%)	1787.7	2918	46.9 (61%)	1462.8	3891	53 (50%)	1400.3	4864	62.7 (48%)	1427.5	2648	92.8 (54%)	1780.9

Note: (%) signifies the % rail based transit (heavy rail and LRT/trams) operating in the city as part of the Total PT Service

Table 4c Road based summary data for 26 global cities for decades 1960-2000 (\* denotes archetypes not allocated by Thomson (1977) and interpreted by authors)

City	Region	J.M. Thomson (1977) City Archetype	1960			1970			1980			1990			2000		
			Park. Spaces /1000 CBD Workers	Cars /1000 People	Rd Length /Capita	Park. Spaces /1000 CBD Workers	Cars /1000 People	Rd Length /Capita	Park. Spaces /1000 CBD Workers	Cars/1000 People	Rd Length /Capita	Park. Spaces /1000 CBD Workers	Cars/1000 People	Rd Length /Capita	Park. Spaces /1000 CBD Workers	Cars/1000 People	Rd Length /Capita
Houston	USA	Full Motorisation *	497.2	388.1	-	363.1	647.9	11.7	369.9	602.6	10.6	612.3	607.7	11.7	721	714.1	9.1
Washington	USA	Weak Centre *	217.9	289.8	-	295	400.9	5.1	257.1	561.4	5.1	252.9	620.1	5.2	281	606.8	5.1
Denver	USA	Full Motorisation	595.2	479.1	8.8	578.3	522.7	11	497.6	666.2	9.4	605.6	752.6	7.6	542	693.8	8.7
San Francisco	USA	Weak Centre	135.1	407.4	4.7	154.5	487.9	4.7	145.2	543.4	4.9	136.6	603.5	4.6	182	629	4.5
Los Angeles	USA	Full Motorisation	372.8	459.1	4.9	534.8	521.2	4.8	523.6	541.5	4.5	520.4	543.6	3.8	674	563.4	3.6
Phoenix	USA	Full Motorisation *	619.2	367.8	15.4	836.3	499.1	12.7	1033	498.9	10.4	905.6	643.9	9.6	1106	533.5	8.1
Chicago	USA	Weak Centre	83	307.7	4.8	96.3	391	5	91.1	445	5	128.2	547.1	5.2	119	603.1	4.9
Perth	Australia	Weak Centre *	238.8	561.1	14.1	527.1	356.9	13.7	562.3	474.9	13.3	631.1	522.9	10.7	566	683.8	8.7
Brisbane	Australia	Weak Centre *	162.2	192.3	7.8	227.6	294.3	7.5	268.4	458.1	6.9	321.7	463	8.2	255	635.7	8.3
New York	USA	Strong Centre	-	270.6	4.3	348.2	-	4.1	69.1	411.9	4.7	59.9	483.5	4.6	64	444.8	4.8
Calgary	Canada	Weak Centre *	577.2	323.6	2.8	565.3	409.7	3.8	425.2	563.5	5	522	630.3	4.9	433	667.6	4.6
Melbourne	Australia	Weak Centre	155.6	224	8.1	295.3	192.1	6.8	270.4	445.8	7.9	337.3	518.3	7.7	308	621.2	8.4
Sydney	Australia	Strong Centre	-	268.1	4.7	86.6	366.4	5.1	156	489.3	6.2	222.2	530	6.2	201	534.6	6.9
Vancouver	Canada	Weak Centre *	-	285.3	7	341	401.7	6	342	453.9	6	443	564.5	5	417	513	4.9
Ottawa	Canada	Weak Centre *	-	279.8	-	-	369.7	-	-	473.9	8.4	230.3	510.2	7.1	340	536.7	8.3
Frankfurt	W. Europe	Strong Centre *	110.4	133.3	1.3	189.2	280	1.5	241.8	386.9	2	246.3	477.6	2	264	481.7	2
Copenhagen	W. Europe	Weak Centre	150.7	88.5	2.8	198.5	199.5	3.4	212.3	246.4	4.3	223.2	283	4.6	208	304.4	3.9
Montreal	Canada	Weak Centre *	-	192.5	-	-	248.9	-	313.3	326.5	-	346.8	420.2	4.5	377	437.5	4.5
Toronto	Canada	Strong Centre	191.8	297.8	1.7	198.2	358.2	2.3	197.6	462.5	2.7	175.8	606	2.6	206	474.7	4.4
Zurich	W. Europe	Traffic Limiting *	-	126	-	112.8	253.9	-	140.3	374.6	3.7	136.7	444.2	4	140	488.7	4.7
Hamburg	W. Europe	Strong Centre *	123.7	95.7	1.8	139.1	241.4	2	148.9	344.4	2.2	177.3	410.2	2.6	176	451.4	2.5
Stockholm	W. Europe	Traffic Limiting	99.7	143.2	1.5	130.4	274.7	1.8	153.3	346.5	2.3	193.2	408.9	2.2	162	424.9	4.8
Munich	W. Europe	Traffic Limiting *	-	130.9	1.5	-	261.8	1.5	248.7	359.9	1.7	266.2	468.2	1.8	275	500.2	1.8
London	W. Europe	Traffic Limiting	-	156.3	1.5	126.5	222.8	1.7	120.7	284.1	1.9	-	347.6	2	90	351.3	2
Vienna	W. Europe	Traffic Limiting	-	93.6	1.2	-	213.9	1.6	189.5	311.2	1.7	186.5	363.2	1.8	200	384	1.7
Brussels	W. Europe	Traffic Limiting *	-	157.3	1.4	-	262.3	1.4	185.5	357	1.6	314.1	428.2	2.1	394	468.7	1.9

### **3.2. Econometric Analysis**

A number of model functional forms were trialled and assessed on the basis of model fit and constancy of error variance, including linear, log-linear and log-log model forms. The log-log models performed best on most accounts, and as such they will be the focus of discussion. The added benefit of log-log models is that their coefficient estimates can be interpreted as direct elasticities, apart from the dummy variable coefficients whose impacts can be interpreted as percentages (as these variables cannot be logged). Both direct and indirect effects were estimated for each parameter, which enables greater insight into city structure and form impacts on VKT per capita and also enables the tracing of causal paths.

### **3.3. Structural Equation Modelling**

Structural equation modelling (SEM) is a statistical modelling technique that enables the exploration of complex relationships in datasets by combining statistical data analysis with qualitative assumptions of causality. The technique is carried out by simultaneously estimating a system of equations using maximum likelihood estimation (MLE). By estimating the covariance structures of the variables along designated paths, endogeneity biases can be statistically corrected (Cervero and Murakami, 2010). This modelling technique is useful in exploring urban transport matters where causality debates are common and two-way relationships among variables can lead to misleading statistical inferences in more conventional models.

The process of SEM usually begins with the expression of *a priori* assumptions around associative and causal relationships in the form of a path diagram. This path diagram can form a starting point for an iterative process, defining and estimating a system of equations that can trace out the direct and indirect influence of urban form and transport parameters on private car travel.

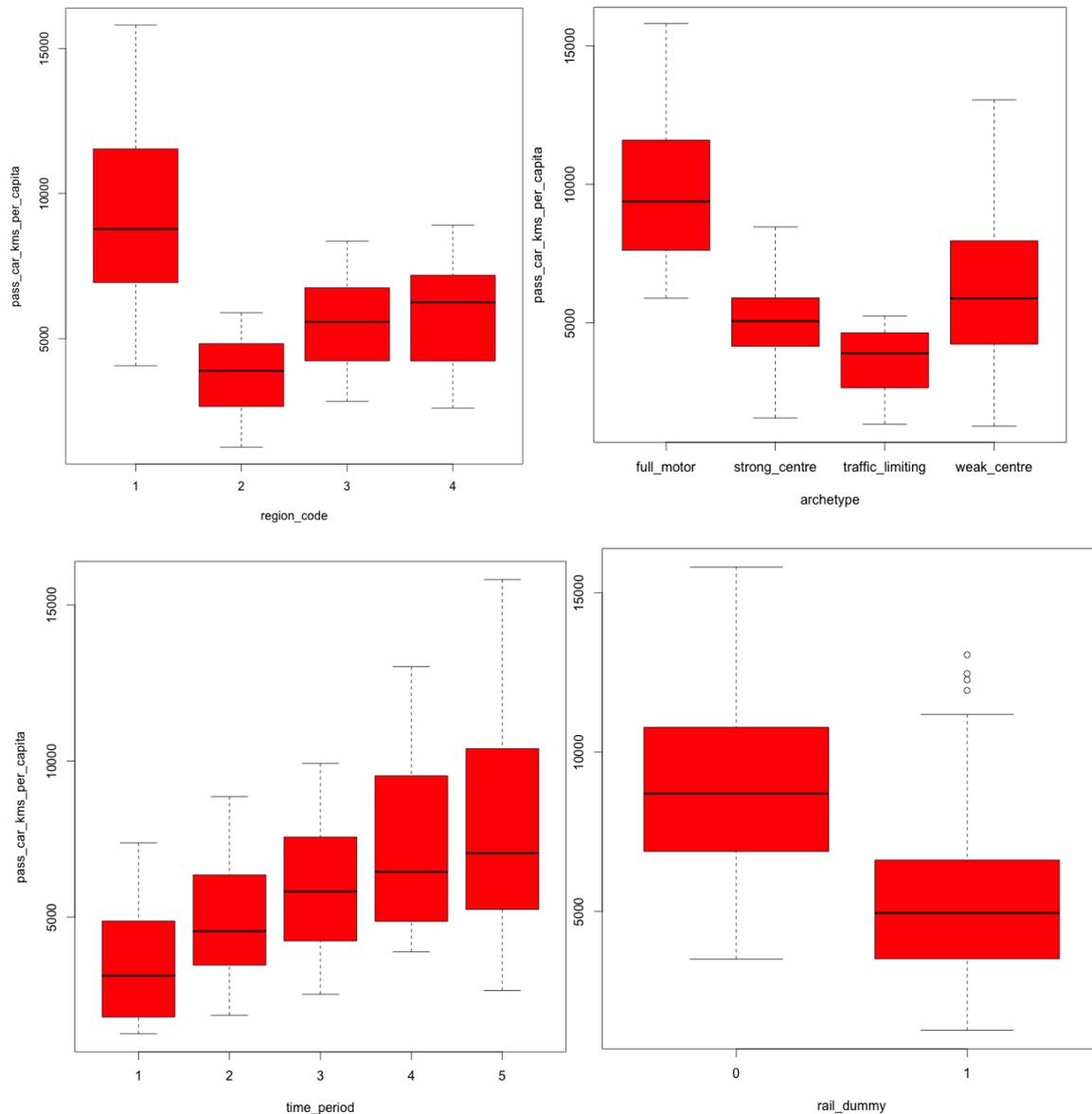
## 4. Results

### *4.1. Region and archetype categorical variable analysis*

Before estimating the models, a number of box plots were prepared summarising VKT by the categorical variables (see Figure 1) to identify any potential fixed effects that may stand out. The categorical variables plotted included the region, archetype, time period and rail transit dummies.

Box plot 1A of VKT per capita against region clearly illustrates the dominance of the US cities (Region 1) in the generation of private car travel. As one would expect, the European cities (Region 2) report the lowest median and variance of VKT while the Canadian (Region 3) and Australian (Region 4) cities fall in between and are similarly matched. The box plot 1B shows car VKT per capita grouped by city archetype, where, as with classification by region, there seems to be evidence of a potential archetype fixed effect. The full motorisation archetype has the highest median per capita VKT followed by the weak centre, strong centre and traffic limiting categories as would be expected.

Box plot 1C shows evidence of a potential time period fixed effect where VKT per capita seems to have increased every decade between the years 1960 and 2000, albeit at a lessening rate and with increasing variance. Finally, Box plot 1D has been included to illustrate the rather striking difference in VKT between cities that do and do not contain rail transit, and this will be discussed in greater depth later in the paper along with urban policy suggestions.



**Figure 1** Model dummy variable box plots:  
**Figure 1A** (Top left) per capita car VKT by region, where 1, 2, 3 and 4 refer to the US, Western Europe, Canada and Australia respectively.  
**Figure 1B** (Top right) per capita car VKT by archetype.  
**Figure 1C** (Bottom left) per capita car VKT by year, where 1, 2, 3, 4 and 5 refer to the years 1960, 1970, 1980, 1990 and 2000 respectively.  
**Figure 1D** (Bottom right) per capita car VKT by rail transit presence, where 0 represents cities with no rail transit and 1 represents cities with rail transit.

#### 4.2. SEM Analysis

The path diagrams shown below in Figure 2 for the SEM analyses were estimated using the Lavaan library in the R statistical modelling software. Lavaan stands for “latent variable analysis” and can be used for structural equation modelling, path analysis and confirmatory factor analysis. A path diagram is a way of visually depicting the relationships between variables in a system of equations, where an arrow leaving a variable identifies it as a regressor in an equation and an arrow leading into a variable identifies it as a dependent variable. Variables with no arrows leading into them, such as the time period dummies, are interpreted as being purely exogenous and not having their values determined from within any equation specified.

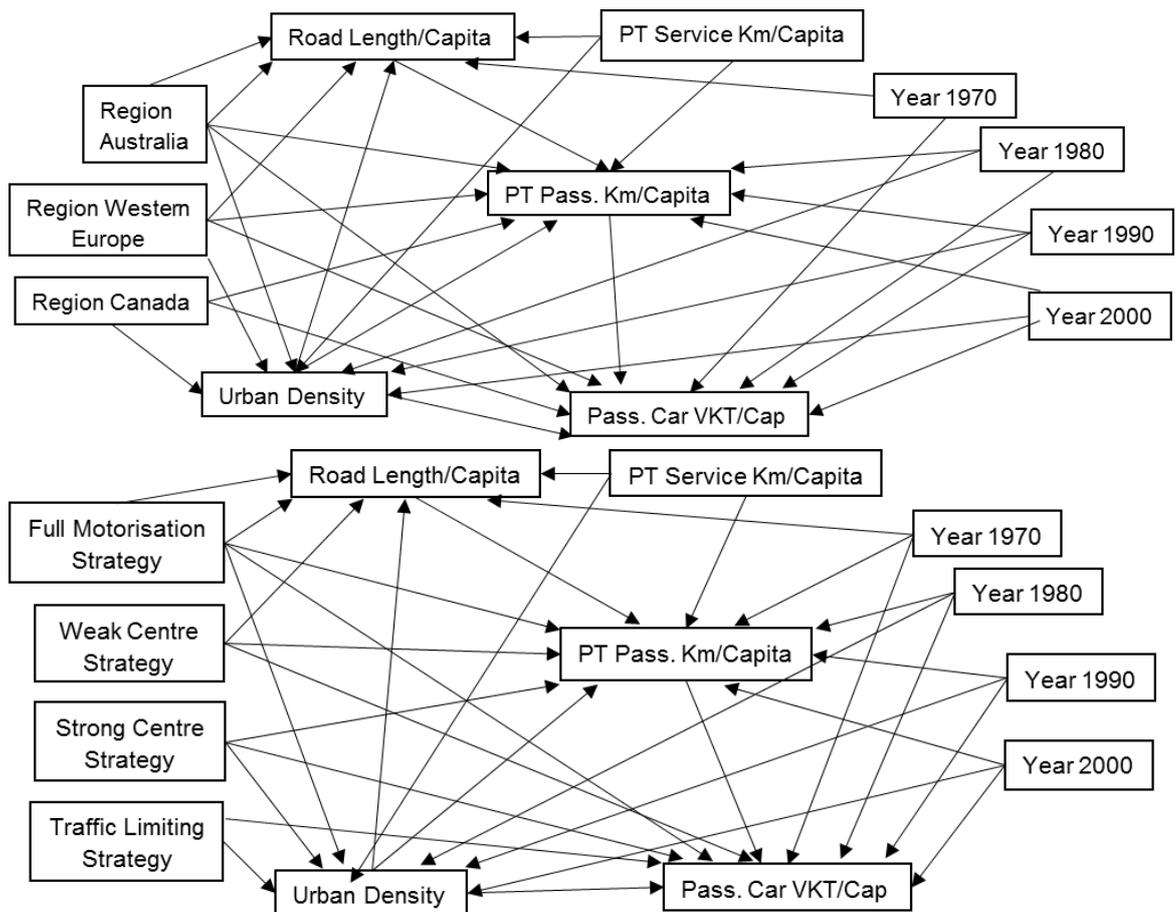


Figure 2 SEM path diagram for the City Region (Top) and Archetype (Bottom) models

The process of refining the system of equations specified in the Figure 2 path diagrams was extensive. This began with model specifications containing region and time fixed effects (as opposed to archetype and time fixed effects) as a variety of functional forms were trialled (linear, log-linear and log-log) and a great many equations and equation specifications were tested before arriving upon the ones finally reported. A step-wise process of progressively removing variables from the overall system was attempted, but the final result was a set of very poor model fit statistics and unrealistic elasticities.

The final SEM model with region and time dummy variables was derived by beginning with theory-based model specifications and following this with a thorough process of variable and equation substitution, until all the final equations reported high adjusted r-squared values (above 70%). All non-dummy variable parameters were significant at the 0.10 level or better and had expected signs, and the overall model fit statistics reported in the recommended ranges. The same model specifications were maintained for the SEM with archetype and time fixed effects for direct comparison with the region and time dummy variable model.

The first equation in the final system included car VKT per capita as the dependent variable with public transit passenger kilometres (distinct from transit service kilometres), urban density and the region and time dummies as predictors. This model provided the direct elasticity estimates impacting per capita VKT. In addition to this equation, three more models were included in the system. The first of these equations specified public transit passenger kilometres as a function of transit kilometres of service (the amount of public transit system available to be used), urban density and road length per capita; the second equation specified urban density as a function of transit kilometres of service; and the third equation specified road length as a function of urban density and transit kilometres of

service; while all models included all the region and time dummies. This same specification was adopted for the archetype SEM by substituting out the region effect dummies.

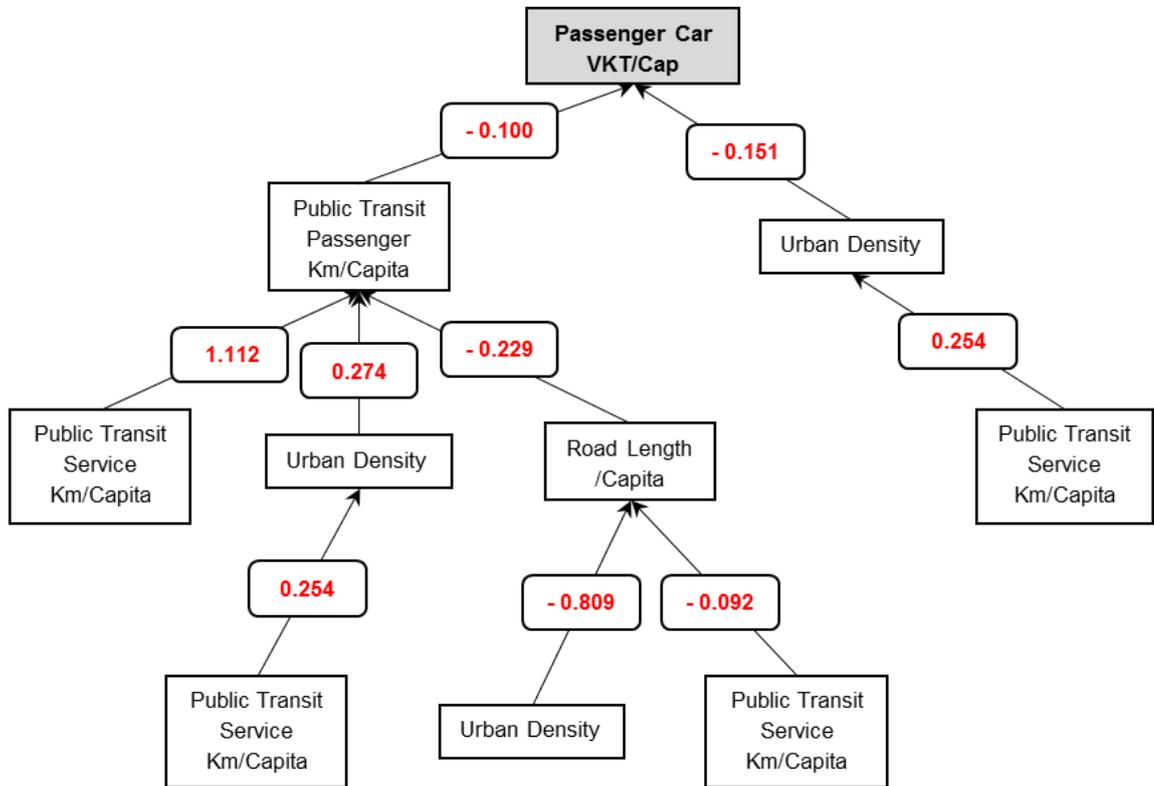


Figure 3 Indirect effect elasticities path diagram for Car VKT per capita (Regional Model), omitting time and region fixed effects

While the direct elasticities can be interpreted directly from the first equation with car VKT per capita as the dependent variable, the indirect elasticities can be calculated by multiplying the coefficients through the system in accordance with the path diagram in Figure 3. The SEM model's elasticities presented in Table 5 clearly demonstrate the key importance of urban density, public transport patronage and service kilometre provision in stemming car dependency and the role of investment in road infrastructure in increasing it. Urban density plays a very significant role in the archetype SEM model, with its elasticity doubling that reported for the region model.

The region SEM was the better performing model than the archetype model, due to the high p-value of the PT passenger km/capita and better overall model fit statistics. In terms of goodness-of-fit of the two SEM models, both reported well but the model with region dummies (as opposed to archetype dummies) was best. This could have been due to the issue that the archetypes were assigned on the basis of the other attributes included as controls.

*Table 5 Log-log structural equation models: direct and indirect coefficient estimates*

<i>Independent Variable</i>	<i>Regions SEM</i>			<i>Archetypes SEM</i>		
	<i>Direct Coefficient</i>	<i>Indirect Coefficient</i>	<i>Total Coefficient</i>	<i>Direct Coefficient</i>	<i>Indirect Coefficient</i>	<i>Total Coefficient</i>
<b>Ln PT passenger km/cap</b>	-0.1	-	-0.1	-	-	-
<b>Ln PT Service Km/Capita</b>	-	-0.157	-0.157	-	-0.071	-0.071
<b>Ln Rd Length/Capita</b>	-	0.023	0.023	-	-	-
<b>Ln Urban Density</b>	-0.151	-0.046	-0.197	-0.352	-	-0.352

The four goodness-of-fit measures considered were the Comparative Fit Index (CFI), Normed-fit Index (NFI), Non-Normed Fit Index (NNFI) and Root Mean Square Error of Approximation (RMSEA), all of which are reported at the end of Table 6 and are important to consider in evaluating structural equation models (Fan et al., 1999; Hooper et al., 2008). The region dummy SEM exceeded all the suggested fit measure thresholds while the archetype dummy SEM model exceeded all but the threshold for the NNFI.

Table 6 SEM path estimations for the Region (compared to Region USA and Year 1960) and Archetype (compared to Archetype Full Motorisation and Year 1960).

To	Regions SEM			Archetypes SEM		
	From	Coefficient	p-value	From	Coefficient	p-value
Ln (Car km/capita)	Ln (PT pass km/capita)	-0.1	0.001	Ln (PT pass km/capita)	-0.052	0.363
Ln (Car km/capita)	Ln (Urban density)	-0.151	0.025	Ln (Urban density)	-0.352	0.000
Ln (Car km/capita)	Region Western Europe	-0.597	0.000	Weak Centre	-0.315	0.003
Ln (Car km/capita)	Region Canada	-0.402	0.000	Strong Centre	-0.3286	0.041
Ln (Car km/capita)	Region Australia	-0.308	0.000	Traffic Limiting	-0.442	0.004
Ln (Car km/capita)	Year 1970	0.316	0.000	Year 1970	0.338	0.000
Ln (Car km/capita)	Year 1980	0.591	0.000	Year 1980	0.561	0.000
Ln (Car km/capita)	Year 1990	0.801	0.000	Year 1990	0.762	0.000
Ln (Car km/capita)	Year 2000	0.856	0.000	Year 2000	0.814	0.000
Ln (PT pass km/capita)	Ln (PT service km/cap)	1.112	0.000	Ln (PT service km/cap)	0.876	0.000
Ln (PT pass km/capita)	Ln (Urban density)	0.274	0.020	Ln (Urban density)	0.149	0.111
Ln (PT pass km/capita)	Ln (Road length/capita)	-0.229	0.018	Ln (Road length/capita)	-0.034	0.699
Ln (PT pass km/capita)	Region Western Europe	-0.39	0.001	Weak Centre	0.483	0.000
Ln (PT pass km/capita)	Region Canada	-0.163	0.070	Strong Centre	0.748	0.000
Ln (PT pass km/capita)	Region Australia	0.151	0.078	Traffic Limiting	0.544	0.000
Ln (PT pass km/capita)	Year 1970	-0.03	0.723	Year 1970	-0.108	0.319
Ln (PT pass km/capita)	Year 1980	0.107	0.192	Year 1980	0.014	0.748
Ln (PT pass km/capita)	Year 1990	0.106	0.199	Year 1990	0.033	0.648
Ln (PT pass km/capita)	Year 2000	0.051	0.543	Year 2000	-0.010	0.888
Ln (Urban density)	Ln (PT service km/cap)	0.254	0.000	Ln (PT service km/cap)	0.203	0.049
Ln (Urban density)	Region Western Europe	0.921	0.000	Weak Centre	0.078	0.629
Ln (Urban density)	Region Canada	0.417	0.000	Strong Centre	0.493	0.011
Ln (Urban density)	Region Australia	-0.322	0.000	Traffic Limiting	1.131	0.000
Ln (Urban density)	Year 1970	-0.099	0.270	Year 1970	-0.090	0.468
Ln (Urban density)	Year 1980	-0.253	0.003	Year 1980	-0.181	0.115
Ln (Urban density)	Year 1990	-0.29	0.001	Year 1990	-0.198	0.083
Ln (Urban density)	Year 2000	-0.324	0.000	Year 2000	-0.228	0.047
Ln (Road length/capita)	Ln (Urban density)	-0.809	0.000	Ln (Urban density)	-0.834	0.000
Ln (Road length/capita)	Ln (PT service km/cap)	-0.092	0.075	Ln (PT service km/cap)	0.153	0.033
Ln (Road length/capita)	Region Western Europe	0.078	0.478	Weak Centre	-0.243	0.026
Ln (Road length/capita)	Region Canada	0.231	0.007	Strong Centre	-0.436	0.001
Ln (Road length/capita)	Region Australia	0.282	0.000	Traffic Limiting	-0.418	0.011
Ln (Road length/capita)	Year 1970	-0.047	0.567	Year 1970	-0.030	0.719
Ln (Road length/capita)	Year 1980	-0.044	0.581	Year 1980	-0.06	0.527
Ln (Road length/capita)	Year 1990	-0.055	0.495	Year 1990	-0.072	0.309
Ln (Road length/capita)	Year 2000	-0.028	0.732	Year 2000	-0.054	0.354
<b>Summary Statistics</b>						
Equation R <sup>2</sup>	Ln (Car km/capita)	<b>0.886</b>		Ln (Car km/capita)	<b>0.821</b>	
	Ln (PT pass km/capita)	<b>0.928</b>		Ln (PT pass km/capita)	<b>0.939</b>	
	Ln (Urban density)	<b>0.833</b>		Ln (Urban density)	<b>0.690</b>	
	Ln (Road length/capita)	<b>0.857</b>		Ln (Road length/capita)	<b>0.849</b>	
N		<b>112</b>			<b>112</b>	
Chi Squared		<b>3.973</b>			<b>12.185</b>	
Degrees of freedom (df)		<b>2</b>			<b>2</b>	
CFI (> 0.900)		<b>0.998</b>			<b>0.988</b>	
NFI (> 0.950)		<b>0.996</b>			<b>0.986</b>	
NNFI (> 0.900)		<b>0.959</b>			<b>0.765</b>	
RMSEA ( >> 0.05)		<b>0.094</b>			<b>0.213</b>	
Note: CFI - comparative fit index; NFI - normed fit index; NNFI – non-normed fit index; RMSEA - root mean square error of approximation. ** With the corresponding analysis limit values shown in brackets						

## **5. Discussion**

This research paper is the first to econometrically model the Global Cities database over a four-decade period, use regional classifications to segment the data, and introduce the use of city archetypes to explain car VKT/capita. The results of the time, region and archetype dummy variables across all the econometric methods applied will be discussed first, followed by an analysis of the key individual explanatory variables: urban density and public transit extent and usage.

### ***5.1. Time Period Dummy Explanatory Variables***

The time period dummy variables were included in the global cities data for the years 1960, 1970, 1980, 1990, and 2000 to estimate time period fixed effects. All the modelling techniques demonstrated that VKT per capita has been growing over time, though the data in Table 4 and the box plot in Figure 1C show the rate has slowed. This is consistent with the peaking in car use in the next period of urban development in the 21<sup>st</sup> century (Newman and Kenworthy, 2011).

The variance in VKT across the 26 cities analysed has grown with time. The year 1960 was treated as the base year and the subsequent time periods were seen as changes in VKT per capita with respect to that in 1960. The average absolute growth in VKT per capita since 1960 across the 26 cities was 120%. The SEM analysis results in Table 5 suggest that VKT growth of 86% can be attributed to the time period, all other things held equal.

### ***5.2. Region Dummy Explanatory Variables***

The US had the highest levels of car VKT per capita, while the other regions were at significantly lower levels. The econometric modelling methods were structured to treat the US as the reference region, with the other regions being compared to it.

The SEM method illustrated in Figure 3 compared the US cities to those in Western Europe had the lowest VKT per capita (-60%), followed by the Canadian cities (-40%) and then the Australian cities (-31%). Table 6 also illustrates the SEM method's analysis of urban density, where the Western European cities had the highest urban density (92% greater than US cities), followed by the Canadian cities (42% greater than the US) and finally the Australian cities having the lowest density (32% lower than US cities).

Whilst some of these results are intuitive and reflect the regional changes that result from regional transport modal preference and city form, the results as a whole suggest that the regional differences may be only part of the way to explain car VKT per capita.

### **5.3. City Archetype Dummy Explanatory Variables**

The *Full Motorisation Strategy* cities predictably had the largest car use, followed by the *Weak Centre Strategy* cities, and then the *Strong Centre Strategy* and *Traffic Limiting Strategy* cities. The strong centre and traffic limiting strategies clearly result in the lowest VKT per capita, better than that achieved by the regional difference model for the Western European and Canadian cities.

The traffic-limiting archetype had the lowest car use (49% less than the full motorisation strategy cities) and the highest density (120% higher than the full motorisation strategy cities). The strong centre, and weak centre strategies had the same car use (34% less than the full motorisation strategy cities) though there was a marked difference in the urban density rates between the cities (56% strong centre, and 11% weak centre strategy).

In line with the archetype specifications in Table 3, the SEM results in Table 5 demonstrate that the strong centre strategy cities have the highest transit passenger kilometres per

capita (51% higher than the full motorisation strategy), followed by the traffic limiting and weak centre strategies at 30% higher than the full motorisation strategies.

These strong relationships between urban typologies and their underlying frameworks strongly point to these being an underlying explanation of car VKT per capita. This explanation is pursued next.

#### ***5.4. Urban Density, Transit and Car Ownership Explanatory Variables***

In the SEM model with region and time period fixed effects, increasing both urban density and transit kilometres of service by 1% reduces VKT by 0.2% and 0.16% respectively, while increasing road length per capita by 1% increases VKT by 0.02%. The car ownership and parking spaces per 1000 CBD workers controls did not make it into the final model as they fell out during the iterative system specification process. The SEM with archetype dummies produced a similar urban density elasticity compared to the region SEM but reported a more modest transit service level elasticity of -0.07.

## **6. Conclusions**

The structural equation modelling undertaken in this study indicates that urban density and transit service provision have a causal relationship with private vehicle travel and are additional to the influences of the region and typology of cities. A further causative factor beneath this is the provision of road capacity. The modelling also very clearly demonstrates that rail-based transit services are the most strikingly linked to reduction in VKT per capita (Figure 1D). Thus the policy implications for global cities seeking to limit car dependence are that they should be supporting the investment in quality rail transit systems and building up urban densities around them, rather than increasing road capacity.

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## **BOOK CHAPTER 1: URBAN TRANSPORT AND SUSTAINABLE DEVELOPMENT**

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## **Urban Transport and Sustainable Development.**

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### **1. INTRODUCTION**

The idea of sustainable development is highly relevant to the world's cities. Cities have been the major source of social and economic opportunity for the growing world population for around 8000 years, but in the last century this has dramatically increased. In this period of industrialization and globalization, the world's cities have been creating opportunity at the expense of ecological footprint. Growing consumption of resources and the subsequent growth in wastes has had its local, regional and global impacts (Newman and Kenworthy, 1999). Today cities are responsible for around 40% of the world's greenhouse gases (GHG). Thus the challenge of sustainable development in cities is how they can continue to play their historic role as providers of social and economic opportunity whilst reducing, not increasing, in their ecological footprint. Put simply the challenge to the world's cities is to reduce their ecological footprint whilst improving liveability (Newman and Kenworthy, 1999, Newman, 2006).

Transport is the fundamental technological force that shapes cities. As most ecosystems are shaped by certain limiting parameters such as their temperature, rainfall, or nutrients, cities are limited in size by their transport systems due to the Marchetti limit on travel time. As humans do not like to travel more than one hour a day on average (Marchetti, 1994, Newman and Kenworthy, 1999, Zahavi and Ryan, 1980), cities have grown to be 'one hour wide'. Traditional Walking Cities were usually no more than 3 to 5 kilometres (km) across (as walking speeds are around 3 to 5 kilometres per hour (kmph)). The 19th and early 20th century Transit Cities could spread out 20 km and followed the train and tram tracks (based on average tram and train speeds of 20 kmph). Once the car became the dominant force in cities they could spread out more than 50 km (based on an average car travel speed of 50 kmph). The Automobile City was not tied to train and tram lines, nor to the time and

speed limitations of walking, and cities were able to spread in every direction a road could be built. Many cities developed around the transport technology and infrastructure requirements of cars to such a point that residents became dependent on using a car to access all their daily needs – known as *automobile dependence* (Newman and Kenworthy, 1989, 1999).

All cities have combinations of these three city fabrics. No city has yet been found that is not shaped by these primary movement functions. Thus urban transport has a major role in shaping future cities to meet the multiple dimensions of sustainable development. The challenge for urban transport is to see how to enable the transport system and its associated urban form to facilitate the reduction in ecological footprint whilst enabling the city to improve its liveability. Whilst this will undoubtedly involve a significant improvement in the technological efficiency of motor vehicles and also a greater use of more sustainable fuels, if the city continues to build in more and more car dependence it will not address the issues of ecological footprint or enhanced liveability. There are many transport based economic issues related to the inefficient use of land and infrastructure budgets as well as automobile congestion, urban sprawl, GHG emissions and health issues (Trubka et al, 2010 a, b, and c). Automobile City expansion will mean cities are unable to achieve a more sustainable future (Asian Development Bank, 2012, United Nations Human Settlements Programme, 2013). Awareness of this has not been without contention as many commentators in automobile dominated cities could not imagine a more liveable city (e.g. Gordon and Richardson, 1989). However the global debate has shifted to seeing how a more balanced city can be created where car use is not such a requirement for all trips and destinations (see above and Intergovernmental Panel on Climate Change (IPCC), 2007) in order to create outcomes that are more equitable, healthy and economic (Matan and Newman, 2012, Newman and Matan, 2012, Matan et al., 2012, Trubka et al., 2010a, b and c).

The next phase of urban development is therefore often described as a Polycentric City with a much greater role for the Walking City and the Transit City together with modifications to the Automobile City.

This chapter will look at the recent trends in urban transport and city development that suggest how these roles are beginning to transition from the less sustainable to the more sustainable, and how the changes can be accelerated and structured into three urban form typologies: the Walking City, the Transit City and the Automobile City.

## **2. THE WALKING CITY**

Walking, until the popularity of motorised transport, was the dominant form of transport in cities since urban settlements began (Crawford, 2002, Kostof, 1992, Newman, 2003, Newman and Kenworthy, 1999) and cities have traditionally developed around walking (“the slow pedestrian”) as the dominant mode of transport (Burchard, 1957:112). 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 rapid form of social and economic interaction. Modern cities are now redeveloping and restructuring their urban cores to be more walkable and vibrant in order to address the growing cultural and economic shift towards more sustainable and more urban lifestyles (Brookings Institution Metropolitan Program, 2008, Newman and Kenworthy, 2011b, Newman and Newman, 2006). Many cities are seeking to attract educated residents to facilitate knowledge-oriented and services-oriented economic development and this happens best in Walking City fabric where face-to-face interactions are easy (Florida, 2002, Gehl, 2010). There is also a social equity motivation with the need to accommodate the car-less in such walkable urban centres.

The Walking City goes beyond providing basic pedestrian infrastructure to be more about creating cities that are attractive, liveable and equitable. Walkable urban environments need to be accessible, containing not only appropriate pedestrian infrastructure but also have the necessary urban destinations within close proximity

(Forsyth and Southworth, 2008, Matan, 2011). This requires urban areas that are dense and compact with mixed land use and accessible public transport and public space, particularly green space (Ewing and Cervero, 2010, Forsyth and Krizek, 2010, Guo, 2009, Handy et al., 2005, Jackson, 2003, Larco et al., 2011, Saelens and Handy, 2008, Saelens et al., 2003, Soltani, 2006). Pedestrian infrastructure needs to be safe, barrier-free, pleasant and interesting, inviting people to walk. These features go beyond simply encouraging walking for transport purposes to include understanding and recognition of how people experience and use urban spaces and thus refocus transport planning within Walking Cities to suit people and their needs, rather than car-based mobility (Matan, 2011, Wunderlich, 2008).

The sustainability of the Walking City is well recognised. Walking is one of the healthiest ways to get around our cities for both public and environmental health (Hoornweg et al., 2011, Huy et al., 2008, Newman and Kenworthy, 1999, Newman and Matan, 2012, Pucher and Buehler, 2010). Furthermore, walkable areas have been shown to have significant economic benefits, including increased real estate values (Sohn et al., 2012), increased productivity (Trubka et al., 2010c), reduced physical health costs (Litman, 2012, Frank et al., 2004, Matan et al., 2012, Trubka et al., 2010c), reduced mental health costs (Stanley et al., 2011a, Stanley et al., 2011b), and reduced congestion related costs, vehicle related costs and reductions in roadway provision (see for example Sinclair Knight Merz and Pricewaterhouse Coopers, 2011). Walkable areas also enable a reduction in transport externalities such as noise and air pollution and GHG emissions (Rabl and de Nazelle, 2012). This reduction in motorised traffic externalities in addition benefits pedestrians and cyclists, who can be exposed to high levels of air pollution in certain urban microenvironments of the Automobile City such as in busy street canyons (Kaur et al., 2007).

Globally there is a move towards reclaiming space that was for cars and car parking and to turn this space into spaces for people (Gehl, 2010). This process can be seen in the pedestrianisation of city centres, the implementation of bicycle ways and in the reduction of the provision of on and off street parking. The adaptation to Walking City design has been facilitated by the work of Danish academic, architect and urban

designer Jan Gehl and Gehl Architects. Gehl is one of the most internationally recognised urban designers and has made substantial contributions in over 40 cities around the world including in Copenhagen, Melbourne and New York (Matan, 2011, Matan and Newman, 2012, Gehl Architects, 2013). Gehl has demonstrated that each improvement to the pedestrian environment results in an increase in the level of activity in the city spaces.

Perhaps the biggest current example of a city implementing sustainable streets and reclaiming public space is New York. To become a sustainable city and to accommodate an additional one million people by 2030, the City of New York and the Department of Transportation (NYDOT), headed by Commissioner Janette Sadik-Khan, hired Gehl Architects in 2007 to survey the pedestrian environment in New York. Unsurprisingly, the survey found that New York has many pedestrians, however, it also found that many of the footpaths were overcrowded, there were few places to sit, and although New York has many public places, many were difficult to access and exhibited an unwelcoming environment (as measured through numbers of youth and older users). It was determined that people were primarily walking only for transport purposes—they were on the streets to move quickly from A to B—rather than to spend time in the public realm.

Following the conclusion of the surveys, the City of New York and NYDOT have rapidly been implementing changes to the public realm and to the walking and cycling environment with the aim of using road capacity more efficiently. The most visible changes include new plazas throughout the city, most notably at Times Square, and the redevelopment of Broadway into a ‘Boulevard’ (New York City Department of Transport, 2010). In addition, the City and NYDOT have been rapidly building cycle paths throughout the city. They completed 320 km of cycle ways between June 2007 and November 2009 with a plan to have nearly 3000 km in their bicycle network, as well as extending footpaths and other pedestrian infrastructure throughout the city. Most of the changes have been quick and simple infrastructure changes focusing on repainting road surfaces and the redistribution of road space through bollards, planting boxes and fold-out chairs.

The closing of Broadway to cars at Times Square has been the most visible symbol of the city's pedestrianisation. On May 23rd, 2009, Broadway was closed to through traffic at Herald Square between 47th and 42nd Streets initially as an experiment. This was made permanent in February 2010. The closure has resulted in a "seven percent improvement in traffic flow" (Gehl Architects, 2011: n.p.n.), with northbound taxi trips found to be 17% faster after the Broadway shutdown (comparing Fall 2009 to Fall 2008) (City of New York, 2011, New York City Department of Transport, 2010). The closure has shown significant economic benefits to the businesses at Times Square, with 71% projecting revenue increases after the closure (City of New York, 2011).

The changes in New York did not happen smoothly, and created much controversy. The City and NYDOT persevered, however, and now the results are becoming evident. Throughout the project areas pedestrian numbers have increased, pedestrian injuries have fallen by 35% and 80% fewer pedestrians walk in the roadway in Times Square (City of New York, 2011, Taddeo, 2010). Between June 2007 and November 2009, cycling to work doubled in New York, with commuter cycling increasing by 35% between 2007 and 2008 (New York City Department of Transport, 2010). These changes to the city's multimodal transport system demonstrate how quick changes can be made to improve the walkability and public realm, and to reclaim the Walking City from the automobile. The Commissioner explains these changes: "until a few years ago, our streets [in New York] looked the same as they did fifty years ago. That's not good business... We're updating our streets to reflect the way people live now. And we're designing a city for people, not a city for vehicles" (Taddeo, 2010: n.p.n.).

The City of Melbourne shows perhaps the most dramatic results of all the Australian cities in illustrating how positive changes to the public realm can result in synergistic increases in walking and city life, offering "a remarkable case study in an emerging pedestrian city, having shown some dramatic, positive change in its pedestrian character and public sphere in the relatively short span of twenty years" (Beatley and

Newman, 2009: 134). The City of Melbourne deliberately focused on restoring and strengthening the city's traditional grid pattern and redesigning footpaths and alleyways to create a walkable interesting urban environment. Two surveys (1993-94 and 2004) measuring and monitoring the changes have been made by Gehl and the City of Melbourne enabling a decade of work by the City to be evaluated. The surveys demonstrate that there have been:

- An increase in the number of people walking in the city centre. The number of pedestrians in the city centre on weekdays in the evening has increased 98% (from 45,868 in 1993 to 90,690 in 2004), and daytime pedestrian traffic has increased by 39% (from 190,772 in 1993 to 265,428 in 2004);
- An increase in public space by 71% via creation of new squares, promenades and parks (From 42,260 m<sup>2</sup> in 1994 to 72,200m<sup>2</sup> plus Birrarung Marr Park's 69,200m<sup>2</sup> in 2004) and an increase in the number of people spending time in urban spaces;
- More places to sit and pause, with an increase in cafés and restaurants (from 95 in 1994 to 356 in 2004), a threefold increase in café seats outdoors (from 1,940 in 1993 to 5,380 in 2004) and an integrated street furniture collection; and
- Improved streets, including the revitalization of a network of lanes and arcades (Gehl Architects, 2004).

These examples of Melbourne and New York illustrate the growth of the Walking City. There are many other examples around the world of this growing cultural and economic shift towards creating walkable urban cores and redistributing city space from automobiles to people, reinvigorating the liveability of the Walking City and at the same time reducing the ecological footprint.

### **3. THE TRANSIT CITY**

Trends in car use and transit use are reversing globally with most developed cities showing 'peak car use' and most cities in the developed and developing world are

now rapidly growing in transit use, especially in rail (Newman and Kenworthy, 2011b, Newman et al., 2013).

The biggest change in the economy during the period leading up to and including the period of car use decline and transit growth has been the digital transformation and the consequent knowledge/service economy. This has been a concentrating force in terms of city structure and fabric across the world's cities. Newman and Kenworthy (2011b) present new data on global cities showing a universal increase in urban density in the past decade or so, reversing over one hundred years of decline in most cities. The knowledge economy and digital jobs are focused in city centres, as these are where the creative synergies between people occur (Kane, 2010). This has been best achieved in the old central business district's (CBD's) as well as the sub centres based along transit lines. As shown above, the transformation of Walking Cities is well underway but so too is the transformation of the old inner suburbs based along tram lines or metros and the old rail corridors of centres strung along like pearls on a string. All these areas are where high intensity people-based activity gravitates such as large health and education facilities enabling creative synergies between business people requiring especially intensive information technology (Kane, 2010). Transit-oriented development (TODs) at all these centres has begun transforming the existing urban fabric and has become the basis for the revival of the Transit City.

As with many economic changes, there is also a cultural dimension to this change that perhaps explains the rapidity of the changes in transport observed by Newman et al (2013) as well as the demographic complexion of the change. Young people (especially those involved in knowledge economy jobs) are moving to reduce their car use, with a significant trend in the reduction in those obtaining a driver's license (0.6% per annum), as they switch to alternative transport faster than any other group (Delbosc and Currie, 2013, Metz, 2013). This has been recognized by a few commentators and is related to the use of social media devices (Florida, 2010, Metz, 2013). Whilst on transit or while walking, people are already connected by their smart technology phones and tablets, thus driving is less preferred as it is increasingly being outlawed to drive while using such devices. The Davis, Dutzik

and Baxandall (2012) report shows that the mobile phone is a far more important device than a car for younger people and this is part of the cultural revolution that underlies the rail transit revolution. Baby-boomers (those born after the Second World War, from 1946 to 1964) gained freedom and connection with a car, Gen Y's (those born early 1980s to the early 2000s) are not needing one but like to save time on a fast train while constructively relating to their friends and work (Goodwin and Van Dender, 2013).

The other expression of this change is that younger people are moving to live in the Walking City or Transit City, as these locations more readily enable them to express the kind of urban experience and culture that they aspire to (Florida, 2010, Metz, 2013). Thus they feed the market that enables the Transit City and Walking City renewal to continue.

Other parts of the economy such as manufacturing, small and large industry, freight transport and storage, have remained vehicle-based and are outside this new knowledge economy. It is expected that they will remain so, as they are also not where the growth in jobs or the growth in wealth is happening. Thus the Automobile City economy and culture has become somewhat distinct from the new regenerated urban economy of knowledge/services and its basis in Walking and Transit City locations. In many cities the Automobile City fabric is becoming significantly less wealthy than the Walking City and Transit City fabrics (Florida, 2010, Glaeser, 2011, Newman et al, 2009).

The rise of rail transit (as well as the reduction in per capita car use) can be explained by a combination of urban structural limits together with urban cultural and economic change that together enable us to see a different kind of urban future emerging. Cities that are responding to the powerful new agenda for building rail transit systems can enable this new, less car dependent city to emerge. However, if a city does not adequately develop or build the rail infrastructure required then it can easily miss out on this important social and economic change (Metz, 2013). The biggest threat is if car dependent cities do not recognize that the golden age of the car is over. Metz (2013) suggests that this transition, which is observable in most

developed cities, could occur at a lower level of Gross Domestic Product (GDP) in most developing cities and thus enable a rapid global transition to reduced ecological footprints especially GHG from transport.

There are a few emerging trends in best practice for Transit Cities that can enable large and small cities to capitalize on the opportunities that are now presented by this global new world. These include:

- 1. Integration of modes.** Rail is most effective when it is properly integrated with bus feed-in services to enable a broader catchment to be served. This is particularly evident in car dependent cities, where rail cannot be served by just by walk-on passengers. This requires ticket integration and fast and convenient transfer systems. Perth's Mandurah rail line (outlined in more detail below) illustrates this well with some 80% of the ridership coming from bus transfers and only a very small percentage from Park and Ride, despite generous Park and Ride provision (McIntosh et al., 2011). The provision of bus right-of-way into stations is a critical part of enabling this integration. Of course, integration with bicycles is also an opportunity that offers huge rewards, as evidenced by looking at the surroundings of any Dutch or Danish railway station, or even the new, specially designed secure bike parking areas around Sao Paulo's commuter rail system or those in Seoul.
- 2. Integration of land use.** Rail transit will be optimised if there is a chance to redevelop non supporting land uses around the stations in order to enable more people to have easy access. Measuring this potential and making it part of the planning process seems to be an emerging standard practice (Bachels and Newman, 2011, Renne and Curtis, 2011). Where Park and Ride is needed, it should be integrated with attractive high density, mixed use development and not as vast swathes of bitumen, which destroy station environments (Schiller and Kenworthy, 2011).

- 3. Speed.** The value of travel time will not change much in this new world and must be central to how any rail system is designed. Giving reasonably long station distances and separate right-of-way is critical in order to enable speed that is competitive with the car (McIntosh et al, 2013). Light rail running on dedicated right-of-way, rather than on-street tram or bus options, will be mostly needed in car dependent cities to compete with the car in speed.
- 4. PPP (Private-Public Partnership) Procurement.** The delivery process can enable all of these options to be highlighted if procurement is based on a PPP process, as suggested by many (e.g. Bottoms, 2003, Infrastructure Australia, 2012). The Gold Coast Light Rail provides the best example in Australia of how PPP approaches can be achieved in light rail and the new Manchester City Deal shows how rail PPP's can work in the UK. The full integration with land use remains to be done and is much more likely if land value capture (see below) is made part of the package.
- 5. New assessment approaches for rail.** There are two major ways for the assessment of rail projects to be improved through the transport economic assessment process: recognizing the role of agglomeration economies in the Benefit-Cost Ratio (BCR) and recognizing the role of avoidable land development costs. Agglomeration economies are being included in transport BCR's since the Eddington Transport Study in the UK (Eddington, 2006). The application of BCR and agglomeration economies in rail is considerably better than road projects as rail acts as a focusing feature that enables the synergies and clustering of knowledge economy productivity. The London Cross Rail went from 1.5 to 3.0 in its BCR when agglomeration economies were added. Trubka (2011) has outlined the value of agglomeration elasticities for Australian cities. Even more significant (though rarely done) is the use of avoidable costs in assessment of transport. Rail and its focusing ability in land use can enable reductions in urban sprawl that invariably are heavily subsidized and have many external costs. Trubka et al (2010a, b and c) have shown considerable cost savings and health benefits from rail-

oriented development as opposed to car-based development that can be included in any transport assessment.

6. **New approaches to funding rail through value capture.** Rail infrastructure increases land value due to its accessibility benefits. This increase in financial value can be captured and used to help fund the infrastructure. McIntosh et al (2011) have shown that a five-step process can work in the following way:
  - a. Accessibility benefits analysis to demonstrate the land area where owners will benefit most from the new infrastructure.
  - b. Land value data collection of the differential between those areas varying in accessibility. This can be around 20-25% for residential land values and over 50% for commercial land values.
  - c. Assessment of the various potential financing mechanisms available in the city through public and private value capture, e.g. government land and parking revenues.
  - d. Economic and financial assessment of how much land value can contribute to the funding of the rail through a dedicated fund based on land value taxes that are going to increase due to the new rail system.
  - e. Delivery through a planning mechanism and a fund established to bring it together, probably in a PPP as in the Manchester City Deal project.

If rail is going to continue to grow and car use to decline then a range of sophisticated value capture mechanisms will be needed for each city to make the most of this opportunity for funding.

Perhaps the most significant trend in recent years in Australia and America following the lead of Europe has been the emergence of light rail as a solution in small car dependent cities. Lobby groups in Australia have been actively pushing the political case for light rail in Canberra, Hobart, Bendigo, Darwin, Newcastle, Cairns, the Sunshine Coast and Parramatta. These cities are mostly well under 300,000 people, Canberra being the largest at a little over 300,000. Similar trends have been observed in the US (Bottoms, 2003).

There are 545 cities with light rail according to Wikipedia; from this there are now 118 cities with populations under 150,000 that have light rail or are constructing light rail. This appears to suggest that a changing appreciation of the value of light rail in small cities has occurred. The change is probably associated with the shift in value associated with the trends in peak car use, fuel prices, urban traffic speed trends and urban economic and cultural changes outlined above and in Newman et al (2013).

The question needs to be asked whether light rail is likely to be a viable option for these small cities, since the traditional approach would suggest it was not. Bus options have long been considered the only viable option for small cities. However, the above dramatic turnaround in the fortunes of light rail may be indicating that a new era of desirability and viability for light rail in small cities is emerging. The case for these cities to be considered suitable for light rail is based on an understanding of what is likely to be causing the above trends in traditionally car-dominated cities, as well as some new options for assessing and funding light rail in such cities as the basis of regenerating or extending the Transit City in smaller cities.

#### **4. THE AUTOMOBILE CITY**

Newman and Kenworthy (1989) first coined the term automobile dependence in their book *Cities and Automobile Dependence*. The data from 32 global cities provided urban metrics for their analysis, including:

- gasoline consumption,
- public and private transport system modal split,
- degree of infrastructure provision for the automobile (road supply and parking) relative to transit, and
- a measure of urban density and of urban centralisation.

Twenty years later the parameters are all showing that automobile dependence has begun to decline and perhaps we are witnessing its demise (Newman et al, 2013). The one hundred year growth in the use of the automobile in cities appears to have plateaued and then declined across the world's developed cities (Goodwin and Melia,

2011, Gargett, 2012, Newman and Kenworthy, 2011b). Demonstrations of how Automobile Cities are being restructured with rail transit are now being seen. This trend back to rail based transit is perhaps to be expected in the relatively dense cities and in countries in Europe, the Middle East and Asia. However, perhaps the more surprising trends have been in the traditional car dependent cities of the US, Canada and Australia that were once only considered suitable only for bus transit in their suburbs but are now seeing a future based around rail down corridors deep into their traditional Automobile City fabric.

The beneficiaries from the investment in transit infrastructure in all cities are broad and in areas often not accounted for when deciding on whether to invest in new transit infrastructure. This is often the case in the Automobile City fabric where the key beneficiaries from the investment in transit include:

- Land owners: due to increases in underlying land values.
- Property developers: the potential increase in developed real estate values, faster sales rates and thus reduced holding costs, and lower construction costs due to reduced parking requirements, thus inducing urban infill and TOD.
- Transport system users: a more efficient, less congested transport system results in less time spent in transit, allowing more time for other activities and better transit experience.
- Business owners: increased economic activity due to improved accessibility for their customers and employees to their business, with workers arriving at work less stressed and more productive.
- Federal/State and Local Governments: due to increases in land property based revenue from existing levies and taxes from increased land and property values.
- It is the transit beneficiaries who are driving the change away from the private vehicle to transit, and are helping reshape the centres and suburbs of the Automobile City.

The growth in public transport patronage has occurred for all transit modes, but the highest growth has been in urban rail systems (Newman et al, 2013). In Perth,

Western Australia, the development of a fast rail system deep into car dependent suburbs has been a major success and indicates the main elements necessary for the regeneration of the Automobile City fabric.

Perth's 72 km long Mandurah Rail System opened in 2007. With a maximum speed of 137 kmph and an average speed of almost 90 kmph, this system acts more like a fast rail than a suburban rail system, which in Australia typically averages around 40 kmph for an all-stops services. The Mandurah rail line was very controversial when being planned as the urban areas served by the line are not typical of those normally provided with rail but instead were highly car dependent scattered low density land uses. Nevertheless the rail line has been remarkably successful, carrying over 70,000 people per day (five times the patronage on the express buses it replaced) and has reached the patronage levels predicted for 2021 a decade ahead of time. The reasons for this success include well-designed interchanges, careful integration of bus services, the use of integrated ticketing and fares without transfer penalties and, crucially, the high speed of the system when compared to competing car based trips. Perth's Mandurah rail line was the second in Australia to be implemented in the median of an existing freeway (after the section to the north of Perth). As a result, there is only limited pedestrian catchment along the alignment, and the patronage model for the Mandurah rail line is:

- 7% pedestrian (walk-able) catchment;
- 85% of the total patronage come from passengers that are dropped off and the feeder bus services; and
- 8% of total patronage to come from the 5260 park and ride bays.

This low pedestrian catchment/transfer based patronage model for transit is a major shift for the roles of the different public transport modes, with the park and ride facilities and closely integrated bus interchanges designed to extend the rail line's catchments into the surrounding low density suburbs, using the regional bus network as a feeder service for areas that had previously been car dependent. The other major difference to other public transport systems in Australia is that the public transport

system was designed to be competitive with the private motor vehicle in both time and cost (generalized cost).

One of the most contentious debates in public transport planning is the role of transfer costs in deterring patronage due to time losses. This has been used to stop many rail projects (Hensher, 1999, Currie, 2009). The Mandurah rail line was designed to minimize transfer penalties through well integrated bus interchanges and bus services, and as a result these are responsible for 85% of the patronage, a figure much higher than for most rail systems. This seems to be acceptable to the patrons as the speed of the train means that the overall journey saves time compared to the private vehicle.

There would appear to be a lesson here for all rail planning but especially fast rail in car dependent cities: it is essential to minimise transfer penalties and create speeds that mean the generalized costs of choosing to travel on fast rail are lower than the alternatives (car).

The Mandurah rail line maintains a strong focus on the competitiveness of the public transport against the private motor vehicle in a time and financial generalized cost model for access from the Mandurah suburbs to the Perth CBD and the rest of the rail network. This is illustrated by:

- The competitiveness of the train to the car in time due to the high speed of the trains (maximum speed 137 kmph) compared to the car (freeway speed limit 100 kmph), and due to the congested nature of the competing Kwinana Freeway, which is increasing with peak hour travel speeds being much lower than the theoretical speed limit.
- The introduction of the electronic ticketing system that enabled zero cost transfer between the bus and rail modes, hence removing any transfer cost penalty associated with transferring between modes.

- The frequency of the feeder bus services and the ease and speed of interchange between the bus and rail modes, minimizing the time penalty for transferring between modes.
- The majority of the feeder bus services that transfer to the rail stations do very quickly and conveniently, operate within the single transport ticketing zones, therefore not adding to the trip cost for the overall journey.

This model for the minimization of public transport generalised cost when compared to the private vehicle has enabled Perth's Mandurah rail line to be very competitive with the private vehicle in a region where the Mandurah rail line is located. This area is where the private vehicle has been historically extremely dominant due to low dwelling and population density, and long travel distances for the journey to work. The low generalized cost network design minimizes the time and financial cost for the multimodal trip and induces traditionally car based ridership onto the transfer designed feeder services to the stations, and this is the key success for the intermodal public transport model that operates for the Mandurah rail line.

The application of the Mandurah rail model to the design of high speed intra-city and regional rail for large, low density car dependent cities has now been demonstrated. It shows that a viable alternative is possible to build into any Automobile City.

Recent studies have demonstrated that the land value associated with the Mandurah rail line have increased by over 28% over a five year period. This has been modelled to show that the rail line could have used value capture as a major means of creating finance for building the train service (between 40 and 60% of the capital cost of the project could have been raised by this mechanism) (McIntosh et al, 2014). The land value increases also show why dense Transit City fabric is now being built into the Automobile City fabric and can be further anticipated as the market for these locations becomes more and more attractive. This indicates that the viability of building rail into Automobile City fabric can now be envisaged.

## 5. CONCLUSIONS

This chapter has shown that a major factor in the sustainable development of cities in the future will depend on the extent to which they can create or regenerate areas of Walking City and Transit City rather than areas of Automobile City. Economic change and cultural change seem to be now favouring this opportunity. Demonstrations are happening in cities of all kinds and it will only be the lack of growth opportunities or the legacy of institutional barriers that will prevent it from happening rapidly in cities across the world. Urban transport infrastructure changes can provide the fundamental transformative force in creating more sustainable development patterns in the world's cities.

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# Why Fast Trains Work: An Assessment of a Fast Regional Rail System in Perth, Australia

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## ABSTRACT

Perth's new 72 km long Southern Rail System opened in 2007. With a maximum speed of 137 km/hr and an average speed of almost 90 km/hr this system acts more like a new high speed rail than a suburban rail system, which in Australia typically averages around 40 km/hr for an all-stops services. The Southern Rail Line was very controversial when being planned as the urban areas served are not at all typical of those normally provided with rail but instead were highly car dependent and scattered low density land uses. Nevertheless it has been remarkably successful, carrying over 70,000 people per day (five times the patronage on the express buses it replaced) and has reached the patronage levels predicted for 2021 a decade ahead of time. The reasons for this success are analyzed and include well-designed interchanges, careful integration of bus services, the use of integrated ticketing and fares without transfer penalties and, crucially the high speed of the system when compared to competing car based trips. The Southern Rail Line in effect explodes the current paradigm of transfer penalties, exposing this as a myth. The lessons for transport planning in low density cities are significant, and are explored further in the paper.

**Keywords:** Integrated Ticketing; Fast Rail; Multimodal Patronage Modelling; Feeder Buses; Perth; Western Australia

## 1. Introduction

This paper will try to suggest why a fast rail line that runs within the urban region of Perth works so well and why this may help in the assessment of high speed rail projects. We will initially provide a background to the Southern Rail infrastructure and the catchment which it serves, followed by a description of the Southern Rail patronage model, the rail line's operational model, and a description of its station configurations. This background information will lead to a more detailed discussion of the time and financial costs, or "generalized cost" comparisons between private vehicles and public transport within the Southern Rail's catchment.

Through this lens the paper demonstrates that the Southern Rail line's success in generating a significant mode shift to public transport has occurred through physical, operational and regulatory integration. The paper concludes by examining the possible implications of high speed integrated urban rail systems for making travel in dispersed cities more sustainable.

## 2. Background to the Perth Southern Rail

The Perth Southern Suburbs rail line opened on the 23rd

of December 2007, and it runs 72 km from the Perth CBD to Western Australia's second largest city at Mandurah at speeds up to 137 km/hr. The rail line runs for 70 km of its 72 km length at grade in the median and along the western edge of the Kwinana Freeway.

The line has eleven rail stations along the way at major centers and major road intersections including the underground Perth CBD and Esplanade Stations (see **Figure 1**), with 18 new bridges and 5500 park and ride bays [1].

The Perth Southern Suburbs rail line replaced an existing separated Rapid Busway-based service with an integrated multimodal bus-rail service. The introduction of the rail service cut the journey time from approximately 68 minutes to 48 minutes for the journey from Mandurah to Perth, and increased the existing busway's patronage from approximately 14,000 boarding's/day [2] to the rail line's 48,000 when opened in early 2008 and to 70,000 boarding's/day in 2013.

The Perth Southern Rail Line catchment density (presented in **Figure 2**) is mainly between 6 - 15 dwellings per hectare, which is a very low dwelling density for rail-based public transport services to be considered viable. South of Murdoch station, the average density of



Figure 1. The Perth Southern Rail Line stops and key feeder roads/bus routes [1].

development is even lower, with significant gaps of rural land between settlements.

### 3. Perth Southern Rail Patronage Model

The Perth Southern Rail Line was the second in Australia to be implemented in the median of an existing freeway (after the section to the north of Perth). As a result, there is only limited pedestrian catchment along the alignment. The business case patronage model for the Perth Southern rail line assumed [1]:

- 9% pedestrian (walk-able) catchment.
  - 91% patronage to come from outside the pedestrian catchment, comprising.
- 28% of total patronage to come from the 5260 park and ride bays.
  - 63% of the total patronage to come from kiss and ride

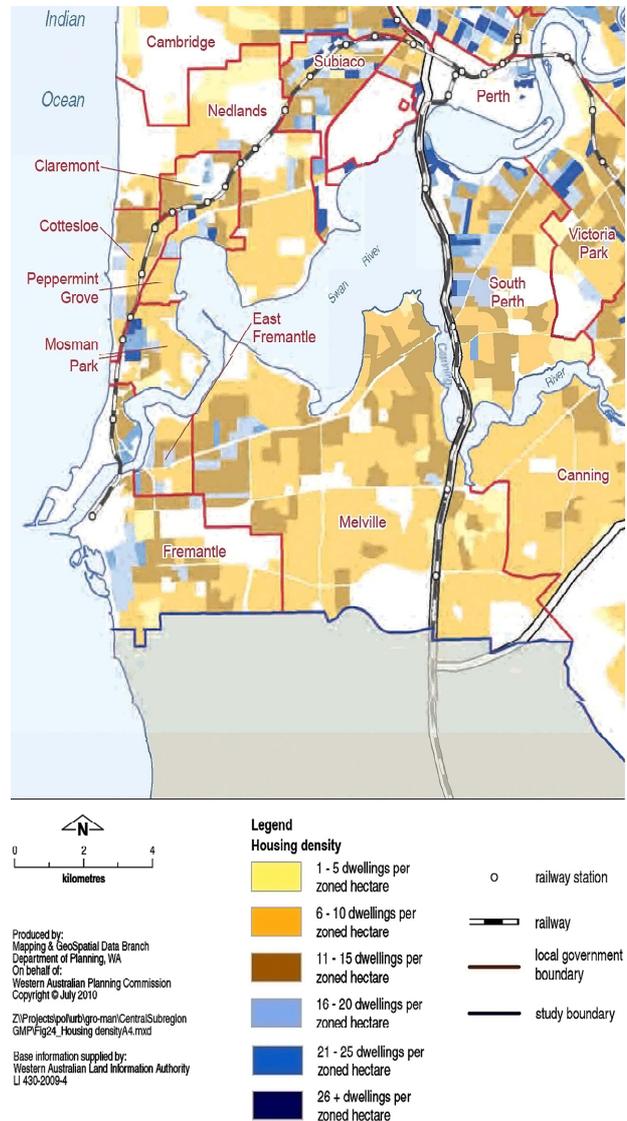


Figure 2. The Perth Southern Rail Line station catchment densities [3].

and the feeder bus services.

The low pedestrian catchment model for public transport infrastructure is a major shift for the roles of the different public transport modes, with the park and ride facilities and closely integrated bus interchanges designed to extend the rail line’s catchments into the low density surrounding suburbs, using the regional bus network as a feeder service for areas that had previously been car dependent.

As discussed later, actual patronage has been significantly higher than forecast, particularly from the feeder bus system. As a result, 85% of the Southern Rail patrons access the train by a bus service, (or line to line transfer), around 8% from the park and ride and the remainder from pedestrian catchment and kiss and ride [4]. This patronage model appears to be a major part of the suc-

cess of the rail system.

The other major difference to other public transport systems in Australia is that the public transport system was designed to be competitive with the private motor vehicle in both time and cost (Generalized cost). This low generalized cost model is a function of the station configurations and the rail line’s patronage and operational model in this low residential and commercial density environment. The “low generalized interchange cost” station configuration will be described in detail later in the paper and show how all the time and financial cost components of the bus to rail interchange have been minimized.

#### 4. Perth Southern Rail Operational Model

The transfer based operational model for the Southern Rail Line is based on a high level of convenience and a low generalized cost to passengers. The Western Australian Public Transport Authority (PTA) achieved this by providing an integrated multi-modal public transport service able to compete with the car for journeys from Perth’s CBD to the key centers and southern suburbs.

The PTA maintains Strategic, Tactical and Operational (STO) control over Perth’s public transport network, with bus operator contracts managed by the PTA, with the PTA retaining the service fare box revenue. The STO framework [5] defines the three levels, or tiers of activities of the transport agency (see **Figure 3**).

The retention of Strategic and Tactical control over the network has enabled the PTA to deliver Perth’s transfer oriented public transport system for the southern suburbs and through the introduction of specific operational attributes primarily:

- Integrated network design and timetabling;
- Integrated ticketing;
- A zone based fare system that enables seamless bus

interchange;

- Additional elements such as the free Central Area Transfer buses.

#### 4.1. Integrated Ticketing and Fares

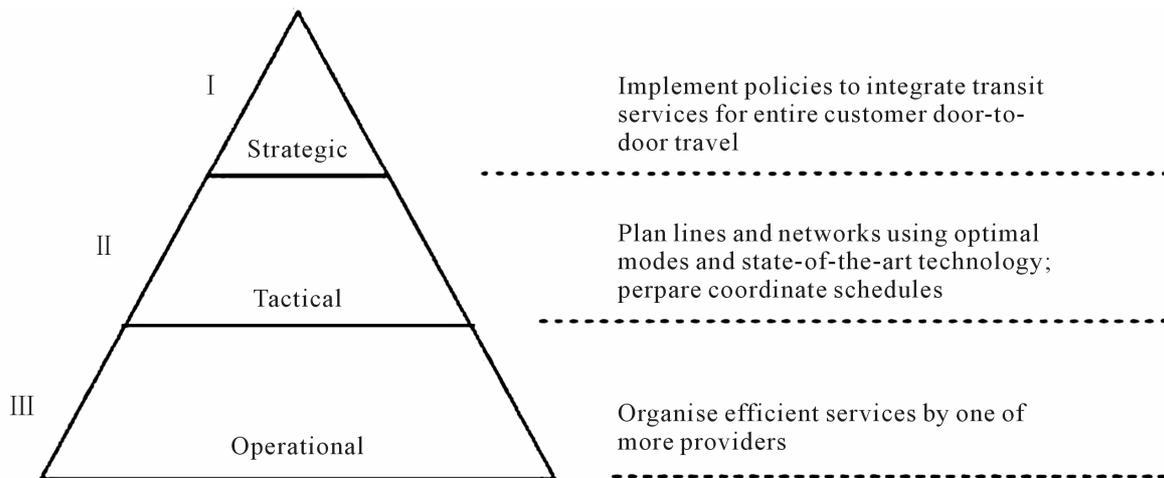
The introduction of integrated multi-modal electronic ticketing prior to the opening of the Southern Rail Line enables convenient transferring between modes without the need to purchase separate tickets. In addition, the fare system used means there is no financial penalty for changing between modes, regardless of modal operator (all of whom are under tactical control of the PTA). The ticketing model for Perth is presented in **Figure 5**.

#### 4.2. Zone Based Fare Structure Facilitating Bus Interchange

Perth’s public transport broad zone based structure (shown in **Figure 5**) has enabled most, if not all, of the bus based feeder services to be “intra-zonal” trips.

Whereby the bus based trip to one of the Southern (or Northern) Rail line stations for a multi-zonal journey does not incur an additional financial cost for the journey. The zone based fare structure therefore enables the feeder bus services to travel along the urban highways that cross the Southern Rail Line stations to quickly interchange people at no financial cost to the passenger thus removing the financial cost penalty to intermodal transfers for the line.

The feeder buses are integrated into stations by placing these at the points where highway overpasses occur thus leading to a direct pedestrian feed-in down an escalator from the bus stop to the train. The feeder buses are integrated into stations by placing these at the points where highway overpasses occur thus leading to a direct pedestrian feed-in down an escalator from the bus stop to the train.



**Figure 3. Conceptual transit operation framework [5].**

### 4.3. Regional Bus Network Structured to Feed the Southern Rail Line

The Southern Rail Line's broad feeder bus patronage catchment is served by a comprehensive bus network that has been structured to enter the low density suburbs and quickly bring the bus patrons to the Southern Rail stations, as well as stations on other lines, to transfer to the rail network.

These transfers are not "forced" as the buses continue onto other key trip attractors and centres. However the system provides bus passengers the opportunity to transfer to a fast trip to the CBD (and other centres across the public transport network) at generally no additional financial cost as the majority of these bus trips are contained within a single travel zone (illustrated in **Figures 4 and 5**).

### 4.4. Central Area Transfer Bus Services

The Perth "Central Area Transfer" bus (CAT bus) services operate free of charge from the rail stations at Fremantle and Joondalup and within the Perth City Council municipal boundaries as a "Free Transit Zone", thus minimizing the cost of travel at either end of the trip origin and destination at these major centers.

To fund the CAT services, the Perth Parking Management Act, 1999 operates within the Perth CBD, and hypothecates the revenue generated to alternative non car

based modes, and in particular public transport (it wholly funds the capital and operating costs of the Perth CAT bus services). This not only acts as a public transport revenue source (and PT trip cost reduction due to the CAT services), but as an additional cost (and disincentive) to private vehicle trips to the CBD.

### 4.5. Perth Southern Rail Station Configurations

As previously mentioned the Perth Southern Suburbs Rail Line corridor is located in the median of the Kwinana freeway for the majority of its distance, and as such the rail stations and their intermodal interchanges are located in the middle of the freeway as well. This constrained location reduces the opportunities for pedestrian catchments for the station. However it does have a number of advantages, in that the station does not require additional land, while the negative externalities of the rail operation are confined to an existing transport corridor.

The integration of a significant bus interchange at the entrance to each of the stations minimizes the transfer time cost between modes (as part of the low generalized cost trip model), and given its controlled nature makes a very safe environment to transfer between modes, and for accessing the park and ride facilities both during the day and at night. The challenges associated with its location are that it limits the amount of ancillary infrastructure that can be co-located within proximity of the station



**Figure 4.** A sample of the western feeder bus catchments for the Southern Rail Line stations of Canning Bridge, Bull Creek and Murdoch [6].





**Figure 6.** (Top) Murdoch station viewed from the Kwinana freeway [8]; (Second top) park & ride facilities in front of the new Fiona Stanley hospital and cycle way between the off ramp and park & ride; (third Top) bus discharge and entry into the station, with electronic bus timetable information at bus bays; (Bottom) lockable bike parking for the cycle commuter, thus providing a full multimodal interchange.



**Figure 7.** Murdoch station [10].

ther road based or public transport congestion, that could be spent doing something more productive.

The concept of generalized cost of a public or private trip is integral in transport planning for the development a transport link's modal choice model through the preparation of a modal utility (a quantitative measure of the benefit/dis-benefit of a particular transport mode). The Southern Rail modal choices can be viewed in a Nested Multinomial Logit model (**Figure 8**).

The modal utilities assigned to each mode are used to determine the probabilities of which mode would be used for a trip for the Southern Rail catchment to the CBD. Due to data limitations this paper has provided a qualitative presentation of the generalized cost input time cost, financial cost and opportunity costs components to understand the generalized cost for private vehicles and the Perth Southern rail line. The actual patronage figures presented later, validate the operational model proposed.

Whilst the financial cost of the car trip is increasing significantly due to the increases in cost of fuel and parking costs into the CBD (see **Figure 9**), it is the competitiveness of the Southern Rail Line with the private vehicle due to congestion on the competing Kwinana Freeway which gives the Southern Rail its real edge.

The effect of road based congestion on Perth's com-

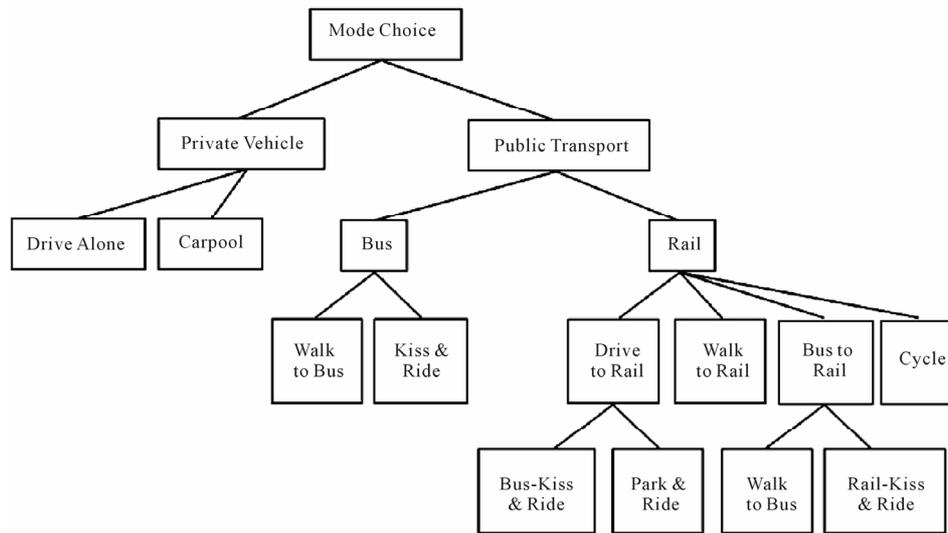


Figure 8. The Perth Southern Rail Line catchment multinomial nested logit mode choice model (using [13]).

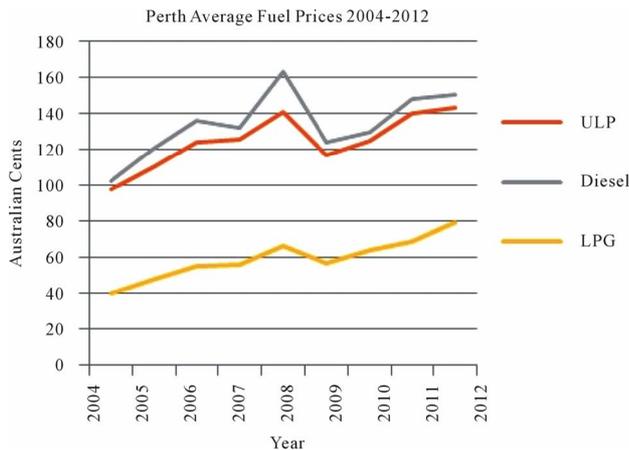


Figure 9. Perth retail fuel prices 2004-2012 [14].

muters has been verified by the Royal Automobile Club of Western Australia (RACWA), which in 2012 conducted their annual survey of 400 Perth businesses on the effects of road based congestion. This survey showed clearly that congestion was having a significant impact on the operation of their businesses and staff. This is reflected in **Figure 10**, which disturbingly shows that 82% of business believed congestion was causing lost productivity and 74% believed it was reducing staff punctuality.

This road based congestion on Perth’s road network is at its peak on the northern Mitchell freeway and southern Kwinana freeway, both of which are served by the high speed rail network, and it is argued that it is this road based congestion and high speed nature of the competing rail journeys that is driving the modal shift over the public transport in the Northern and in particular Southern catchments.

**Table 1** qualitatively presents the generalized costs for a private vehicle and public transport “Journey to Work”

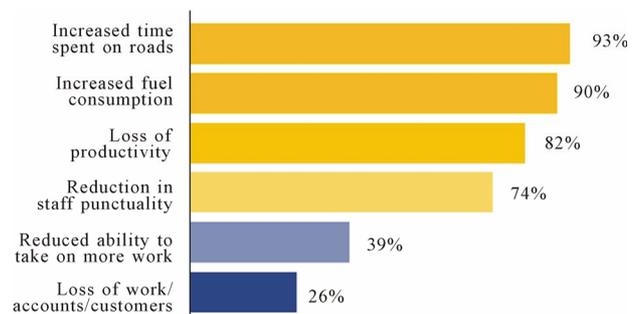


Figure 10. RACWA 2012 survey results on the prompted impact of traffic congestion [15].

trip to the CBD during the AM peak, and these are used to frame the mode choice discussion with regard to the Southern Rail catchment.

**Table 1** clearly demonstrates that the public transport trip can provide a lower generalized cost for the trips to the CBD, and although this is only qualitative, the impact on passenger’s modal utility and subsequent mode choice is obvious. This is reflected in the growth in the patronage of the Southern Rail line.

## 6. Perth Southern Suburbs Rail Operational Performance

The overall Perth rail network has increased patronage by 83% from 2007 to 2012, (see **Figure 11**). The transport business case for the Perth Southern Suburbs rail line was developed for the WA State government, by the consulting firm Sinclair Knight Merz (SKM) initially in 1999, and then this model was independently reviewed by Planning and Transport Research Centre in WA (PATREC) in 2004 [2].

Neither SKM nor PATREC were able to model how successful the Southern Rail Line would be at attracting

patronage from the low density southern suburbs of Perth (as shown in **Figure 2**), as SKM’s 2031 patronage forecast for the project was exceeded in the Southern Rail’s first year of operation. The significantly more optimistic patronage model prepared by PATREC [2] (shown as PATREC Rail in **Figure 11**) still underestimates the impact of the patronage from the Southern Rail line, where the estimated 2021 total annual boardings for the network were exceeded in 2012.

Indeed the 2031 patronage forecast for the line and the greater Perth rail network is likely to be exceeded in 2014/2015 assuming that rail line does not get affected by a capacity constraint incurred by insufficient rolling stock provision which subsequently limits the growth of

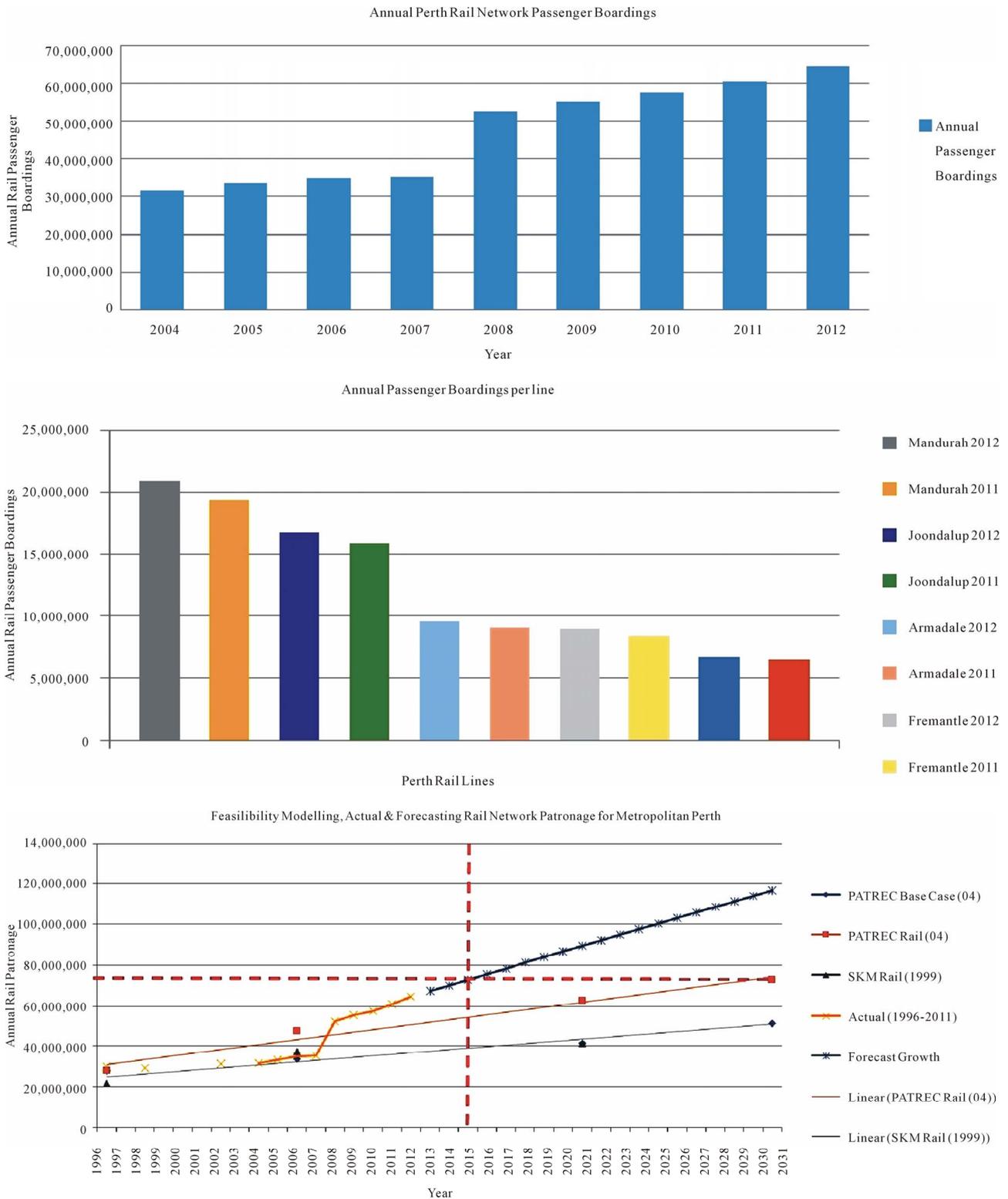
the network (**Figure 11**).

### 7. Lessons of Fast Rail for Low Density Cities

One of the most contentious debates in public transport planning is the role of transfer costs in deterring patronage due to time losses. This has been used to stop many rail projects [18,19]. The Southern Rail was designed to minimize transfer penalties by well-integrated bus interchanges and bus services. As a result these are responsible for 85% of the patronage, a figure much higher than for most rail systems. This seems to be acceptable to the patrons as the speed of the train means that the overall

**Table 1. Qualitative generalised cost inputs for the perth southern rail mode choice model.**

	Time/\$Cost Attribute	Private Transport	Public Transport	Discussion
Time Cost	Access time	nil	low	Low time cost to access PT due to the options to get the Southern Railway; High frequency feeder services; Park and ride at stations
	Waiting time	nil	low	The high frequency of feeder and southern rail services during peak times mean minimal waiting time
	in vehicle travel time	medium	med	In peak times private vehicles are not competitive with the Southern Rail as the Kwinana Freeway is relatively congested and is increasing. Combined bus plus rail in-vehicle travel times are therefore competitive with car-only times in peak periods
	Egress Time	high	low	The egress time from private vehicles is relatively high due to the dispersed nature of the city and the limited parking available, the out of vehicle time is significant, whereas the Southern Rail has two stops in the city and is connected to the Free CAT Service
	Transfer Time	nil	low	Given the frequency of the feeder buses to the Southern Rail Stations, as well as the CAT services in the Perth CBD (which might be used by private vehicle users to get from the car parking to work) the transfer time cost is minimal
\$ Cost	fuel	high	nil	Given the distances travelled from the Southern Rail catchment to the CBD, fuel costs can be significant. Fuel is an increasing cost for private vehicles, with a 14% increase since the opening of the Southern Railway, and 47% since 2004 (presented in <b>Figure 8</b> )
	wear & tear, insurance	high	nil	Ongoing driving of vehicles in congested environments increases vehicle wear and tear.
	parking costs	high	P&R - Free	After the introduction of the Perth Parking Management Act in 1999, car parking in the Perth CBD has been both constrained in number, and had a levy charged to it (\$633.60/commercial space) [16] with the revenue hypothecated to the provision of Free Transit Zone within the City of Perth Municipal Bounds. The Wilson Parking Rates are shown in <b>Table 2</b> [17]
	tolls	nil	nil	Currently there are no public road user tolls on any roads in Western Australia
	fares	nil	low - med	The current fare structure for public transport trips is shown in <b>Figure 10</b> [7]
	Transfer Cost	nil	nil	The introduction of the electronic ticketing system enabled zero cost transfer penalty between the bus and rail modes, hence removing any transfer cost penalty associated with transferring between modes. The zone based fare structure also means that the majority of the feeder bus trips to the Southern Rail stations are intra zonal trips and are therefore nil cost to the overall trip cost. See <b>Figure 11</b> for the Transperth zone map [7]
Opportunity Cost	Road Congestion	Very High	low	The impact of Road Congestion has been significant for road users and is significant in the modal distribution for the Southern Railway catchment
	Public Transport crowding	nil	med	Public transport crowding on the Southern rail and its feeder services is increasing, and this issue will continue until more rolling stock is added to the line during peak times. (illustrated in <b>Figure 9</b> , [15])
	Ability to use travel time productively for work or leisure	low	high	The positive utility of rail based public transport travel time is becoming increasingly noticeable with the introduction of electronic media and devices. A major change in this area was the introduction of WIFI onto the Southern Rail line, thus enabling passengers to work and conduct online leisure activities on their journey to and from work. This is a major change in how public transport travel time is viewed when compared to private vehicle use where this time is dedicated to the purpose of driving on increasingly congested roads



**Figure 11. (Top) The Perth rail network lines annual patronage from 2004-2012 [4]; (Middle) Annual Perth rail network passenger boardings by line 2011-2012 [9]; (Bottom) Perth rail network annual patronage forecasts for the business case for the Southern Suburbs rail line [2,9], and the actual network patronage since the commencement of operation (purple line) with a propagation of the existing patronage into the future to be used to predict infrastructure capacity limitations (blue line). The red dashed cross over the graph illustrates that the rail network system 2031 patronage as specified [2] though this network patronage will be achieved in 2015 if current patronage growth continues (subject to capacity constraints).**

journey saves time compared to the private vehicle.

There would appear to be a lesson here for all rail planning but especially high speed rail: it is essential to minimize transfer penalties and create speeds that mean the generalized costs of choosing to travel on fast rail are lower than the alternatives (car, bus or plane).

The Perth Southern Rail Line has maintained a strong focus on the competitiveness of the public transport against the private motor vehicle in a time and financial generalized cost model for access from the southern suburbs to the Perth CBD and the rest of the rail network. This is illustrated by:

- The competitiveness of the train to the car in time due to the high speed of the trains (maximum speed 137 km/hr) compared to the car (freeway speed limit 100 km/hr).
  - The congested nature of the competing Kwinana Freeway, which is increasing with peak hour travel speeds being much lower than the theoretical speed limit.
- The frequency of the feeder bus services and the ease and speed of interchange between the bus and rail modes, minimizing the time penalty for transferring-between modes
- The introduction of the electronic ticketing system that enabled zero cost transfer between the bus and rail modes, hence removing any transfer cost penalty associated with transferring between modes.
  - The majority of the feeder bus services that transfer to the rail stations do very quickly and conveniently, and operate within the single transport ticketing zones, therefore not adding to the trip cost for the overall journey.

This model for the minimization of public transport generalized cost when compared to the private vehicle has enabled Perth Southern Suburbs rail line to be very competitive with the private vehicle in a region where the Southern Rail Line is located. This area is where the private vehicle has been historically extremely dominant due to low dwelling and population density, and long travel distances for the journey to work.

The low generalized cost network design minimizes the time and financial cost for the multimodal trip and induces traditionally car based ridership onto the transfer designed feeder services to the stations, and this is the key success for the intermodal public transport model that operates for the Southern Rail Line.

The application of the Southern Rail model to the design of high speed intra-city and regional rail for large, low density cities as well as very fast intercity train systems would appear to be clear.

## 8. Acknowledgements

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# **CAN VALUE CAPTURE WORK IN A CAR DEPENDENT CITY? WILLINGNESS TO PAY FOR TRANSIT ACCESS IN PERTH, WESTERN AUSTRALIA**

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**Keywords:** *Willingness to Pay, Transit Accessibility, Land*

## **Abstract**

This paper investigates the impact of transit on urban land markets in the highly car dependent corridors of Perth with a focus on where new fast rail transit services have recently been built. It determines people's willingness to pay for transit access within different pedestrian catchments for each of the corridors based on hedonic price modelling using land value data on over 460,000 households. The case study uses cross sectional and panel data hedonic price modelling methodology for the calculation of willingness to pay for transit. It finds that land market increases of up to 40% can be achieved, and is particularly relevant to car dependent cities looking to capture the financial and economic value created to build transit extensions or entirely new systems, thus making a strong case for value capture funding of transit projects into car dependent suburbs and the potential for density increases near stations.

## **Research Highlights**

- a. Analysis of rail transit in a car dependent city, Perth, demonstrates an increased willingness to pay in the affected land markets.
- b. Cross sectional and panel data hedonic price modelling methods produce differing results for willingness to pay for transit accessibility for a new commuter rail line.
- c. Together they demonstrate that in non-traditional transit land markets, without transit oriented designed development, there is still a significant increase in the willingness to pay for the investment in commuter rail transit.

## **1. Introduction**

The need to build new transit infrastructure is back on the agenda in many cities (Newman et al, 2013) though several questions remain about how new urban transit can work in car dependent areas and the potential for using land value capture to help fund it (McIntosh et al., 2011). This paper seeks to answer these questions by first introducing the concepts of land markets and willingness to pay (Rosen, 1974) and in particular the willingness to pay for transit accessibility. Following this, an assessment methodology will be proposed to show how willingness to pay for different land attributes is reflected in residential land markets and how it can be calculated using hedonic price modelling to determine the value placed on transit accessibility. This methodology will then be applied in a case study of Perth, Western Australia, a city built around the car, which like many cities worldwide is now grappling with the issues of car dependence by investing in extensions to its urban transit network.

### **1.1. Land Markets, Consumer Behaviour and Willingness to Pay Theory**

Economically, land is the most basic resource and a heterogeneous good that differs in terms of its characteristics and location. Although land markets are imperfect (due to the unstandardized commodities they trade) they perform four important functions (Hannonen, 2009):

- they bring buyers and sellers together to facilitate transactions,
- they set prices for land parcels,
- they allocate land by setting land prices that clear at the quantity of land demanded, and
- they play an important role in ensuring that land is efficiently used.

An important factor in land markets is that land is spatially immobile, which implies that location is an intrinsic attribute of the land parcel and should form the basis of its economic analysis. Importantly, land market prices reflect the interaction between the buyers and sellers in the land market as costs (such as travel) are traded-off against land rents (and population densities) in a bid rent curve (Alonso, 1964; Muth, 1969). Figure 1 illustrates the Bid-Rent Curve with respect to the investment in transit, and how it relates to the change in travel time for urban accessibility to employment.

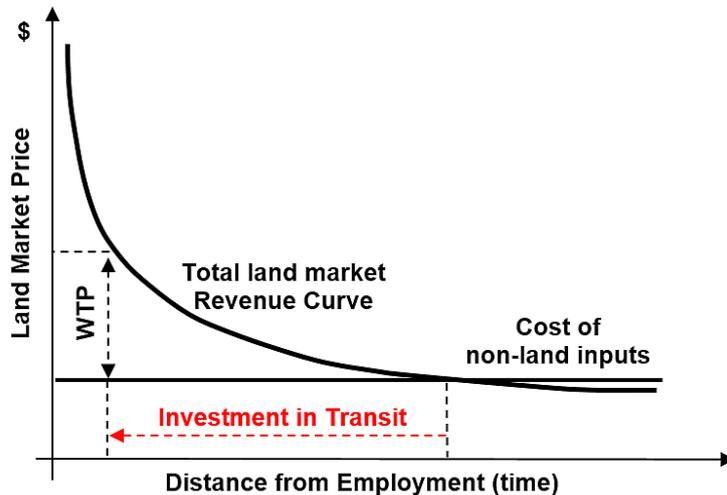


Figure 1 Land bid rent curve (land bid rent = Total Revenue – Cost of non-land inputs) (Adapted from O’Sullivan, 2012)

Lancaster’s (1966) theory on consumer behaviour theory suggests that goods (in this case land) are not direct objects of utility but it is their properties or characteristics from which utility is derived, and it is these properties that drive consumption. Following this theory, land parcels can have multiple relationships between them, making consumption decisions generally a set of joint decisions across multiple attributes.

Consumer preference/welfare theory was further developed quantitatively by Rosen (1974) through hedonic price modelling (HPM) and the calculation of willingness to pay. Hedonic price modelling posits that in the case of land, it is typically sold as a package of inherent attributes (topography, physical conditions, patterns of land ownership, availability of infrastructure and government regulations), and HPM enables the determination of the willingness to pay for each attribute. Therefore the price of one land parcel relative to another will differ with the additional units of the different attributes inherent in one parcel relative to another (Chin and Chau, 2003; Tiebout, 1956). Models of household location choice provide a theoretical foundation for measuring the willingness to pay for public goods (Kuminoff et al, 2010). The willingness to pay for the access to transit can be developed through a unified framework that relates land value capitalization to the underlying concept of market equilibrium on which welfare measurement is based (Kuminoff et al, 2010), where the relative price of a land parcel is the summation of all its marginal or implicit prices that can be estimated through HPM regression analysis.

## 1.2. Hedonic Price Modelling

The term “hedonics” is derived from the Greek word *hedonikos*, which simply means pleasure, and in an economic context refers to the utility or satisfaction one derives through the consumption of goods and services (Chin and Chau, 2003). HPM has been employed extensively in land and property research and whilst there are some issues with regard to data and measurement accuracy, the technique is valid for empirical studies of the housing market (Chin and Chau, 2003).

There are five key assumptions in economic analysis, and they are particularly important for HPM analysis:

1. Land market homogeneity
2. Perfect competition in the market
3. Buyers and sellers have freedom to enter and exit the market
4. Buyers and sellers have perfect information concerning the product and price
5. Market equilibrium with no interrelationships between price and attributes

HPM generally involves the application of Least Squares regression analysis, where the relationship between the dependent variable and explanatory variables is expected to be linear. The parametric equation for the observed land price (P) is shown in Equation 1.

Equation 1 Parametric Land Price Equation

$$P_i = f(X_j; \beta_j) + \varepsilon_i$$

Where

- $P_i$  is the estimated land/property price of the i-th observation,
- $X_j$  is a vector of quantitative and qualitative land/property attributes,
- $\beta_j$  is the unknown hedonic, or implicit price, of the land/property for attribute j, and
- $\varepsilon_i$  is the stochastic error term.

### 1.2.1. Different Functional Forms of HPM

As the relationship between the dependent and explanatory variables in HPM of land markets is often non-linear there are several common functional form specifications of HPM for land and property based models to overcome this non-linearity; the most common are illustrated in Table 1, which assume that all the explanatory variables are continuous, not dichotomous, in nature. Hannonen (2009) asserts that the choice of an appropriate functional form for the HPM is one of the main methodological concerns of the hedonic estimation process, and a poor choice can invalidate much of the subsequent analysis. In parametric HPM it is necessary to work on a range of different model specifications to determine which better suits the land market (or submarket) being analysed, with an incorrect choice of functional form of the HPM resulting in inconsistent estimates (Chin and Chau, 2003; Bloomquist and Worley, 1981). Despite its long history, HPM theory provides little guidance on the choice of the proper functional form for differing applications.

Table 1 The different HPM functional forms of HPM (McCarthy, 2001)

Model	Marginal Effect	HPM Functional Form	HPM Interpretation	Interpretation of the $\beta_j$ coefficient
Linear	$\frac{\Delta \text{Land Price per } m^2}{\Delta x_i} = \beta_j$	$\text{Land Price per } m^2 = \beta + \beta_1(x_1) + \beta_2(x_2) \dots + \beta_j(x_j) + \varepsilon$	Unit change in land value per $m^2$ from a unit increase in explanatory variable $x_i$	Unit change
Log-Linear	$\frac{\Delta \text{Land Price per } m^2}{\Delta \log(x_i)} = \beta_j$	$\log(\text{Land Price per } m^2) = \beta + \beta_1(x_1) + \beta_2(x_2) \dots + \beta_j(x_j) + \varepsilon$	Percentage change in land value per $m^2$ from a unit increase in explanatory variable $x_i$	Unit change
Linear-Log	$\frac{\Delta \log(\text{Land Price per } m^2)}{\Delta x_i} = \beta_j$	$\text{Land Price per } m^2 = \beta + \beta_1[\log(x_1)] + \beta_2[\log(x_2)] \dots + \beta_j[\log(x_j)] + \varepsilon$	Unit change in land value per $m^2$ from a 1% increase in explanatory variable $x_i$	Percentage
Double-Log	$\frac{\Delta \log(\text{Land Price per } m^2)}{\Delta \log(x_i)} = \beta_j$	$\log(\text{Land Price per } m^2) = \beta + \beta_1[\log(x_1)] + \beta_2[\log(x_2)] \dots + \beta_j[\log(x_j)] + \varepsilon$	Percentage increase in land value per $m^2$ from a 1% increase in explanatory variable $x_i$	Elasticity

### 1.3. Willingness to Pay

The willingness to pay (WTP) for a parcel of land consisting of a range of site and neighbourhood characteristics can be calculated by evaluating the estimated HPM and then taking the partial derivative of the HPM with respect to a characteristic of choice (Rosen, 1974). In the case of an application of the log-log estimator where the coefficients are approximates of the expected percentage change in land value, the WTP for a one unit change of an attribute can be estimated as in Equation 2, and will be applied to a variety of land characteristics including transit access.

Equation 2 (WTP)

$$WTP_{t,i} = \frac{d(P_t)}{d(x_{i,t})} \cdot \bar{P}_t = \beta_{i,t} \cdot \bar{P}_t$$

Where:  $\bar{P}_t$  is the mean catchment land value in time period  $t$   
 $x_{i,t}$  is the hedonic price of attribute  $i$  at time period  $t$

The Center for Transit Oriented Development (CfTOD) (2008) provides a theoretical value WTP premium curve for the monetisation of the access to transit infrastructure (Figure 2). It is the effect of transit accessibility in different stages of its development and life-cycle that will be analysed and calibrated for an Australian context, particularly in a corridor that was built around the car. The significant contribution of this paper is in the estimation of whether a dispersed car dependent corridor can demonstrate the same kind of land value uplift after a transit system is built through it, as has been found in traditional transit corridors in other global cities.

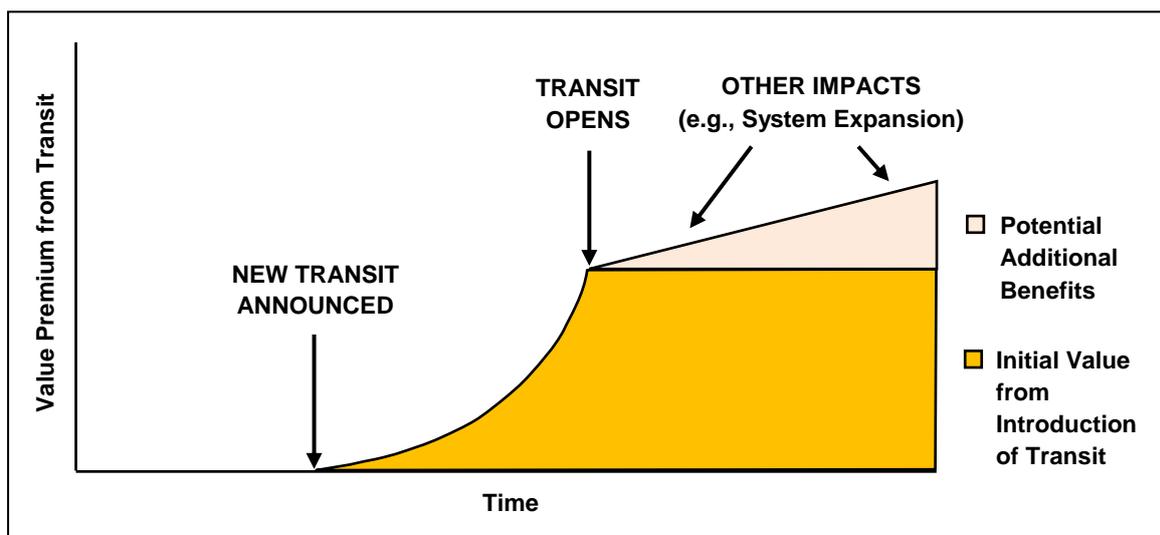


Figure 2 Theoretical Value Curve from Transit Infrastructure  
 Redrawn from Center for Transit-Oriented Development (2008)

Meta-analysis of hedonic price modelling studies of the impact of transit on land and property prices has been conducted by Debrezion et al. (2007) (using 57 HPM studies), and Mohammad, et al. (2013) (using 23 HPM studies). With Debrezion et al. (2007) reporting average effect of 4.2% premium for residents within 0.25 Mile of a rail station. Though Mohammad, et al. (2013) stated that the level of variability in the studies made comparison between different modes and land uses possible, producing a reliable absolute interpretation of the results was deemed impossible.

Tables 2a, 2b, 2c and 2d illustrate a selection of international HPM studies on differing transit modes, their analysis method, functional form and differing dependent and explanatory variables. These studies frame the state of HPM impact analysis for the investment in different transit modes.

Table 2a Authors' compilation of academic studies on BRT induced HPM value uplift on residential property and land markets;

	Author	Location & Transit System	HPM Form	HPM # Obs. (Model R <sup>2</sup> )	Dependent Variable	Explanatory Variables					
						Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Bus Rapid Transit	Rodriguez and Targa, (2004)	Bogota, Colombia TransMilenio BRT	OLS – Linear, Log/Linear, Log/Log	494 (0.71)	Linear, Log (Rental Cost)	5 min walk	6.8% to 9.3%	<ul style="list-style-type: none"> <li>Property Area,</li> <li># Beds,</li> <li>#Baths,</li> <li>Living Room,</li> <li>Age</li> </ul>	<ul style="list-style-type: none"> <li>Socio Econ.,</li> <li>Pop. Density,</li> <li>Employ. Density,</li> <li>%Diff. Land Uses,</li> <li>Crime,</li> <li>Poverty,</li> <li>400m Busway</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to BRT,</li> <li>Ped. Time to BRT,</li> <li>BRT Travel Time,</li> <li>Dist.to CBD</li> </ul>	-
	Rodriguez and Mojica, (2008)	Bogota, Colombia TransMilenio BRT	OLS WLS – Log/Linear	3976 (0.694)	Ln (Advert. Sale Price)	150m	13% to 15%	<ul style="list-style-type: none"> <li>House/Apt.,</li> <li>Age,</li> <li>#Bedroom,</li> <li>#Bath,</li> <li>#Garage,</li> <li>Area</li> </ul>	<ul style="list-style-type: none"> <li>Socio Econ.,</li> <li>Pop. Density,</li> <li>Employ. Density,</li> <li>%Diff. Land Uses,</li> <li>Crime</li> </ul>	<ul style="list-style-type: none"> <li>Prox.150m BRT,</li> <li>500m BRT</li> </ul>	<ul style="list-style-type: none"> <li>Year Dummies</li> <li>Interaction terms</li> </ul>
	Perk and Catala, (2009)	Pittsburgh, USA MLK, Jr East Busway	Robust LS - Linear	128717 (0.80)	Appraised Property value	Dist. to BRT	Significant and +ve	<ul style="list-style-type: none"> <li>Lot Area,</li> <li>Living area size,</li> <li># Beds,</li> <li>#Bath,</li> <li>#1/2Bed,</li> <li>Age,</li> </ul>	<ul style="list-style-type: none"> <li>Income,</li> <li>Socio. Econ.,</li> <li>Pop. Density,</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to BRT</li> </ul>	-
	Cervero and Kang, (2010)	Seoul, South Korea Seoul BRT	Multi Level Logit	25410 (0.992)	Land value	90m to 300m of BRT stop	5% to 10%	<ul style="list-style-type: none"> <li>Land use,</li> <li>Building coverage ratio,</li> <li>floor area ratio,</li> <li>%Age Demo.,</li> <li>%College degree</li> </ul>	<ul style="list-style-type: none"> <li>Pop. Density,</li> <li>Employment Density,</li> <li>Dist to River,</li> <li>%Park,</li> <li>%Land Developed,</li> <li>Road area ratio,</li> <li>%Res &amp; Comm. Develop. capacity</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to fwy ramp,</li> <li>Dist to BRT,</li> <li>Dist to CBD,</li> <li>Dist to Subway,</li> <li>Dist. to Major Rd.,</li> <li>Dist to Bus,</li> <li>Job Accessibility by Car</li> </ul>	-
	Mulley & Tsai, (2013)	Sydney Australia Liverpool-Parramatta BRT	ANOVA & OLS	1167 (0.67)	Ln (Sale Price)	400m	-% to 3.3%	<ul style="list-style-type: none"> <li>#Bed.</li> <li>#Bath,</li> <li>#Parking,</li> <li>House/Apt</li> </ul>	<ul style="list-style-type: none"> <li>%Eng. Language,</li> <li>Unemployed,</li> <li>Income,</li> </ul>	<ul style="list-style-type: none"> <li>Within 50m of BRT stop</li> </ul>	<ul style="list-style-type: none"> <li>Time dummies &amp; interaction terms;</li> <li>preconstruction,</li> <li>during const. &amp; operations</li> </ul>
Notes:											

Table 2b Authors' compilation of academic studies on LRT induced HPM value uplift on residential property and land markets;

	Author	Location & Transit System	HPM Form	HPM # Obs. (Model R <sup>2</sup> )	Dependent Variable	Explanatory Variables					
						Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Light Rail Transit	Golub, et al., (2012)	Phoenix, USA Phoenix LRT	OLS – Log/Log	88308 (0.533)	Ln (Adjusted Sale Price)	200ft	25%	<ul style="list-style-type: none"> <li>• Living size,</li> <li>• Lot size,</li> <li>• Age,</li> <li>• #Patios,</li> <li>• #Bath,</li> <li>• #Floors,</li> <li>• Pool,</li> <li>• TOD Zoning</li> </ul>	-	<ul style="list-style-type: none"> <li>• Dist. to LRT Stn.,</li> <li>• Dist. to LRT Alignment,</li> <li>• Dist. to CBD,</li> <li>• Dist. to Airport</li> </ul>	<ul style="list-style-type: none"> <li>• Time dummies</li> <li>• Prior NEPA,</li> <li>• During NEPA Review,</li> <li>• Planning &amp; Design,</li> <li>• Construction,</li> <li>• Operations</li> </ul>
	Atkinson-Palombo, (2010)	Phoenix, USA Rezoning around the Phoenix LRT	GLS Log/Linear	9177 (0.76)	Ln(Sales Price)	1/2 mile	<ul style="list-style-type: none"> <li>• 17% Transit</li> <li>• 34% Transit +TOD Overlay</li> </ul>	<ul style="list-style-type: none"> <li>• Lot Size</li> <li>• House size</li> <li>• Pool</li> <li>• Age</li> </ul>	<ul style="list-style-type: none"> <li>• Socio Economic Data</li> <li>• TOD Overlay Zoning</li> </ul>	<ul style="list-style-type: none"> <li>• LRT Ped Catchment</li> <li>• Dist. to Fwy</li> <li>• Dist to CBD</li> </ul>	<ul style="list-style-type: none"> <li>• Pre and Post dates from the introduction of the TOD overlay</li> </ul>
	Du and Mulley (2007)	England, UK Tyne & Wear light rail	OLS & GWR Log/Linear	1700 (0.38)	Ln (House Price)	200m	17.1%	<ul style="list-style-type: none"> <li>• House Type,</li> <li>• #Bedroom,</li> </ul>	<ul style="list-style-type: none"> <li>• Local School Indicator,</li> <li>• % unemployed,</li> <li>• %Higher Profession Occupation</li> </ul>	<ul style="list-style-type: none"> <li>• PT Access (School, College...),</li> <li>• Car Access (School College...),</li> <li>• Dist. to LRT</li> </ul>	-
	Cervero & Duncan (2002)	San Diego, USA LRT	OLS - Linear	14756 (0.605)	Sale Price	400m	3.8% to 17.3%	<ul style="list-style-type: none"> <li>• Size,</li> <li>• #Units</li> <li>• #Bath,</li> <li>• Bed,</li> <li>• Age</li> </ul>	<ul style="list-style-type: none"> <li>• Housing Density</li> <li>• Income</li> <li>• Race Profile</li> <li>• %Senior</li> <li>• %Vacant Land</li> </ul>	<ul style="list-style-type: none"> <li>• ½ Mile LRT</li> <li>• Dist. to Hwy/Fwy</li> <li>• Dist. to Fwy Ramp</li> </ul>	<ul style="list-style-type: none"> <li>• Time Dummies</li> <li>• Monthly to reflect different sale times</li> </ul>
	Garrett, (2004)	Missouri, USA St Louis Metrolink LRT	OLS Log/Linear	1516 (-)	House Price	700m	32%	<ul style="list-style-type: none"> <li>• #Bed</li> <li>• #Bath</li> <li>• #Stories</li> <li>• Garage</li> <li>• Pool</li> <li>• Age</li> <li>• Lot Size</li> <li>• House size</li> </ul>	<ul style="list-style-type: none"> <li>• Dist. to Hwy interchange</li> <li>• %Res. With College Education</li> <li>• Income</li> <li>• Property Tax rate</li> <li>• School District Test Scores</li> <li>• Does nearest LRT have P&amp;R?</li> </ul>	<ul style="list-style-type: none"> <li>• Dist. to nearest LRT Stn</li> <li>• Noise impact from LRT by Dist. to LRT</li> </ul>	-

Notes:

Table 2c Authors' compilation of academic studies on Metro induced HPM value uplift on residential property and land markets;

	Author	Location & Transit System	HPM Form	HPM # Obs. (Model R <sup>2</sup> )	Dependent Variable	Explanatory Variables					
						Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Metro / Heavy Rail	Banister (2007)	London, UK , London Metro Jubilee Line	GWR	-	Land & Property Valuations	2000m Access to metro	75%	-	<ul style="list-style-type: none"> <li>Comm. &amp; Environ. amenity</li> <li>Car Ownership</li> <li>Socio. Economic</li> </ul>	<ul style="list-style-type: none"> <li>Access to shops</li> <li>Dist. to School</li> <li>Access to metro</li> </ul>	-
	Gatzlaff and Smith (1993)	Miami, USA Heavy Rail/Metro	OLS Linear Log/linear Exp. Log/Log	912 (0.72-0.84)	Sale Price	Dist. to metro	Mixed between stations	<ul style="list-style-type: none"> <li>House Area</li> <li>Lot Size</li> <li>Age</li> </ul>	<ul style="list-style-type: none"> <li>Est. House Price Index</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to Metro</li> </ul>	<ul style="list-style-type: none"> <li>Construction announcement dummy</li> </ul>
	Laakso (1992)	Helsinki, Finland Helsinki Metro	OLS Log/Linear	6732 (0.940)	Ln (Sale price)	250m	3.5% to 6%	<ul style="list-style-type: none"> <li>Ln(Age)</li> <li>Ln(Area)</li> <li>Terrace House</li> <li>Pool</li> <li>Indoor Sports</li> <li>Health Stn</li> <li>Library</li> <li>Day Care</li> </ul>	<ul style="list-style-type: none"> <li>Ln(%Park)</li> <li>Ln(Income quartile)</li> <li>Dist. to Coast</li> <li>Ln(Dist. to CBD)</li> </ul>	<ul style="list-style-type: none"> <li>Metro Station dummies</li> <li>Feeder Bus Dummies</li> <li>Commuter Rail Dummy</li> <li>Shopping centre Dummy</li> </ul>	<ul style="list-style-type: none"> <li>Transaction time dummies</li> </ul>
	Bae et al. (2003)	Seoul, South Korea Heavy Rail KoRail	GLS Log/Linear	956 (0.9542)	Ln (Sales Price)	400m	0.3% to 2.6%	<ul style="list-style-type: none"> <li>Apart. Size,</li> <li>Age,</li> <li>#Houses block</li> <li>#Parking</li> <li>Heating Type</li> <li>Dist. to Park</li> </ul>	<ul style="list-style-type: none"> <li>Dist. from Han River</li> <li>School District</li> <li>Pop. Density</li> <li>Job Density</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to Subway</li> <li>Dist. to CBD</li> <li>Dist. to Sub centre</li> </ul>	<ul style="list-style-type: none"> <li>Time dummies</li> <li>Sales in 1995</li> <li>Sales in 1997</li> <li>Sales in 2000</li> </ul>
	Yankaya and Celik (2004)	Izmir, Turkey Izmir Metro	OLS Linear Log/linear Log/Log	360 (0.83)	Sale Price	500m	0.7% to 13.7%	<ul style="list-style-type: none"> <li>House size</li> <li>#Apt in Bldg.</li> <li>#Apts. in Floor</li> <li>Age</li> <li>#Bed</li> <li>#Storey of Bldg.</li> <li>Corner location</li> <li>Parking</li> <li>Heating</li> </ul>	<ul style="list-style-type: none"> <li>Location</li> <li>Type of ground</li> </ul>	<ul style="list-style-type: none"> <li>Dist to Subway</li> <li>Dist. to Bus</li> <li>Dist to Shop</li> </ul>	-
	Medda (2011)	Warsaw, Poland Warsaw Metro	OLS Log/Linear	1130 (0.696)	Sale Price	1000m	6.7%-7.13%	<ul style="list-style-type: none"> <li>Area</li> <li>#Rooms</li> <li>#Floors in Bldg.</li> <li>Age</li> <li>Parking</li> </ul>	<ul style="list-style-type: none"> <li>School District</li> </ul>	<ul style="list-style-type: none"> <li>Dist to Hospital</li> <li>Dist. to Green Area</li> <li>Metro Catchment dummy</li> </ul>	<ul style="list-style-type: none"> <li>Time Dummy for year of sale</li> </ul>

Notes:

Table 2d Authors' compilation of academic studies on Commuter Rail induced HPM value uplift on residential property and land markets;

	Author	Location & Transit System	HPM Form	HPM # Obs. (Model R <sup>2</sup> )	Dependent Variable	Explanatory Variables					
						Proximity Variable	Proximity Premium	Land /Structural Variables	Neighbourhood Variables	Accessibility Variables	Time Based Variables
Commuter Rail	Cervero and Duncan, (2002)	San Diego, USA Commuter Rail	OLS	25923 (0.7)	Sales Price	½ mile	-7.1% to 46.1%	<ul style="list-style-type: none"> <li>House Size</li> <li>Lot Size</li> <li>#Bath</li> <li>#Bed</li> <li>Age</li> </ul>	<ul style="list-style-type: none"> <li>Housing Density</li> <li>Income</li> <li>%White Neighbourhood</li> </ul>	<ul style="list-style-type: none"> <li>½ Mile Commuter Rail</li> <li>Dist. to Hwy Ramp</li> <li>Job Access Hwy</li> <li>Job Access Transit</li> </ul>	Time Dummies <ul style="list-style-type: none"> <li>Monthly to reflect different sale times</li> </ul>
	Sedway Group (1999) Mathur and Ferrell, (2009)	San Francisco USA Bay Area Rapid Transit (BART)	OLS Log/Log	2133 (0.74)	Ln (Sales Price)	½ mile	20% 1.5%	<ul style="list-style-type: none"> <li>House Size</li> <li>Lot Size</li> <li>#Bath</li> <li>#Bed</li> <li>Age</li> </ul>	<ul style="list-style-type: none"> <li>Income</li> <li>%Hispanic Neighbourhood</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to BART</li> <li>Dist. to Bus</li> <li>Dist. to Hwy/Fwy</li> </ul>	Time Dummies for years 1995 – 2002
	Gruen, (1997) Chaney (2005)	Chicago, USA METRA, Commuter Rail	OLS Log/linear	796	Property Value	400m	14.5 to 20%	<ul style="list-style-type: none"> <li>House Size</li> <li>Lot Size</li> <li>#Bath</li> <li>Age</li> <li>Furnished</li> <li>Garage</li> <li>Fireplace</li> <li>House Type</li> </ul>	-	<ul style="list-style-type: none"> <li>Dist. from Station</li> <li>Dist. from Hwy</li> <li>Squared Dist. from Station</li> <li>Squared Dist. from Hwy</li> </ul>	-
	Voith (1991)	Pennsylvania & New Jersey, USA Commuter Rail	OLS	571 (0.711)	Property Value	½ mile	6% to 10%	<ul style="list-style-type: none"> <li>Size</li> <li>Detached</li> <li>Age</li> <li>#Rooms</li> </ul>	<ul style="list-style-type: none"> <li>%Black Neighbourhood</li> </ul>	<ul style="list-style-type: none"> <li>Auto Commute</li> <li>Station</li> <li>Rail Commute</li> </ul>	-
	Lochl and Axhausen, (2010)	Zurich, Switzerland, Commuter Rail	OLS, Spatial Autoregressive model, GWR Log/Log	8592 (0.85)	Ln(Rent)	500m	4% to 8%	<ul style="list-style-type: none"> <li>House Size</li> <li>Lift</li> <li>Balcony</li> <li>#Bath</li> <li>Age</li> <li>Furnished</li> <li>Garage</li> <li>Fireplace</li> <li>Single house</li> <li>View</li> </ul>	<ul style="list-style-type: none"> <li>Within 100m Autobahn</li> <li>Air Noise</li> <li>Job within 1km</li> <li>Pop. Density per hectare</li> <li>%Foreigners per Hectare</li> <li>Local Tax level</li> <li>Slope</li> </ul>	<ul style="list-style-type: none"> <li>Dist. to CBD</li> <li>Car Access time to employment</li> <li>PT Access to employment</li> <li>Rail stn. catchment</li> </ul>	Transaction time dummies
Notes:											

## **2. Case Study and Data**

Perth is the capital city of the state of Western Australia with a current population of 1.81 million people, making it the fourth most populous city in Australia and the most rapidly growing (Australian Bureau of Statistics, 2013). The major growth of Perth has been since the 1960's and was built around the car in dispersed but formally planned car dependent suburbs. Metropolitan Perth has had rail transit since the late 19<sup>th</sup> century and increased its distribution in the late 20<sup>th</sup> and early 21<sup>st</sup> centuries under considerable political and community pressure. This is particularly evident in the provision of the northern and southern rail lines, which were built deeply into Perth's post 1960's car dependent suburbs. The high speed of the new rail lines has led to some spectacular increases in patronage, especially in the past 5 years (McIntosh et al, 2013).

The current map of the Perth rail network is presented in Figure 3 showing the traditional "heritage" east-west rail lines from the 19<sup>th</sup> century and the modern "rapid transit" north-south lines constructed in the last 20 years. Important for this study is the difference in land use and transport integration between the two rapid transit lines and the heritage lines. The former are located in the median of major north/south freeways (Mitchell and Kwinana Freeways) and stations are mostly surrounded by large park-and-ride facilities, while the heritage lines operate at slower speeds and are more integrated with surrounding neighbourhoods though without the densities of cities like Melbourne and Sydney (Newman and Kenworthy, 1999).

## 2.1. The Differing Levels of Land Use and Transit Integration in Perth

The difference in land use and transport infrastructure integration between the heritage and rapid transit lines can be highlighted using two stations from the Perth rail network: one from the Fremantle Line (Subiaco Station) and one from the Mandurah Line (Murdoch Station). The different forms of land use and transport infrastructure integration for the heritage and rapid transit lines will become more evident in the analysis of the HPM for the different rail lines.

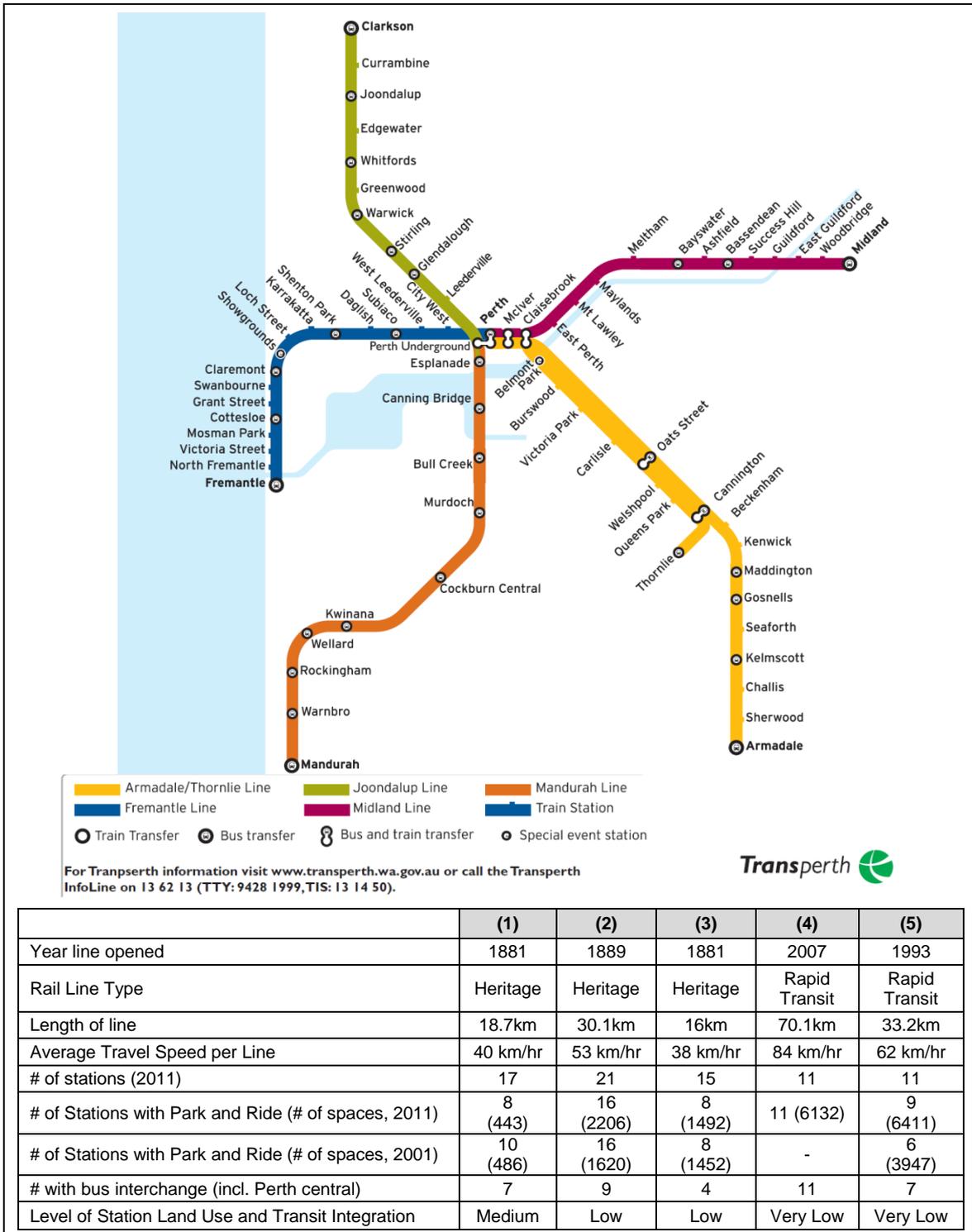


Figure 3 Perth Rail Network (Transperth, 2013) and Descriptive Statistics of the Perth Metropolitan Rail Lines analysed in the HPM (1) Fremantle, (2) Armadale, (3) Midland, (4) Mandurah (Southern) and (5) Joondalup (Northern)

### **2.1.1. Subiaco Station (Fremantle Line)**

The Subiaco Station precinct, which is three stops from Perth Central Station (a distance of 3.7km and 6 minutes travel time), is an excellent example of how a modern Transit Oriented Development (TOD) can be designed and implemented into existing rail lines in an Australian context (Figure 4). The station was sunk between 1997 and 1998 as part of the redevelopment of the station precinct to create a TOD to minimize the negative impacts of proximity to the rail line and allow residential development to fully integrate with the station. This decision further enhanced Subiaco's role as a multimodal public transport hub and one of Perth's designated activity centres. As the station has no park-and-ride facilities there is significant benefit (and willingness to pay) to be within the pedestrian catchment, as this reinforces the train as the primary mode of access to and from the precinct for the residents and business.

### **2.1.2. Murdoch Station (Mandurah Line)**

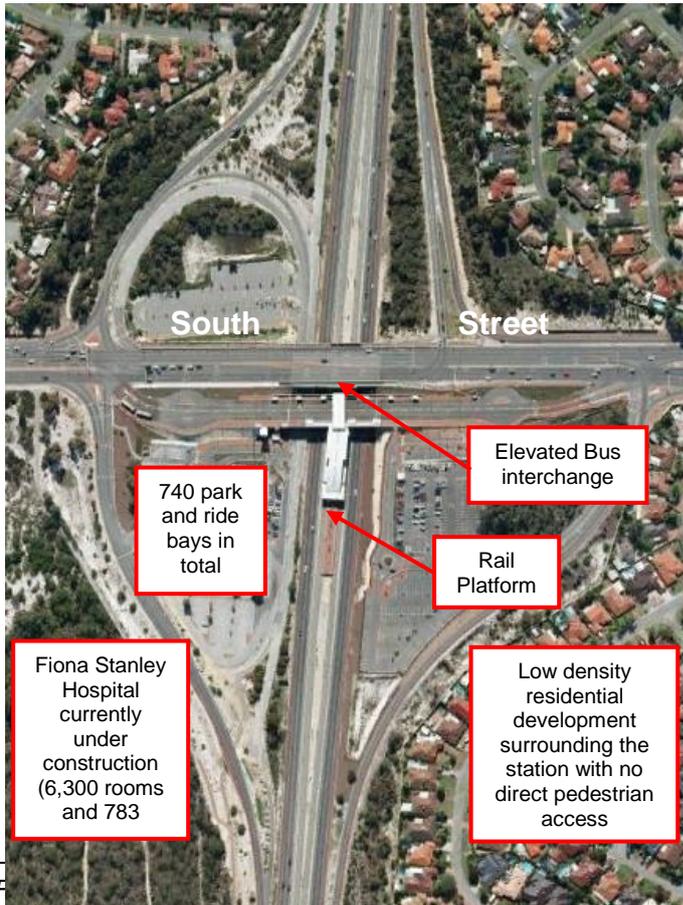
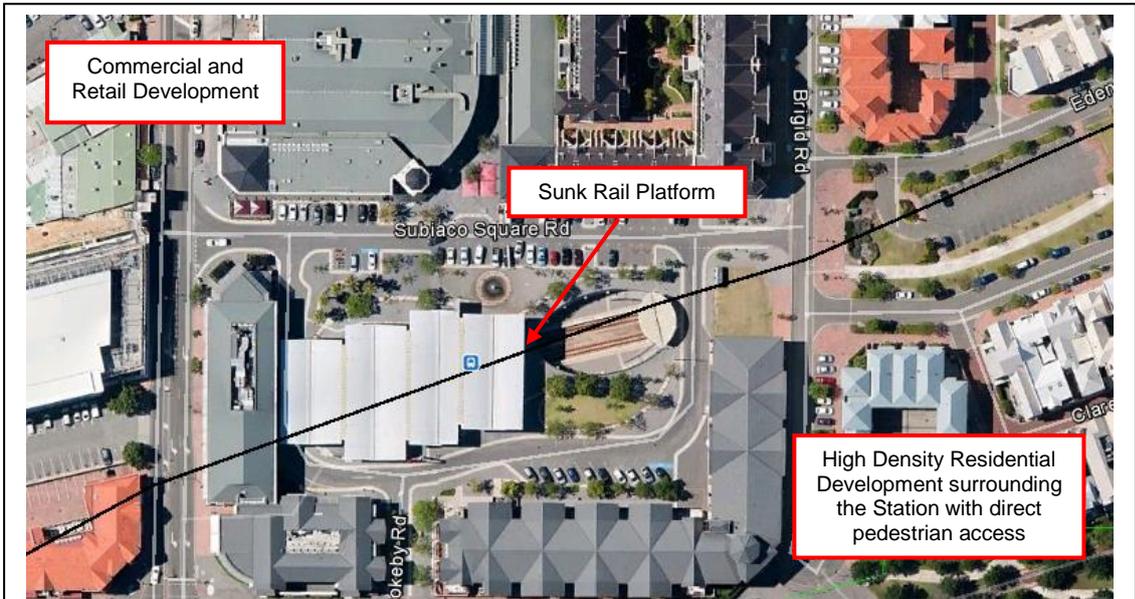
The Murdoch rail station, which is four stops from the Perth Central Station (approximately 13.8km and 14 minutes travel time), in contrast to Subiaco has effectively no residential pedestrian catchment given the walking distance from the nearest property to the station is over 800m (or 10 minutes walking time). Low levels of walkability around the station are due to the configuration of the road network adjacent to the station, a lack of any pedestrian walkways (Figure 4), and the presence of large park-and-ride facilities (over 740 spaces) to preclude any TOD activity near the station. These factors further reduce the perceived benefit of being within the extended pedestrian catchment of the station as they give cars and buses priority access. The station, however, is within extended walking distance to a large hospital precinct and Murdoch University and has an extensive bus integration system in place that has enabled it to have the highest rail patronage outside the central city stations. McIntosh et al. (2013) set out more detail on how the new rail line to the south has worked so successfully. Figure 4 highlights the differing forms of land use and transport integration between the WTP for transit accessibility on the metropolitan Perth rail network and the differences between the heritage and rapid transit corridors. The Joondalup and Mandurah lines have increasing amounts of housing being built near stations and the analysis below helps to understand why this is happening.

### **2.1.3. Negative externalities of proximity to transport infrastructure**

Proximity to transport infrastructure in general, however, is not without some negative consequence. In 1980, the Washington State Transport Commission conducted a comprehensive HPM study into highway proximity impacts on property values, which presented decreases in value between 7.2% and 2.0% for highway noise areas at 70 dBA (Washington State Department of Transport, 1980). Palmquist, (1992) undertook HPM studies on the externality of traffic noise on a major urban freeway and its effect on property values in Portland, Oregon in the USA. The results from the study showed that upper middle class neighbourhood property values were reduced by 0.48 % for each additional decibel (dBA  $L_{10}$ ) of highway noise above the ambient noise levels of about 55 dBA  $L_{10}$ . This value was 0.3 % per decibel for a lower middle class neighbourhood. In the poorest neighbourhoods the effect was even smaller, only 0.08 % per decibel, indicating that the marginal willingness to pay for quiet in poorer areas is comparatively low, or alternatively it could represent a lower ability to pay.

One specific externality to consider for the study of the rail accessible land markets in Perth is the impact of the Mitchell and Kwinana freeways (both with over 100,000 vehicles per day) on the Joondalup and Mandurah rail lines respectively. A noise survey conducted in 2009 of properties within 400m of the Kwinana Freeway (Lloyd George Acoustics, 2011) demonstrated that on average the outside background noise levels were 60 dBA  $L_{10}$  and up to 66 dBA  $L_{10}$ . The Kwinana Freeway catchment area could be deemed an upper middle to lower middle class area, and if the Palmquist (1992) results were used as a guide, the traffic noise impact alone could account for up to a 6% negative impact on the land and property submarkets around the freeways. Though the results from the Palmquist (1992) study are not necessarily transmutable between regions, let alone countries, it provides a background to the analysis of the impact of traffic noise on residential

properties in the Joondalup and Mandurah rail pedestrian catchments which would be expected to be lower or negative due to the presence of the freeway and the hostile pedestrian catchments.



Photos of Subiaco Station and surrounding precinct, **(Bottom)** Murdoch Station Precinct (Mandurah Rail Line) (Google Earth, 2013); **(Bottom Right)** Photos of Murdoch Station and surrounds.

### **3. Methodology**

#### **3.1. Hedonic Price Modelling in the Land Markets of Perth**

Using the evidence from the other studies presented in Table 2, the case study into the effect of rail transit on the land markets of metropolitan Perth was conducted using two HPM methods (cross sectional analysis and panel data analysis) and trialling four different functional forms (Linear, Log-Linear, Linear-Log and Log-Log) to correct for possible non-linearity of the data and estimation efficiency issues. This investigation into the different functional forms of HPM was necessary as whilst each of the studies presented in Table 2 used differing forms, there was little guidance as the optimum one to be used for land market analysis of transit.

Land market rather than property market analysis was conducted to highlight and comprehensively understand the role of rail transit in Perth's land markets and to highlight the proximity benefit exclusive of any other heterogeneous property related factors. These HPM methods were then used to analyse residential land values to determine the impacts of rail transit on each urban land market at a single time period, and as it changed over time, and to also ensure the implications of adopting different functional forms were fully understood.

##### **3.1.1. Description of the HPM input data**

Government assessed land value data were sourced for this study from the Western Australian Valuer General's Office in Landgate to determine the hedonic price benefit of rail transit accessibility. These land valuation data were beneficial due to their comprehensive nature, the reliability of the assessment method, and in particular the uniform nature of the dataset when compared to property valuation data that include capital improvements. Whilst there are some limitations in the dataset, such as a lack of responsiveness to market demand in particular, the benefits include its uniformity and its true representation of "proximity benefit" without built form distortions. Included in the land valuation estimates is the uplift or influence of scenic views; however, the precise uplift applied to the estimates is stated as a percentage in the valuations' datasets so the influence of views on land values could be removed, essentially controlling for this effect. Land value per square metre with the view percentage removed was modelled as the HPM dependent variable using 462,476 residential land parcels across metropolitan Perth with the aim of modelling the impact of rail based public transport infrastructure on per square metre land values.

One of the public transport accessibility controls employed in the analyses included the Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) composite index, which is a GIS-based tool that assesses the relationship between public transport network configuration, performance and service standards and the geographical distribution or clustering of land use activities across a metropolitan area (Scheurer, 2010). This enabled a variable to be included in the HPM that served to measure public transport accessibility. The residential land hedonic models also included a range of control variables including zoning (i.e. R-Codes), school district rating, proximity to a major water body (i.e. river or ocean), proximity to major road infrastructure (i.e. highways and freeway on-ramps), proximity to the CBD and other activity centres, and the Australian Bureau of Statistics' (ABS) Socio Economic Index For Areas (SEIFA). The HPM included 400m, 800m, and 1600m (5, 10 and 20 minute) pedestrian catchments to rail stations, calculated as road network service areas using Network Analyst in ESRI's ArcGIS.

##### **3.2. Residential Cross-sectional HPM**

The three descriptive statistics of the dependent and explanatory variables for the residential cross sectional models are shown in Table 3 which also presents the average land value for the All Regions model and for each of the five rail line sub-regions. The residential cross-sectional HPM for value per square metre with the view uplift percentage removed (vpsm\_no\_view) for the Log-Log model functional form is presented in Equation 3.

Table 3

Descriptive Statistics for the Residential Cross-sectional HPM for 2011  
(1) Fremantle, (2) Armadale, (3) Midland (4) Mandurah and (5) Joondalup

		Mean or Percentage Values					
Dependent Variables		All Regions	(1)	(2)	(3)	(4)	(5)
	Land Value/m <sup>2</sup> (no view) (AUD\$ 2011)	590.69	1646.59	366.95	425.29	542.88	632.00
	Log Land Value/m <sup>2</sup> (no view) (AUD\$ 2011)	6.121	7.306	5.692	5.714	6.103	6.336
	Number of Land Parcels	462476	28487	85108	67761	128136	152974
<b>Explanatory Variables</b>							
Transit and Road Transportation Proximity	<b>400m train catchment (Dummy Variable)</b>						
	number of parcels	5300	1913	1401	1440	224	321
	(% of total catchment number of parcels)	(1.2%)	(6.7%)	(1.6%)	(2.1%)	(0.2%)	(0.2%)
	[Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011]	[1044.03]	[1885.62]	[473.19]	[701.85]	[325.27]	[556.69]
	{Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	{6.65}	{7.46}	{5.99}	{6.47}	{5.67}	{6.28}
	<b>800m train catchment (Dummy Variable)</b>						
	number of parcels	15998	4643	5068	4000	890	1396
	(% of total catchment number of parcels)	(3.5%)	(16.3%)	(5.9%)	(5.9%)	(0.7%)	(0.9%)
[Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011]	[1002.33]	[1930.44]	[466.18]	[770.63]	[588.45]	[789.61]	
{Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	{6.62}	{7.50}	{5.96}	{6.57}	{6.16}	{6.52}	
<b>1600m train catchment (Dummy Variable)</b>							
number of parcels	51388	6797	15749	7424	9238	12179	
(% of total catchment number of parcels)	(11.1%)	(23.9%)	(18.5%)	(11.0%)	(7.2%)	(8.0%)	
[Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011]	[768.32]	[1961.71]	[403.95]	[800.36]	[555.87]	[713.54]	
{Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	{6.35}	{7.48}	{5.84}	{6.55}	{6.09}	{6.47}	
<b>0-100m Hwy # of parcels (Dummy Variable)</b>							
(% of total)	17811	1306	3746	2585	4753	5420	
(% of total)	(3.9%)	(4.5%)	(4.4%)	(3.8%)	(3.7%)	(3.5%)	
<b>100-200m Hwy # of parcels (Dummy Variable)</b>							
(% of total)	26215	2355	5365	4566	7108	6820	
(% of total)	(5.7%)	(8.3%)	(6.3%)	(6.7%)	(5.5%)	(4.5%)	
<b>200-400m Hwy # of parcels (Dummy Variable)</b>							
(% of total)	48942	4105	9643	8106	13784	13302	
(% of total)	(5.7%)	(14.4%)	(11.3%)	(12.0%)	(10.8%)	(8.7%)	
<b>Dist. to freeway onramp (Dist to Fwy onramp)</b>							
	8.63	6.89	13.54	17.41	5.52	4.94	
Accessibility Measure	<b>PT Accessibility (SNAMUTS)</b>	6.62	11.02	7.34	5.58	6.98	5.56
	<b>Dist. to CBD (km) (Dist to CBD)</b>	17.422	12.16	17.97	18.37	18.76	16.56
	<b>Dist. to secondary centre (km) (Dist. 2nd Centre)</b>	4.80	2.44	5.10	6.78	5.33	3.75
Lot Attributes	<b>Lot Area (m<sup>2</sup>) (Area)</b>	1746	688	2067	4072	1488	942
	<b>Residential Density (R-Code)</b>	20.98	21.11	21.56	18.81	20.52	22.36
Neighbourhood Attributes	<b># of Dwellings within 1600m (Dwelling_1600)</b>	4680	5772	4228	3880	4404	5314
	<b>Senior high school rating (Schools)</b>	5.52	17.34	7.33	2.80	4.88	7.05
	<b>Socio Economic Index For Areas (SEIFA)</b>	58.641	87.49	42.39	51.88	60.89	63.43
	<b>Dist. to water (km) (Dist. to water)</b>	3.17	1.15	5.01	4.08	2.13	3.00
<b>Note: The explanatory variable used in the HPM are shown in <i>Bold Italics</i>, and these can be traces through the analysis paper</b>							

Equation 3 (Cross Sectional HPM - Log-Log)

$$\begin{aligned} \text{Log}(\text{vpsm\_no\_view}/\text{m}^2) = & \text{Constant} + B_1 [\text{Log}(\text{Area})] + B_2 [\text{Log}(\text{R-Code})] + B_3 [400\text{m Catchment}] + \\ & B_4 [800\text{m Catchment}] + B_5 [1600\text{m Catchment}] + B_6 [\text{Log}(\text{SNAMUTS})] + \\ & B_7 [\text{Log}(\text{SEIFA})] + B_8 [\text{Log}(\text{Schools})] + B_{10} [\text{Log}(\text{Dist. to Water})] + \\ & B_{11} [\text{Log}(\text{Dwelling 1600})] + B_{12} [\text{Log}(\text{Dist. to CBD})] + B_{13} [\text{Log}(\text{Dist. 2}^{\text{nd}} \text{Centre})] + \\ & B_{14} [100\text{m Highway}] + B_{15} [200\text{m Highway}] + B_{16} [\text{Log}(\text{Dist. To Fwy onramp})] \end{aligned}$$

### 3.3. Panel Data (Log-Log) Hedonic Pricing Model Case Study

Panel data modelling of the temporal variation in land prices is important for understanding the behaviour of land prices over time. Many of the cross sectional variables are non-stationary in a temporal sense and can reflect a number of factors such as:

- economic changes;
- technology changes;
- political shifts; and
- cultural movements (gentrification, etc.)

In addition to these factors, the most important reason for undertaking the panel data HPM analysis in this study was to determine the changes in the Metropolitan Perth land market hedonic prices prior to and during construction as well as after the commencement of operations of the southern rail line. The introduction of the southern rail line (Mandurah) was one of the most significant investments in rail transit in Australia in the last twenty years (opened on 23<sup>rd</sup> of December, 2007) along with the northern rail line in the 1990's. The two rail lines went against national and global trends to avoid building rail into car dependent suburbs and were both immediately successful at generating a new model for transport planning now being copied across Australia and other car dependent urban areas (Newman et al, 2013). Both lines carry over 70,000 passengers per day where the bus lines and bus ways in the corridors previously carried around 14,000 passengers per day. The panel data enabled us to examine the impact of these dramatic patronage increases on the land values in the corridors.

The panel data modelling method employed time dummies as well as time-catchment interaction terms with the rail line pedestrian catchments over the period 2001 to 2011. The annual datasets were then stacked to form a single complete panel dataset containing all the residential land valuations over the 11-year period.

The Log-Log form of the HPM was adopted from the cross sectional analyses as it had the best Adjusted R<sup>2</sup> values for each of its models, the smallest spread of residuals on the plots, and was determined to be the best performing functional form of all those trialled. The panel data Log-Log model is presented below in Equation 4 and the results are presented in Table 5 with interaction terms omitted for brevity. Figure 6 plots the annual rail catchment hedonic prices that were calculated by adding the individual rail catchment coefficients to the time-catchment interaction term values for each year (2001 to 2011).

*Equation 4 (Panel data HPM Log-Log)*

$$\begin{aligned} \text{Log}((\text{vpsm\_no\_view})/m2) = & \text{Constant} + \beta_1 [\text{Log}(\text{Area})] + \beta_2 [\text{Log}(\text{R-Code})] + \beta_3 [\text{400m Catchment}] + \\ & \beta_4 [\text{800m Catchment}] + \beta_5 [\text{1600m Catchment}] + \beta_6 [\text{Log}(\text{SNAMUTS})] + \beta_7 [\text{Log}(\text{SEIFA})] + \\ & \beta_8 [\text{Log}(\text{Schools})] + \beta_{10} [\text{Log}(\text{Dist. to Water})] + \beta_{11} [\text{Log}(\text{Dwelling 1600})] + \\ & \beta_{12} [\text{Log}(\text{Dist. to CBD})] + \beta_{13} [\text{Log}(\text{Dist. 2nd Centre})] + \beta_{14} [\text{100m Highway}] + \\ & \beta_{15} [\text{200m Highway}] + \beta_{16} [\text{Log}(\text{Dist. To Freeway onramp})] + \beta_{16}[\text{dt\_2002}] + \beta_{16}[\text{dt\_2003}] + \\ & \beta_{17} [\text{dt\_2004}] + \beta_{18} [\text{dt\_2005}] + \beta_{19} [\text{dt\_2006}] + \beta_{20} [\text{dt\_2007}] + \beta_{21} [\text{dt\_2008}] + \\ & \beta_{22} [\text{dt\_2009}] + \beta_{23} [\text{dt\_2010}] + \beta_{24} [\text{dt\_2011}] + \beta_{25} [\text{t400(2001\_2002)}] + \\ & \beta_{26} [\text{t800(2001\_2002)}] + \beta_{27} [\text{t400(2001\_2002)}] + \beta_{28} [\text{t800(2001\_2002)}] + \\ & \beta_{29} [\text{t1600(2001\_2002)}] + \beta_{30} [\text{t400(2001\_2003)}] + \beta_{31} [\text{t800(2001\_2003)}] + \\ & \beta_{32} [\text{t1600(2001\_2003)}] + \beta_{33} [\text{t400(2001\_2004)}] + \beta_{34} [\text{t800(2001\_2004)}] + \\ & \beta_{35} [\text{t1600(2001\_2004)}] + \beta_{36} [\text{t400(2001\_2005)}] + \beta_{37} [\text{t800(2001\_2005)}] + \\ & \beta_{38} [\text{t1600(2001\_2005)}] + \beta_{39} [\text{t400(2001\_2006)}] + \beta_{40} [\text{t800(2001\_2006)}] + \\ & \beta_{41} [\text{t1600(2001\_2006)}] + \beta_{42} [\text{t400(2001\_2007)}] + \beta_{43} [\text{t800(2001\_2007)}] + \\ & \beta_{44} [\text{t1600(2001\_2007)}] + \beta_{45} [\text{t400(2001\_2008)}] + \beta_{46} [\text{t800(2001\_2008)}] + \\ & \beta_{47} [\text{t1600(2001\_2008)}] + \beta_{48} [\text{t400(2001\_2009)}] + \beta_{49} [\text{t800(2001\_2009)}] + \\ & \beta_{50} [\text{t1600(2001\_2009)}] + \beta_{51} [\text{t400(2001\_2010)}] + \beta_{52} [\text{t800(2001\_2010)}] + \\ & \beta_{53} [\text{t1600(2001\_2010)}] + \beta_{54} [\text{t400(2001\_2011)}] + \beta_{55} [\text{t800(2001\_2011)}] + \\ & \beta_{56} [\text{t1600(2001\_2011)}] \end{aligned}$$

The calculation of the WTP for access to transit is conducted by the multiplication of the annual catchment hedonic prices with the annual average land value.

## 4. Results

### 4.1. Results of the Residential Cross Sectional HPM

The Ordinary Least Squares HPM models for the Linear, Log-Linear, Linear-Log and Log-Log functional forms had varying levels of success in modelling land vpsm\_no\_view, with the Log-Log models having the highest Adjusted Coefficients of Determination ( $Adj-R^2$ ) and the smallest and most homoscedastic distribution of model residuals. From this analysis the Log-Log functional form of the OLS was selected for use in the analysis as it has the optimum residual distribution, and highest  $R^2$  and therefore the others were discarded. To illustrate the differences in the models, the respective residual plots and congruence statistics for each model are shown in Figure 5.

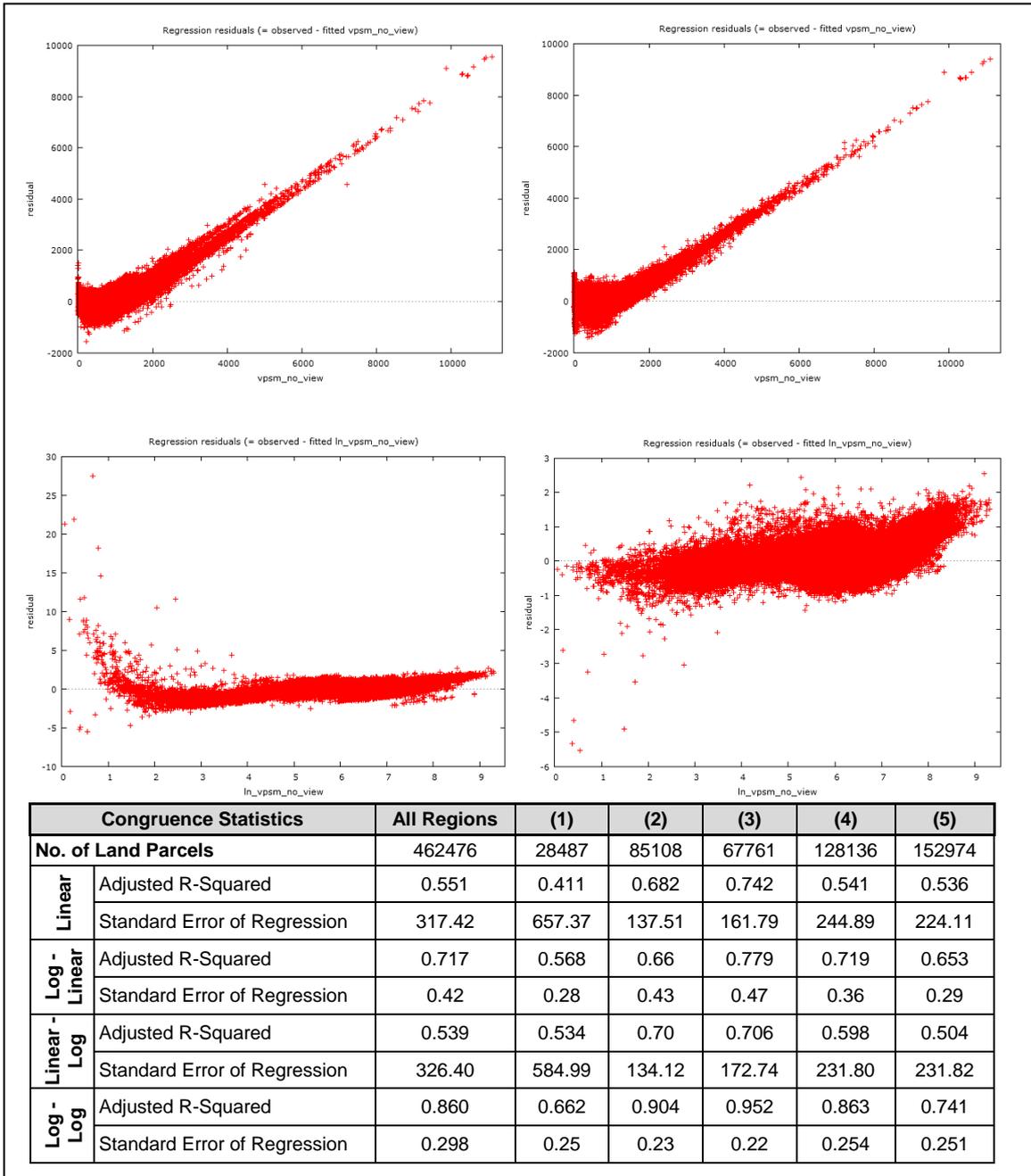


Figure 5 Residual Plots from the All Regions Ordinary Least Squares HPM of Residential Land Parcels for each of the functional forms (Top Left) Linear, (Top Right) Linear-Log, (Middle Left) Log-Linear (Middle Right) Log-Log (Bottom) Ordinary Least Squares HPM Congruence Statistics for each functional form (1) Fremantle, (2) Armadale, (3) Midland (4) Mandurah and (5) Joondalup

Table 4 OLS Log-Log HPM of Residential Land Parcels in Metropolitan Perth, (2011)  
(1) Fremantle, (2) Armadale, (3) Midland (4) Mandurah and (5) Joondalup

Explanatory Variables	Estimated Hedonic Prices <sup>(1)</sup>					
	All Regions	(1)	(2)	(3)	(4)	(5)
Constant	8.270 (0.015)***	10.176 (0.071)***	8.169 (0.024)***	9.217 (0.026)***	6.696 (0.029)***	6.481 (0.026)***
Area (m2)	-0.601 (0.001)***	-0.380 (0.004)***	-0.602 (0.002)***	-0.655 (0.002)***	-0.513 (0.002)***	-0.420 (0.002)***
R-Code	0.016 (0.001)***	-0.014 (0.005)***	0.005 (0.002)**	0.0005 (0.002)	0.112 (0.003)***	0.289 (0.003)***
400m train catchment	<b>0.142</b> <b>(0.004)***</b>	<b>0.148</b> <b>(0.007)***</b>	<b>0.069</b> <b>(0.006)***</b>	<b>0.041</b> <b>(0.006)***</b>	<b>-0.176</b> <b>(0.017)***</b>	<b>-0.198</b> <b>(0.014)***</b>
800m train catchment	<b>0.123</b> <b>(0.002)***</b>	<b>0.165</b> <b>(0.005)***</b>	<b>0.032</b> <b>(0.004)***</b>	<b>0.047</b> <b>(0.004)***</b>	<b>-0.051</b> <b>(0.009)***</b>	<b>-0.074</b> <b>(0.007)***</b>
1600m train catchment	<b>0.011</b> <b>(0.001)***</b>	<b>0.144</b> <b>(0.004)***</b>	<b>-0.045</b> <b>(0.002)***</b>	<b>0.089</b> <b>(0.003)***</b>	<b>-0.032</b> <b>(0.003)***</b>	<b>-0.068</b> <b>(0.003)***</b>
SNAMUTS score	0.002 (0.0001)***	0.004 (0.0005)***	0.005 (0.0002)***	0.006 (0.0002)***	-0.008 (0.0002)***	0.008 (0.0002)***
Socio Economic Index For Areas (SEIFA)	0.246 (0.001)***	0.191 (0.006)***	0.173 (0.001)***	0.133 (0.001)***	0.273 (0.001)***	0.221 (0.001)***
Senior high school rating	0.052 (0.001)***	0.212 (0.004)***	0.047 (0.0003)***	0.020 (0.0003)***	0.054 (0.0002)***	0.165 (0.0007)***
Distance to water	-0.155 (0.0005)***	-0.239 (0.002)***	-0.051 (0.001)***	-0.100 (0.001)***	-0.149 (0.001)***	-0.156 (0.001)***
Dwellings within 1600m	0.139 (0.001)***	-0.213 (0.005)***	0.166 (0.002)***	0.132 (0.002)***	0.203 (0.002)***	0.091 (0.002)***
Distance to CBD	-0.029 (0.001)***	-0.015 (0.002)***	-0.014 (0.001)***	-0.029 (0.001)***	-0.013 (0.001)***	-0.028 (0.001)***
Distance to secondary centre	-0.030 (0.001)***	-0.054 (0.002)***	0.017 (0.001)***	0.003 (0.001)***	-0.018 (0.001)***	0.003 (0.001)***
0 – 100m of a highway	-0.070 (0.002)***	-0.166 (0.007)***	-0.072 (0.004)***	-0.065 (0.005)***	-0.056 (0.004)***	0.003 (0.004)
100 – 200m of a highway	0.004 (0.002)***	-0.070 (0.006)***	-0.014 (0.003)***	-0.001 (0.003)	0.021 (0.003)***	0.057 (0.003)***
200 – 400m of a highway	0.020 (0.001)***	-0.023 (0.006)***	-0.006 (0.003)**	-0.002 (0.003)	0.025 (0.002)***	0.074 (0.002)***
Distance to nearest freeway onramp	0.030 (0.001)***	0.008 (0.002)***	-0.011 (0.001)***	-0.075 (0.001)***	-0.018 (0.001)***	0.014 (0.001)***
<b>Congruence Statistics</b>						
No. of Land Parcels	462,476	28,487	85,108	67,761	128,136	152,974
Adjusted R-Squared	0.860	0.662	0.904	0.952	0.863	0.741
Standard Error of Regression	0.298	0.251	0.229	0.221	0.254	0.251
Notes: <sup>(1)</sup> Figures in brackets report parameter standard errors. Significance at the 0.01 level is indicated by three asterisks, significance at the 0.05 level is indicated by two asterisks, and significance at the 0.10 level is indicated by a single asterisk.						

#### 4.2. Results from the Residential Panel Data HPM

The data and graphs of the OLS panel data HPM's for the period 2001 to 2011 (Table 5 and Figure 6) illustrate interesting metropolitan and regional trends in the hedonic prices.

Table 5 OLS Panel data (Log-Log) HPM of Residential Properties (2001 – 2011)  
 (1) Fremantle, (2) Armadale, (3) Midland, (4) Southern and (5) Northern

Explanatory Variables	All Regions	(1)	(2)	(3)	(4)	(5)
Const	6.048 (0.006)***	9.010 (0.022)***	6.223 (0.010)***	6.877 (0.010)***	-1.124 (0.02)***	4.113 (0.011)***
ln_area	-0.516 (0.000)***	-0.412 (0.001)***	-0.535 (0.001)***	-0.558 (0.001)***	-0.390 (0.0001)***	-0.375 (0.001)***
ln_rcode	0.024 (0.001)***	-0.023 (0.002)***	0.013 (0.001)***	0.055 (0.001)***	0.102 (0.001)***	0.334 (0.001)***
train400	0.235 (0.005)***	0.228 (0.007)***	-0.142 (0.007)***	0.071 (0.007)***	-0.337 (0.002)***	-0.269 (0.018)***
train800	0.176 (0.003)***	0.252 (0.005)***	-0.123 (0.004)***	0.093 (0.004)	-0.094 (0.001)***	-0.050 (0.009)***
train1600	0.074 (0.001)***	0.180 (0.004)***	-0.130 (0.002)***	0.148 (0.004)***	-0.034 (0.003)***	-0.008 (0.003)***
ln_snamuts	0.003 (0.000)***	-0.006 (0.0001)***	0.007 (0.0001)***	0.011 (0.0001)***	-0.009 (0.0001)***	0.010 (0.0006)***
ln_seifa_adv_di	0.304 (0.000)***	0.166 (0.002)***	0.202 (0.0004)***	0.205 (0.001)***	0.283 (0.0004)***	0.281 (0.0005)***
ln_shstrate11	0.058 (0.000)***	0.171 (0.001)***	0.055 (0.0001)***	0.023 (0.0001)***	0.030 (0.0001)***	0.045 (0.0008)***
ln_dist_water	-0.183 (0.000)***	-0.241 (0.001)***	-0.053 (0.0004)***	-0.094 (0.0004)***	-0.214 (0.0003)***	-0.200 (0.0003)***
ln_dwell_1600	0.157 (0.000)***	-0.165 (0.002)***	0.173 (0.001)***	0.125 (0.001)***	0.206 (0.0007)***	0.175 (0.0001)***
ln_dist_cbd	-0.028 (0.000)***	-0.012 (0.001)***	-0.001 (0.0003)***	-0.023 (0.0003)***	-0.004 (0.0003)***	-0.041 (0.0003)***
ln_dist_ctr_non	-0.034 (0.000)***	-0.062 (0.001)***	0.025 (0.0003)***	-0.009 (0.0004)***	-0.004 (0.0003)***	0.005 (0.0003)***
hwy0_100	-0.077 (0.001)***	-0.165 (0.002)***	-0.075 (0.001)***	-0.107 (0.002)***	-0.053 (0.0001)***	-0.015 (0.001)***
hwy100_200	0.006 (0.001)***	-0.062 (0.002)***	-0.018 (0.001)***	-0.025 (0.001)***	0.041 (0.001)***	0.049 (0.001)***
ln_fwyonramp	0.026 (0.000)***	0.021 (0.001)***	-0.013 (0.0004)***	-0.089 (0.001)***	0.015 (0.0001)***	0.032 (0.0003)***
dt_2002	0.067 (0.001)***	0.081 (0.003)***	0.018 (0.001)***	0.047 (0.002)***	0.058 (0.001)***	0.082 (0.001)***
dt_2003	0.18 (0.001)***	0.164 (0.003)***	0.101 (0.002)***	0.163 (0.002)***	0.178 (0.001)***	0.210 (0.001)***
dt_2004	0.367 (0.001)***	0.301 (0.003)***	0.259 (0.002)***	0.317 (0.002)***	0.374 (0.001)***	0.419 (0.001)***
dt_2005	0.549 (0.001)***	0.428 (0.003)***	0.464 (0.002)***	0.505 (0.002)***	0.598 (0.001)***	0.565 (0.001)***
dt_2006	0.769 (0.001)***	0.577 (0.003)***	0.730 (0.002)***	0.765 (0.002)***	0.796 (0.001)***	0.781 (0.001)***
dt_2007	1.187 (0.001)***	0.869 (0.003)***	1.175 (0.002)***	1.216 (0.002)***	1.165 (0.001)***	1.23 (0.001)***
dt_2008	1.315 (0.001)***	1.070 (0.003)***	1.319 (0.002)***	1.387 (0.002)***	1.314 (0.001)***	1.318 (0.001)***
dt_2009	1.24 (0.001)***	1.015 (0.0003)***	1.258 (0.002)***	1.348 (0.002)***	1.247 (0.001)***	1.217 (0.001)***
dt_2010	1.25 (0.001)***	0.994 (0.003)***	1.273 (0.002)***	1.349 (0.002)***	1.234 (0.001)***	1.252 (0.001)***
dt_2011	1.323 (0.001)***	1.071 (0.003)***	1.355 (0.002)***	1.409 (0.002)***	1.297 (0.001)***	1.324 (0.001)***
<b>Congruence Statistics</b>						
No. of Observations	4431363	297855	795028	595669	1200898	1541913
Adjusted R-Squared	84.60%	81.98%	91.12%	92.16%	87.20%	80.32%
Standard Error of Reg.	0.336	0.250	0.239	0.311	0.280	0.243
Notes: Figures in brackets report parameter standard errors. Significance at the 0.01 level is indicated by three asterisks, significance at the 0.05 level is indicated by two asterisks, and significance at the 0.10 level is indicated by a single asterisk. Interaction terms between time dummies and train catchments are omitted here for brevity but the annual uplift estimates can be seen plotted below in Figure 6.						

### 4.3. Willingness to Pay for Rail Transit Accessibility

The calculation of the WTP for access to transit is conducted by the multiplication of the annual catchment hedonic prices with the annual average land value. Table 6 presents the average annual land value for the All Regions and the Subregion models along with the WTP for transit access in the 400m catchments. As demonstrated in Figure 6, the Mandurah Rail Line WTP model represents the most significant change in the hedonic price for land values in the analysis, and this is reflected in the relative changes presented in the WTP for rail transit access here in Table 6. The value capture potential is substantial in this car dependent corridor.

Table 6 The Rail Line's catchment average annual vpsm\_no\_view/m<sup>2</sup> (in \$2011) and \$2011 WTP for transit, 400m catchment (1) Fremantle, (2) Armadale, (3) Midland, (4) Mandurah and (5) Joondalup

	All Regions		(1)		(2)		(3)		(4)		(5)	
	Av. LV \$2011	WTP 400m	Av. LV \$2011	WTP 400m	Av. LV \$2011	WTP 400m	Av. LV \$2011	WTP 400m	Av. LV \$2011	WTP 400m	Av. LV \$2011	WTP 400m
2001	\$133.23	<b>\$30.65</b>	\$634.94	<b>\$145.03</b>	\$128.12	<b>\$(18.19)</b>	\$124.84	<b>\$8.87</b>	\$226.09	<b>\$(76.15)</b>	\$240.35	<b>\$(64.70)</b>
2002	\$141.62	<b>\$20.61</b>	\$671.85	<b>\$152.20</b>	\$124.83	<b>\$(15.68)</b>	\$127.49	<b>\$10.48</b>	\$235.68	<b>\$(88.28)</b>	\$252.16	<b>\$(64.12)</b>
2003	\$165.02	<b>\$16.82</b>	\$705.60	<b>\$132.74</b>	\$140.86	<b>\$(15.74)</b>	\$157.36	<b>\$7.77</b>	\$258.15	<b>\$(94.94)</b>	\$278.52	<b>\$(60.18)</b>
2004	\$192.22	<b>\$15.39</b>	\$796.88	<b>\$122.72</b>	\$160.49	<b>\$(12.53)</b>	\$159.75	<b>\$14.62</b>	\$296.43	<b>\$(68.48)</b>	\$329.67	<b>\$(57.68)</b>
2005	\$229.78	<b>\$11.09</b>	\$879.32	<b>\$110.09</b>	\$191.83	<b>\$(12.10)</b>	\$187.56	<b>\$8.71</b>	\$349.45	<b>\$(57.54)</b>	\$369.23	<b>\$(55.11)</b>
2006	\$288.08	<b>\$14.48</b>	\$978.40	<b>\$133.91</b>	\$236.12	<b>\$2.92</b>	\$229.99	<b>\$(0.22)</b>	\$409.03	<b>\$(49.26)</b>	\$438.27	<b>\$(53.25)</b>
2007	\$436.76	<b>\$15.13</b>	\$1288.22	<b>\$168.63</b>	\$348.04	<b>\$7.21</b>	\$353.16	<b>\$4.23</b>	\$550.62	<b>\$(27.54)</b>	\$641.97	<b>\$(77.47)</b>
2008	\$499.86	<b>\$17.87</b>	\$1500.30	<b>\$140.02</b>	\$387.47	<b>\$11.26</b>	\$403.40	<b>\$1.58</b>	\$608.09	<b>\$0.61</b>	\$684.89	<b>\$(70.06)</b>
2009	\$463.82	<b>\$18.52</b>	\$1396.41	<b>\$143.92</b>	\$362.12	<b>\$4.06</b>	\$379.35	<b>\$(1.58)</b>	\$566.36	<b>\$0.93</b>	\$601.54	<b>\$(51.94)</b>
2010	\$469.39	<b>\$12.78</b>	\$1299.57	<b>\$100.96</b>	\$357.93	<b>\$1.14</b>	\$371.47	<b>\$(1.00)</b>	\$546.67	<b>\$(14.31)</b>	\$608.15	<b>\$(49.39)</b>
2011	\$504.65	<b>\$15.39</b>	\$1387.76	<b>\$117.16</b>	\$376.44	<b>\$6.56</b>	\$383.34	<b>\$(0.88)</b>	\$564.58	<b>\$(27.34)</b>	\$632.65	<b>\$(45.62)</b>

## 5. Discussion and Analysis of the Results

### 5.1. Residential Cross-sectional HPM for 2011

The results for the majority of the residential cross-sectional HPM explanatory variables in the models presented in Table 4 were of expected sign and magnitude. Importantly the evidence of land value uplift as a result of proximity to rail was very compelling. These hedonic prices are relative to all properties within the model and those further than 1600 metres from a train station, which is considered to be well beyond the acceptable distance for pedestrian accessibility to public transport (further than a 20 minute walk). The individual train line models reveal interesting trends related to how passenger rail access impacts land values in different urban corridors.

The majority of the residential HPM's reported Adjusted Coefficients of Determination (Adjusted R-Squared values) over 70%, which is the suggested minimum level of explanatory power for the application of hedonic models in predicting land values (Hannonen, 2009; McCarthy, 2001). When applying a Log-Log functional form to the estimation of HPM, the parameter estimates for continuous variables are interpreted as elasticities (i.e. the percentage change in land value due to a 1% change in a continuous explanatory variable (McCarthy, 2001)).<sup>1</sup>

<sup>1</sup> Dichotomous variables (or dummy variables) on the other hand are interpreted as uplift percentages (i.e. the percentage change in land value due to a unit change in a dichotomous explanatory variable (McCarthy, 2001)). The dichotomous variables include the three train station catchment dummies and the two highway proximity bands while the rest of the variables in the residential models are continuous.

The most interesting of these findings is related to the impacts of rail in the rapid transit northern and southern lines (Mandurah and Joondalup) when compared to the three heritage lines (Fremantle, Armadale and Midland). The impacts of proximity to rail for residential land in the new rapid transit catchments are large, negative and reduce with increased distance from the stations. The three older heritage lines, on the other hand, generate positive uplift that generally diminishes with increased distance from a station; with the Fremantle line's uplift being the largest. The results presented in Table 4 align with expectations because the two newer lines embody a significantly different model of rail service provision and land use and transport integration, as discussed previously. It is suggested that in these circumstances, the negative externalities of being close to the freeway (and having extensive park-and-ride facilities and feeder bus networks operating in the surrounding areas) have negated potential positive accessibility-based land value impacts from being located within the pedestrian catchments of these stations. However the full story on rail's impact on land value in these car dependent corridors needs historic data (see below).

The positive yet reversed nature of the estimated uplift from proximity to rail in the Midland model, however, only partially meets expectations. Rather than the land value uplift estimates being highest in the inner (0 to 400m) catchment, the results suggest they are highest in the outer (800m to 1600m) catchment. This may be occurring because the Beaufort Street activity corridor (an old tram line corridor) offering restaurants, shops and other types of amenity to local residents, runs near parallel to the train line but within these outer walking catchments of the train stations. While we were able to control for the effects of proximity to activity centres, the potential impacts of activity corridors were not included in the models. These types of subregion-specific issues are expected to be normalised to some extent in the All Regions models.

## **5.2. Residential Panel Data HPM (2001-2011)**

The major increases in the land value hedonic price over this time were for the Mandurah and Armadale lines, with the Fremantle and Joondalup lines remaining relatively stable (though the Joondalup 400m catchment maintained a long term upward trend), and the All Regions and Midland models decreasing over the assessment period. This reflects the complex and diverse nature of the land submarkets in the overall land market context for metropolitan Perth.

These submarket differences (with the southern and northern catchments excluded) are likely reflections of the impacts of external factors (transit and road based congestion, transit line level of service, fuel prices, etc.) affecting the individual submarkets differently over the study period. The Midland catchment is an example of this phenomenon, whereby the catchment underwent significant expansion of higher value green field development, while the traditional areas around the rail lines did not experience urban renewal and as such were left behind the rest of the subregion in terms of value growth. Importantly, the design of the transit accessibility model for the heritage lines, and in particular the Midland rail line where some park-and-ride facilities were added at the stations during the assessment period, further reduced the benefit of being within the transit station's pedestrian catchments. This change in the importance of proximity to the rail line is subsequently reflected in the catchment's land market values for each catchment.

## **5.3. Analysis of the Impact of the implementation of the Southern Rail Line to Mandurah**

The southern rail line to Mandurah was added to the rail network in January 2008, which is during the study time period from 2001 to 2011. During this study the most recent land valuation data for the southern corridor became available and has been used to extend the Mandurah Rail catchment panel data analysis, which is presented in Figure 7. Although the Mandurah Rail line pedestrian catchment's hedonic prices are shown to have been negative during the entire study period (2001 – 2012) relative to the land parcels in the rest of the sub-region (due to the negative externalities of being near the freeway), the change in the hedonic prices as a result of the introduction of the rail line is significantly positive.

Though it is outside the scope of the study being undertaken, traffic noise and general traffic movements are likely to be contributing factors in the long term negative hedonic prices for catchments based around freeways.

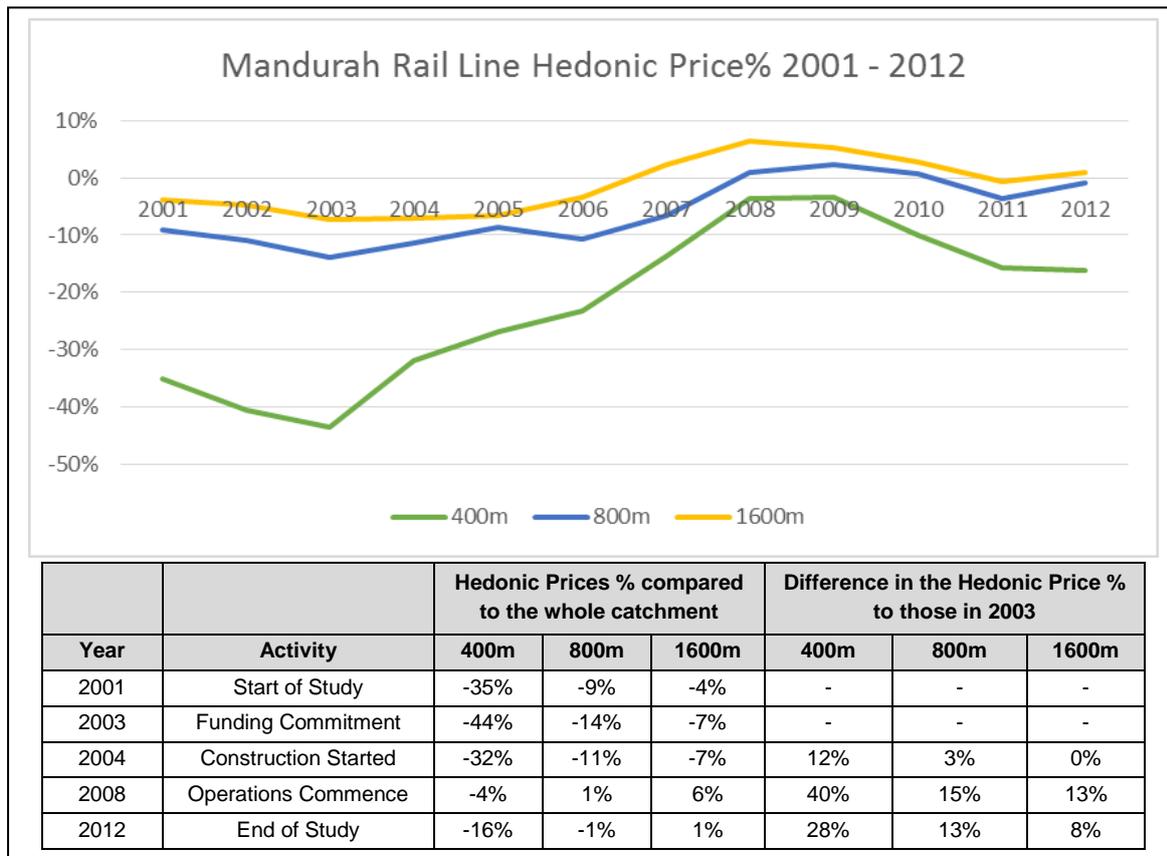


Figure 6 (Top) Mandurah Rail line residential panel data hedonic price (2001-2012) (Bottom) Absolute and relative Hedonic price difference for the Mandurah Rail line's catchments (2001-2012)

This strong positive response in land values (most substantially over the two years prior to the opening of the new line) demonstrates the value of the introduction of the new rapid rail system, and adds another context to the cross-sectional analyses demonstrating strictly negative impacts in 2011. It shows that within five years from the funding commitment to the commencement of operations the value of land near the rail line increased up to 40% when compared to the rest of the catchment, even when being located in close proximity to the freeway reserve. The most important part of the Southern rail line graph in Figure 6 is not the absolute difference between the 400m catchment and the rest of the Southern rail catchment, but the relative difference between the 400m, 800m and 1600m catchments and especially how the differences narrowed. This clearly shows how the willingness to pay for the 400m catchment of the Southern rail line stations significantly increased, and almost reached parity with the 800m and 1600m catchments, as the negative externalities of being in close proximity to the freeway reduced in their importance given the increase in the perceived value of transit accessibility.

Though there was a dip in the Mandurah Line catchment's hedonic prices after 2009, it can be seen as a delayed response to the Global Financial Crisis and can reasonably be expected to correct back to 2008 hedonic prices as has been experienced by the rest of the metropolitan region (as shown in Figure 6). This process commenced after 2011 and returned to positive growth in the hedonic price.

The hedonic price change between funding commitment and transit opening of 40% for the 400m catchment and 13% in the 1600m catchment is a significant difference in land values due to the new rail system accessibility. Even if a conservative view is taken by adopting the 2012 amounts from Figure 6 demonstrating catchment uplift changes in the order of 28% and 8%, the difference is still substantial. This post commencement of operations change is explained by Mohammad et al, (2013) and Bae et al. (2003) that state that the perceived benefit of the rail system at time of announcement is often higher compared to the actual realised benefit after the system stabilises. This stabilisation post commencement of operations has now occurred, and the 28% uplift in land value appears to be permanent.

Figure 6 presents the hedonic prices for each of the pedestrian catchments of the Mandurah rail line over the assessment period. Key dates have been selected to enable a comparison to the Center for Transit Oriented Design's (CfTOD) theoretical value curve, presented in Figure 1, to see whether the traditional TOD value model is of relevance to the new rapid transit rail line down a car dependent low density corridor.

The 28% uplift in residential land market values is large for a commuter rail system, especially in a car dependent cities, like Perth. However, the following contributing factors demonstrates the importance of the rail line to the region and should be taken into account;

- mono-centric nature of employment across the metropolitan region,
- the large (not just incremental) change to accessibility for residents
- the rapidly increasing congestion of the competing highways and freeways, and
- the Mandurah rail line's ability to successfully compete with cars in terms of generalised cost.

The panel data examination of the introduction of the rail line within the Mandurah Line subregion therefore tells a substantially different story to the one portrayed by the cross-sectional analyses for 2011, and is a critical aspect of the analysis of the WTP for rail transit accessibility and value capture potential. Quality transit can significantly impact on land values in car dependent suburbs and is therefore a potential source of value capture as well as creating potential for future TODs.

## **6. Conclusions**

Around the world there is a significant increase in transit patronage and a decline in car usage as various constraints to car dependence begin to change transport systems, and as a result the need to build new transit infrastructure is back on the agenda in most cities. Central questions remain however, about whether transit can work in car dependent areas and if there could be a potential for using land value capture as the way to help fund it. However the paper has shown that even with these obvious issues the attractiveness of living near to the rail system is likely to be strong and hence generate a potential for value capture.

Through the use of cross sectional and panel data hedonic modelling methods this paper has been able to illustrate how residential land value increases can be calculated, and validate the value premium theoretical curve proposed by the Center for Transit Oriented Development. The WTP modelling demonstrates that the land market value increases due to transit can be substantial (up to 40%) even in car dependent corridors, and poorly integrated station locations as illustrated with Murdoch Station in Figure 4. It also suggests that there will be a market for increasing housing densities near stations (such as Subiaco Station presented in Figure 4) even where stations have been designed without this consideration due to the need to integrate bus and car access at stations in car dependent corridors.

This increased willingness to pay for transit accessibility demonstrates that land and property value capture mechanisms like Tax Increment Financing to capture induced increases in existing

land and property taxes resulting from this uplift to substantially defray the cost of building new transit in highly car dependent cities like Perth.

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**JOURNAL PAPER 4: TAX INCREMENT FINANCING FRAMEWORK  
FOR INTEGRATED TRANSIT AND RBAN RENEWAL PROJECTS IN  
CAR DEPENDENT CITIES**

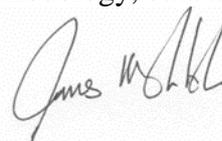
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**Statement of Contributions of Joint Authorship**

**McIntosh, J:**                    **(PhD Candidate)**                    **(80% Contribution)**

Writing and completion of manuscript, established methodology, data analysis,  
preparation of tables and figures.

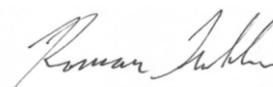



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*James Robert McIntosh, PhD Candidate*

**Trubka, R:**                    **(Research Colleague)**                    **(10% Contribution)**

Assisted with data analysis, editing and co-authored of manuscript




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*Doctor Roman Trubka, Associate Supervisor*

**Newman, P:**                    **(Principle Supervisor)**                    **(10% Contribution)**

Supervised and assisted with manuscript compilation, editing and co-authorship of  
manuscript.




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## **TAX INCREMENT FINANCING FRAMEWORK FOR INTEGRATED TRANSIT AND URBAN RENEWAL PROJECTS IN CAR DEPENDENT CITIES**

**Keywords:** *Transit Accessibility, Hedonic Price Modelling, Infrastructure Funding, Value Capture, Tax Assessment Districts, Tax Increment Financing*

### **Abstract**

Tax Increment Financing (TIF) has long been seen in the USA as a tool for urban regeneration but the use of TIF for funding transit projects is less common. A four-step Transit Tax Increment Financing (TTIF) framework is proposed as a means of funding the investment in integrated land use and transit projects in low-density car dependent cities. The TTIF framework is illustrated through a case study of a retrospective application to the Mandurah rail line in Perth, Western Australia, and demonstrates that much more funding can be generated using this mechanism than has been considered by transit project planners before. It also has the benefits of enabling private sector involvement in transit projects and ensures TODs are built and not just planned.

### **1. INTRODUCTION**

The case for reducing automobile dependence has been ongoing (Thomson, 1977; Newman and Kenworthy, 1999; Noland and Lem, 2002; Steg and Gifford, 2005; TRB, 2009). As car use per capita is peaking in global cities (Klinger et al., 2013; Newman et al., 2013) and transit patronage is growing rapidly (Newman and Kenworthy, 2011; Kenworthy, 2008) there is a need to clarify a mainstream urban planning approach to funding and financing transit to meet the demand for transit services.

It has been well established that transit systems increase the value of the land and property surrounding transit infrastructure through the increase in transport accessibility (Cervero, 1997; Scheurer et al., 2000; Debrezion et al., 2007; Kilpatrick et al., 2007; Duncan, 2010;

McIntosh et al., 2013). This paper shows how cities can analyse and capture the passive financial benefits created in land and property markets by the introduction of new transit systems. The paper first provides a background review of the literature on the impacts of transit infrastructure investments on land and property taxation systems and the nature and prevalence of Tax Increment Financing (TIF) methods. A four-step framework is then proposed to assess and capture the induced tax cash flows created by transit infrastructure through a land and property TIF system to fund new transit.

To illustrate the implementation of a Transit TIF (TTIF) framework, a case study is presented, where the TTIF is retrospectively applied to the Mandurah Line in Perth, Western Australia. Perth is a city built around the car and the Mandurah rail line was implemented to address the issues of car dependence as an extension to the urban transit network. Although the focus is on Perth, the framework is applicable to any city and in particular the cities outside of the US where TIF has not been traditionally implemented.

## **2. BACKGROUND**

Economically, land is the most basic resource and a heterogeneous good that differs in terms of its characteristics and location in relation to other resources (O'Sullivan, 2012). Although land markets are imperfect (due to the unstandardized commodities they trade) they perform four important functions (Hannonen, 2009):

- they bring buyers and sellers together to facilitate transactions,
- they set prices for land parcels,
- they allocate land by setting land prices that clear at the quantity of land demanded, and
- they play an important role in ensuring that land is efficiently used.

An important factor in land markets is that land is spatially immobile, which implies that location is an intrinsic attribute of the land parcel and should form the basis of its economic analysis. Brigham (1956) proposes a simple theoretical model for land value ( $V$ ) as a function of its accessibility to economic activities ( $P$ ), its region's amenities ( $A$ ), its topography ( $T$ ), its use ( $U$ ) and historical factors ( $H$ ) that affect its utilisation. This model for land parcel  $i$  can be expressed as:

$$V_i = f(P_i, A_i, T_i, U_i, H_i)$$

Importantly, land market prices also reflect the interaction between buyers and sellers in the market, as costs (such as travel) are traded-off against land rents (and population densities) in a bid rent curve (Alonso, 1964; Muth, 1969).

Transport network accessibility is a critical aspect of metropolitan spatial and economic structures (Guiliano et al., 2010). There are many examples that demonstrate the monetisation of accessibility into property land values (Cervero and Duncan, 2002; Cervero, 2004; McIntosh et al., 2014). It is therefore intrinsic that transit influences patterns of urban land use and development activity, which Batt (2001) argues is largely within a context based on a perception of economic costs incurred. Therefore, a reduction in the economic cost of travel, which is a function of a land parcel's location, is reflected in property prices due to a willingness to pay (WTP) for a reduction in the economic cost of commuting (Fejarang, 1994; Batt, 2001; Ewing and Cervero, 2010). This reinforces Alonso's (1964) bid rent decay curve of an individual's site selection as well as a site's value. The transit impact on the bid rent curve is illustrated below in Figure 1.

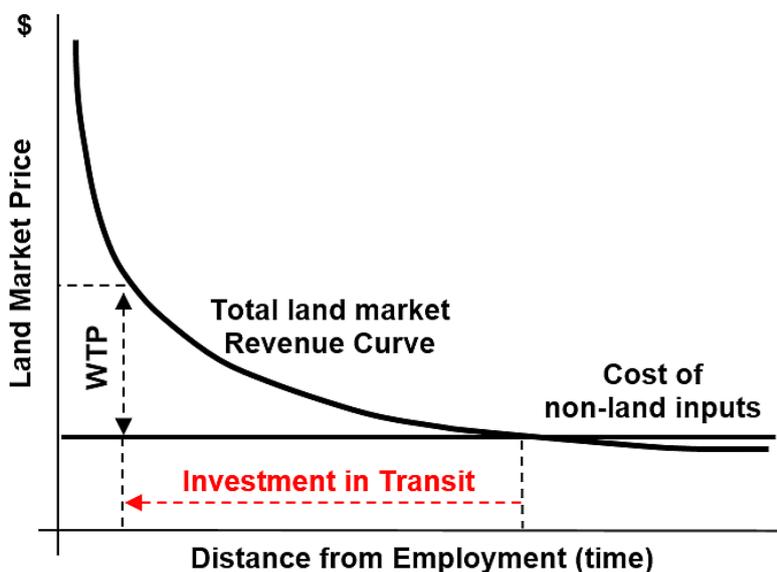


Figure 1 Willingness to Pay (WTP) for transit's impact on the land market bid rent curve  
(Adapted from Alonso, 1964; O'Sullivan, 2012)

The Centre for Transit Oriented Development (2008) provides a theoretical value WTP premium curve where the monetisation of the access to transit infrastructure occurs from project funding to the commencement of operations, which is shown empirically by McIntosh et al. (2014).

Land and property value uplift due to an infrastructure investment will be monetised over time into the ad valorem tax system, with the net revenue of the incremental tax impacts to increase over the assessment time frame with respect to a “no investment” base case.

To quantify the tax implications of a reduction in the economic cost of travel in land and property markets, it is necessary to set the geographic boundary, or district within which to assess and forecast the impact of the investment in transit infrastructure and re-urbanisation. This district could take the form of a land use Planning Control Area (PCA) or a Tax Assessment District (TAD) [also known as Tax Increment Districts (TID) and

Special Assessment Districts (SAD)], which are used extensively in the United States (Johnston et al., 2002; US EPA, 2013; Zhao, 2011). This focus on local infrastructure was broadened to include transit in the US in 2004 when the State of Pennsylvania passed Transit Revitalization Investment District (TRID) legislation, which was designed to fund both transit and Transit Oriented Development (TOD) in station precincts.

The creation of these districts (TAD, TID, SAD, TRID) enables the assessment of the impacts from the investment in transit on the land and property submarkets and the subsequent analysis of the impacts on existing government ad valorem taxes and charges. This is important, as the identification of bounded benefit areas is a crucial component of the TTIF framework.

#### *Tax Increment Financing*

The principle of Tax Increment Financing (TIF) involves forecasting the net tax revenue impacts of future land value increases that are induced from value improving projects that enable finance to be raised. TIF has been used extensively in the US for over 50 years (Zhao et al., 2010; Sullivan et al., 2002; Weber and Goddeeris, 2007; US EPA, 2013), where TIF has generally been used to fund a project-specific Tax Increment District Bond (TID Bond) or other public sector finance mechanism for urban infrastructure improvements and urban renewal projects.

TIF is considered a “self-financing” way to pay for economic development projects in US cities where redevelopment projects are financed through induced increases to local government taxes, predominately through local sales tax revenues generated by new

development. Government officials do not have to impose a new tax, but rather simply reallocate new revenues from development to pay for development costs.

The first TIF law created in the USA was in California in 1952 and has since spread to fifty other states with TIF spurring the redevelopment of blighted areas. Now the use of TIF schemes to generate project finances has expanded into other areas and has developed into an integral part of the revenue structure of many local governments across the US.

There is a history of using dedicated land and property taxes for investment in urban renewal and some transit projects in the US. Some examples of the implementation of TIF for transit projects include:

- Chicago, Illinois - the Randolph/Washington station, the Dearborn subway, and various transit projects within central Chicago's Loop. The City of Chicago allocated \$42.4 million in TIF revenue to the Randolph/Washington station (US EPA, 2013).
- Atlanta, Georgia – Atlanta Belt Line is a comprehensive redevelopment and mobility project that will build a network of public parks, multi-use trails, and transit, including a 22-mile rail line that will serve 45 neighbourhoods and connect to existing MARTA service. The project will cost an estimated \$2.8 billion, with the Atlanta Belt Line TAD generating approximately \$1.7 billion of the total project cost over 25 years (Atlanta Belt Line, 2014).
- San Francisco, California - TIF financing is being used to support redevelopment of the Transbay Transit Center, a multimodal transportation hub that includes a

1,000-foot-tall office tower, a 5.4-acre rooftop park, and 2,600 new homes.

Funding for the \$4.2 billion project will come from a variety of sources, including \$1.4 billion in TIF funds, of which \$171 million will be used to repay a federal TIFIA loan used for the transit centre's construction (USGAO, 2010).

Internationally there has been much less use of TIF for transit. The UK government amended the Local Government Finance Act (1992) in 2010 to allow for TIF in Scotland and now any proposal for a TIF project must demonstrate to Scottish Ministers that the enabling infrastructure will unlock regeneration, facilitate sustainable economic growth, and generate additional (or incremental) public sector revenues (net of a displacement effect). The Manchester City Deal included the "Earn Back Model", a commercial rates/taxes based TIF, which is expected to earn £1.20 Billion over a 30 year period and to repay or fund the finance for the investment in transport and other economic infrastructure (Greater Manchester Combined Authority, 2012).

The Hong Kong Mass Transit Railway Corporation Limited (MTRCL) "Rail and Property" model for financing rail is different to the TIF systems being presented in this paper as the windfall land value uplift that occurs from the transit infrastructure on the land owned or controlled by the government is directly capitalised by the MRTCL by undertaking station precinct land development. Hence the incremental value benefit into property sales revenue is internalised.

The benefits of TIF implementation in the US include the following (Johnson et al., 2002; Sullivan et al., 2002):

- 1) It can provide financing for projects that otherwise would not be fiscally feasible.

- 2) The city loses no tax revenue.
- 3) Property owners in a redevelopment zone pay their full share of property taxes and property owners outside the zone are not required to pay more than a normal tax burden.
- 4) If TIF bonds are used, they are not generally included in a city's general debt obligations.
- 5) Urban re-development is financed from the increases in tax revenues that it generates, not by subsidy from other areas of the city.
- 6) Once TIF bonds are retired, the city and all other affected taxing units are returned the advantage of the full tax base and increased tax revenues.
- 7) If the TIF is funded through a bond issue, projects must be well-planned and economically feasible in order to attract bond investors;
- 8) Voter approval of other taxing units is not required; a city council may act unilaterally.

The benefits of a TTIF framework therefore are not just that a transit infrastructure is built but an integrated delivery of denser urban redevelopment around stations is made into a strongly enhanced urban development process. Such delivery of TODs is rarely achieved despite most car dependent cities having the concept embedded in their plans (Woodcock et al., 2011).

As stated previously, TIF schemes work by recognising and securitising additional funds from induced increases in the existing tax base (local sales tax, or in Australian State Government stamp duty, land tax, or Australian Federal Government capital gains tax and GST<sup>6</sup>). To achieve this the base year assessed value of property (Base AV) belongs to all the existing taxing districts in the TID, and after the base year the increase in the assessed

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<sup>6</sup> Federal taxes however are unable to be hypothecated back to states for such projects though equivalent amounts could be provided in infrastructure grants.

value in the TID above the base value belongs to the TID. This portion of the tax base is referred to as incremental assessed value (Incremental AV) and is illustrated in Figure 2.

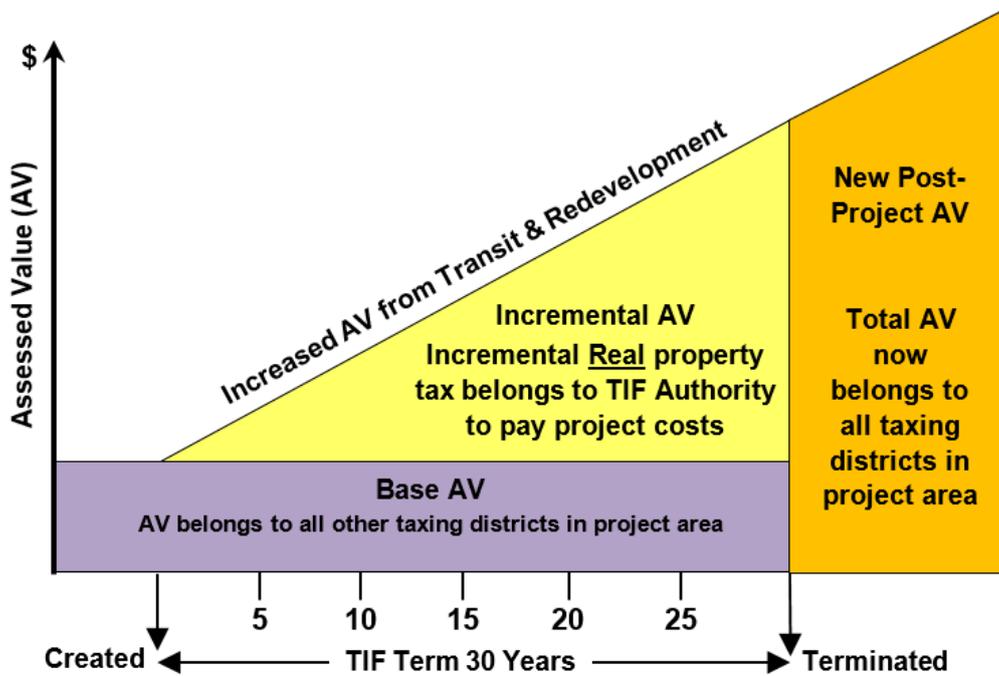


Figure 2 Tax Increment Financing (TIF) Assessed Value (AV) in Real terms over the project life (adapted from Johnson et al., 2002)

The incremental increases in taxes and levies collected within a TID and the securitised increases in ad valorem tax cash flows can help the capital and operating costs of a transit infrastructure.

Sullivan et al. (2002) propose a model for the financial viability of a TIF district, measured by net present value (NPV), as the summed present value of the tax increment less any TIF organizational or infrastructure costs. The TIF NPV equation (as adapted from Sullivan et al., 2002) is presented as follows:

$$NPV_{TIF} = \sum_{t=0}^N \left( \frac{V_{TIF} + AcV_{TIF}}{(1 + g'_b)(r - g'_b)} (tax_x) - \frac{tax_x}{r - g_b} V_{TIF} - cV_{TIF} \right)$$

Where for a given city  $x$  the:

- $V_{TIF}$  is the base valuation of the properties contained within the TIF
- $AcV_{TIF}$  is the proportion of each dollar spent on the TIF that accrues to property values
- $cV_{TIF}$  is the initial capital cost of the TIF
- $tax_x$  is the combined municipal tax rate
- $r$  represents the project discount rate
- $g'_b$  is the annual rate of change in property values in the TIF district
- $g_b$  is the projected growth rate of property values in the TIF district without the TIF
- $NPV_{TIF}$  represents the financial viability of a TIF district, in terms of its net present value
- $N$  is the total number of periods
- $t$  time of the cash flow

If the resulting  $NPV_{TIF}$  is positive then the proposed TIF district is financially viable, with positive cash flows being a “necessary condition” for the creation of a TIF district but not always a “sufficient condition”. Sullivan et al. (2002) argue that the growth in land and property values should exceed the city’s municipal bond rate to make the scheme financially viable. However for a TIF to be efficiency enhancing, growth must exceed the municipal bond rate plus the growth rate that the TIF district property values would have achieved had the investment zone not been created (i.e. the true opportunity cost).

Dye and Sundberg (1998) support the view that prospective TIFs need to be more than just financially viable; they should also be economically efficient. Johnston et al. (2002) and Zhao et al. (2010) describe the process of implementation of TIF in five steps: initiation, formulation, adoption, implementation, and termination, and this TIF process lifecycle is illustrated in Figure 3. Though the TIF lifecycle presented in Figure 3 focusses on the traditional urban regeneration model, it is relevant to the implementation of TTIF model

as it focusses the TIF development process on integrated land use and transport infrastructure project planning to achieve maximum economic and financial gain.

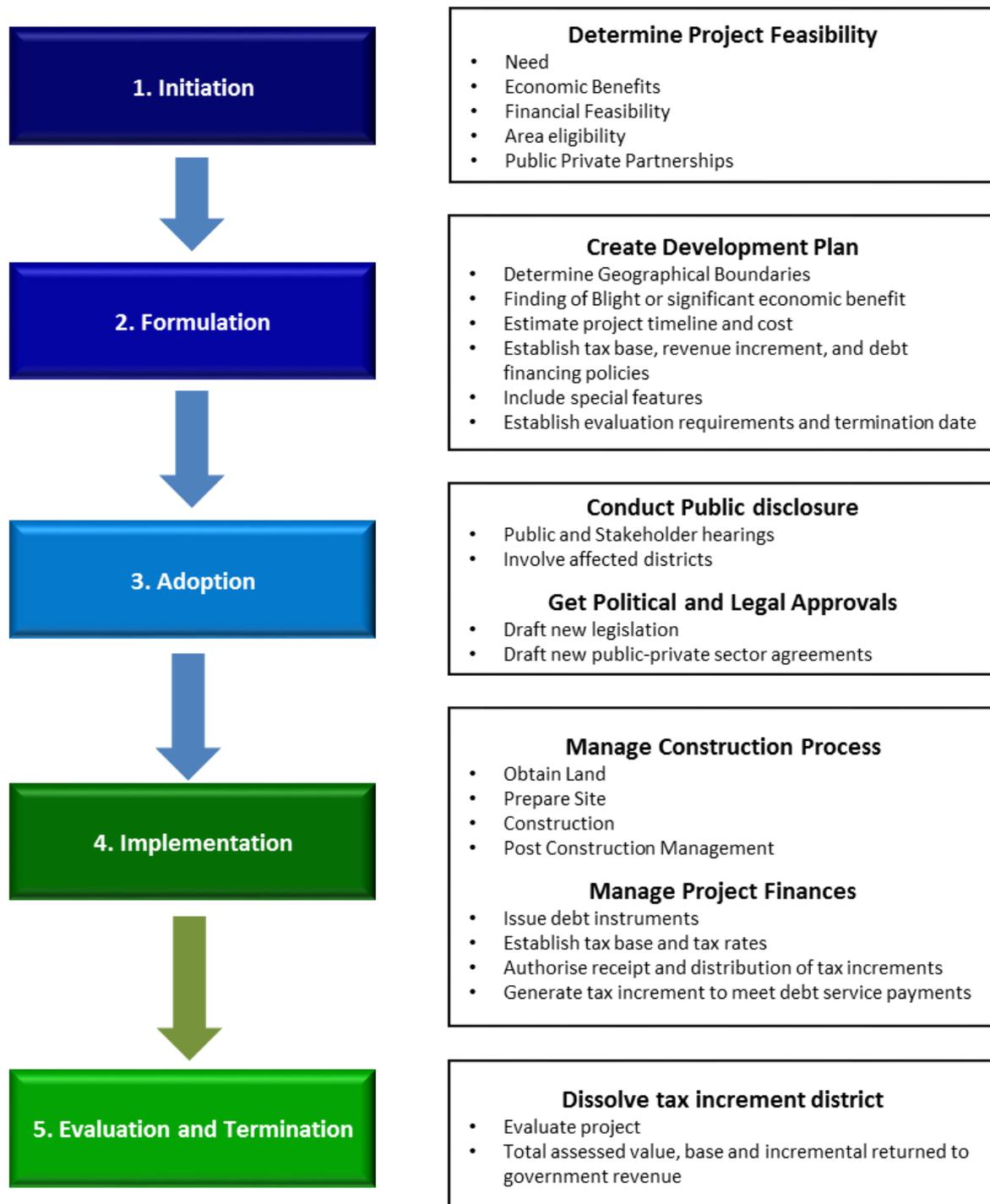
Whilst TIF using the incremental increases in the existing tax base is unlikely to defray the whole capital cost of a transit project (especially ones involving tunnelling), a TTIF's focus could be primarily used to contribute to the overall project cost. In their paper on the use of TIF for transit funding purposes, Schneck and Diaz (1999) identify five variables that impact the expected stream of revenues from TIF for rail transit:

- 1) *Size of the TIF zone (the number of affected land and property parcels),*
- 2) *Potential for new development,*
- 3) *Rate of new development,*
- 4) *Tax rate limitations (equity or legislative bounds to taxation), and*
- 5) *The regional context.*

Sullivan et al. (2002) and Zhao et al. (2010) identify several types of financing partnerships commonly associated with TIF financing in the US, and whilst they do not necessarily directly correlate to all international contexts, they present an existing model for the implementation of TIF. These partnership models include:

- 1) *TID bond support;*
- 2) *“Pay as you go” or payback of a city/state public infrastructure investment loan;*
- 3) *Public Private Partnership government payments (service and availability payments); and*
- 4) *Use of TIF funds as a local contribution to federal or state grants in a combined multijurisdictional investment in a transit project.*

When viewed in the context of low-density car dependent cities, TTIF's could form an important part of a funding and financing model for transit infrastructure and the associated urban renewal. This paper proposes a framework for how TTIF can be structured to enable any of the above transit infrastructure investment partnership models proposed to be achieved.



*Figure 3 Life cycle of the TIF process  
(adapted from Johnson et al. (2002), Sullivan et al. (2002) and Zhao et al. (2010))*

### **3. PROPOSED FRAMEWORK FOR TRANSIT TIF (TTIF) IMPLEMENTATION IN CAR DEPENDENT CITIES**

TIF schemes are not being used widely internationally due to region specific constraints that inhibit implementation in their traditional form based on US local government sales tax. This paper provides a framework to enable the adoption of TIF schemes in car dependent cities struggling to get major transit infrastructure projects funded.

A conceptual framework for the integration of strategic transit and land development projects with induced land and property value based funding/financial mechanisms is proposed. This has a particular focus on implementation in car dependent cities to maximise both city shaping benefits and potential TIF revenues to defray project costs. The proposed steps to achieve an integrated transit and land development funding/financing assessment framework are:

*Step 1. Assess the relevant land and property taxing legislation and policies and define the zone for a Tax Increment District (TID)*

*Step 2. Analyse the Willingness to Pay for Transit Accessibility and Transit Oriented Development (TOD)*

*Step 3. Conduct TID financial analysis to forecast revenue generation and viability*

*Step 4. Propose a project specific TTIF Implementation strategy.*

In addition to the project funding side, the adoption of a TTIF framework can inform the specifications of a transit project to help maximise project economic gains and efficiency while lowering the project's debt obligations, thus supporting a city's transition away from car dependency when budgetary limitations are present.

To demonstrate the TTIF framework application in low-density car dependent cities, a retrospective case study of the implementation of a major rail transit line in Perth, Western Australia is analysed. In addition to the retrospective study, several potential land intensification scenarios are analysed to determine their potential TIF impact on defraying the project's capital cost.

#### 4. CASE STUDY: RETROSPECTIVE TIF SCENARIO FOR THE MANDURAH LINE, PERTH, WESTERN AUSTRALIA

In 2003, Perth's Mandurah Line received funding commitment [\$1.184B (2007 AUD)] and commenced operations on the 23rd of December, 2007 (Waldock et al., 2008). It runs 72km from the Perth CBD through extensive car dependent suburbs built mostly since the 1960's to Mandurah at speeds of up to 137 km/h, running mostly at grade in the either the median or along the western edge of the freeway (see Figure 4). The next sections describe the TTIF framework implementation in a scenario in which it is retrospectively applied to



the historically car dependent Mandurah rail line corridor in Perth, Western Australia.

*Figure 4 (Left) Perth Mandurah line stops and feeder bus routes (Waldock et al., 2008), (Right Bottom) Murdoch Station (Google Earth, 2014); (Right Top) Park-and-Ride facilities, new Hospital*

#### **4.1.Step 1 - Asses the relevant land and property taxing legislation and policies and define the zone for a Tax Increment District (TID)**

The three tiers of government in Australia have a suite of land and property-based taxes and charges that are impacted by land and property value uplift that occurs from a transit investment. The relevant existing local, state and federal government land and property taxing and charging legislation include:

##### *Australian Commonwealth Government Legislation*

- New Business Tax System (Capital Gains Tax) Act 1999 (Capital Gain Tax)
- A New Tax System (Goods and Services Tax) Act 1999 (GST)

##### *Western Australian State Government Legislation*

- Planning and Development Act, 2005 - Metropolitan Region Improvement Tax (MRIT)
- Stamp Act 1921 (Stamp Duty)
- Land Tax Act 2002 (Land Tax)

##### *Western Australian Local Government Legislation*

- Local Government Act 1995 (Council Rates)

While these taxes and charges were not designed to capture revenues for funding transit projects, all the government taxes can be analysed for induced cash flow purposes. In Australia, however, only State Government based taxes would be suitable to be used for a TTIF to defray the cost of the transit investment (McIntosh et al., 2011). This focus on State Government management of the TTIF is pragmatic, as traditionally it is the State Government that has strategic, tactical and operational control of the transit systems, and is traditionally the key investor in transit in Australia. The State Government also has a

much larger tax base than Australian local governments, which is a significant difference to those TIF systems implemented in the US.

In addition to taxing and charging legislation there are a suite of legislation and policies that give the Western Australian State Government power to implement planning control measures to achieve the best land use and development outcomes ensuring the optimum land use and transport integration for a project. These include:

- *Planning and Development Act, 2005 – Planning Control Area's and Improvement Plans*
- *Metropolitan Redevelopment Authority Act, 2011 – Powers to acquire for redevelopment*
- *State Planning Policy 3 - Urban Growth and Settlement policy*

Station precinct Planning Control Areas (PCA)'s enable the optimisation of the land-based mechanisms in the transit districts to facilitate the integration of transit, land use, and funding for TTIF productivity. The Mandurah rail line station pedestrian catchments are proposed as the TTIF TID's and are presented in Figure 5 along with an illustration of the 400m, 800m and 1600m pedestrian catchments for Canning Bridge station. Depending on the level of urban renewal/change proposed, the station pedestrian catchments could form the bounds of a TID and PCA, though for revenue analysis the 400m catchments will be adopted as the primary TID.



Figure 5 (Left) Perth rail line's catchments for each of the rail lines, with the grey train catchments being the proposed TID's. (Right) Canning Bridge Station central location is highlighted by the white star. The stations pedestrian catchments are highlighted as follows: 400m (yellow), 800m (orange) and 1600m (red)

#### 4.2.Step 2 – Analyse the Willingness to Pay for Access to the Mandurah Rail Line

Whilst the level of value uplift can differ depending on the nature of the project, among a number of other local factors, the significance of these can be determined by undertaking hedonic price analysis of the land values of commercial, industrial and residential properties with and without transit amenity (Small and Verhoef, 2007). There is, however, a range of estimation methods used to determine the impact of the investment in rail transit on property and land prices, which include the following (with selected articles to refer):

- Hedonic price modelling (cross section, panel data, time series) (Al-Mosaind et al., 1993)

- *Geographically Weighted Regression (Du and Mulley, 2006)*
- *Comparison of average property/land values (Sherry, 1999)*
- *Direct differencing of land values (Fejarang, 1994).*

While dependent on data availability, the use of time variant panel data hedonic price modelling has been chosen to be the most effective for illustrating the impact of transit investment. Hedonic price modelling was chosen as it takes into account a substantial range of factors that contribute to the value of land, as opposed to comparisons of averages that can be biased by socio economic and regional variations. Geographically weighted regression, whilst a sound regression-based method, is not as easy to interpret and apply to financial modelling and was not selected on that basis.

Cross-sectional and panel data land value hedonic price models (HPM) for the Mandurah rail catchment sub-region (shown in green in Figure 5) were developed in order to predict the impact of the introduction of rail transit and increasing development densities on property values. Land value per square metre was modelled using commercial and residential land parcels across metropolitan Perth with the aim of modelling the impact of the rail based transit infrastructure on land values (per m<sup>2</sup>) within the catchment. The dependent variable for both the cross sectional and panel data HPMS was land value per square metre (vpsm), with the land valuer's percentage allowance for the land parcel's view removed from the assessed value to normalise the analysis of the parcels as much as possible. The descriptive statistics for the HPMS are presented in Table 1.

*Table 1 Residential Cross-sectional HPM Descriptive Statistics for 2011 for the Mandurah line*

Explanatory Variables	Mean or % Values
Land Value/m <sup>2</sup> (no view) (AUD\$ 2011)	542.88
Log Land Value/m <sup>2</sup> (no view) (AUD\$ 2011)	6.103
Number of Land Parcels	128136
<b>400m train pedestrian catchment</b> number of parcels (% of total catchment number of parcels) [Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011] {Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	224 (0.2%) [325.27] {5.67}
<b>800m train pedestrian catchment</b> number of parcels (% of total catchment number of parcels) [Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011] {Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	890 (0.7%) [588.45] {6.16}
<b>1600m train pedestrian catchment</b> number of parcels (% of total catchment number of parcels) [Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011] {Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	9238 (7.2%) [555.87] {6.09}
0 – 100m of a Hwy # of parcels (% of total)	4753 (3.7%)
100 – 200m of a Hwy # of parcels (% of total)	7108 (5.5%)
200 – 400m of a Hwy # of parcels (% of total)	13784 (10.8%)
Parcel distance to nearest freeway onramp	5.52
Public Transport Accessibility (SNAMUTS indicator) <sup>1</sup>	6.98
# of Dwellings within 1600m of parcel	4404
Parcel Distance to CBD (km)	18.76
Parcel Distance to secondary centre (km)	5.33
Parcel Area (m <sup>2</sup> )	1488
Western Australian Government Residential Lot Density Code (R-Code)	20.52
Senior high school catchment rating from ( <a href="http://www.myschool.edu.au/">http://www.myschool.edu.au/</a> )	4.88
Australian Government Census Socio Economic Index For Areas (SEIFA) <sup>2</sup>	60.89
Parcel Distance to water (km)	2.13
<sup>1</sup> SNAMUTS (spatial network analysis for multi-modal urban transport systems) ( <a href="http://www.snamuts.com/">http://www.snamuts.com/</a> )	
<sup>2</sup> ( <a href="http://www.abs.gov.au/ausstats/abs@.nsf/mf/2033.0.55.001/">http://www.abs.gov.au/ausstats/abs@.nsf/mf/2033.0.55.001/</a> )	

#### 4.2.1. Cross-sectional (Log-Log) HPM (2011)

The explanatory variables in the cross sectional Ordinary Least Square (OLS) residential and commercial land HPM models for the analysis of the Mandurah Line are presented in Table 2 while a full description of the HPM model used for this research is presented by McIntosh et al. (2014). The negative impact of proximity of residential land parcels to rail stations in the Mandurah corridor can be explained as a consequence of the train operating in the freeway median. Palmquist (1992) demonstrates that freeway noise can lower property values by up to 0.48% per additional decibel in Portland, Oregon and a similar negative impact is likely present in the analysis here. Using the Palmquist (1992) study it

is not unreasonable to expect traffic noise to account for a 5-10% decrease in the value of affected land parcels when compared to non-affected catchments. The commercial catchment HPM analysis, on the other hand, did not reveal the same negative impact and was consistent with the results of other studies presented in Table 2 and illustrates commercial development's resilience to ambient noise conditions.

*Table 2 Ordinary Least Squares Log-Log Hedonic Price Modelling of Residential and Commercial land parcel values for the Mandurah Line, Perth, Western Australia*

	Mandurah Line Residential Land Market	Mandurah Line Commercial Land Market
Constant	6.696 (0.029)***	-4.965 (0.722)***
Area (m2)	-0.513 (0.002)***	-0.368 (0.012)***
R-Code	0.112 (0.003)***	
400m train station pedestrian catchment	-17.6% (0.017)***	40.2% (0.089)***
800m train station pedestrian catchment	- 5.1% (0.009)***	21.8% (0.073)***
1600m train station pedestrian catchment	- 3.2% (0.003)***	23.9% (0.051)***
SNAMUTS score	-0.008 (0.0002)***	0.038 (0.005)***
Socio Economic Index For Areas (SEIFA)	0.273 (0.001)***	0.130 (0.028)***
Senior high school rating	0.054 (0.0002)***	
Distance to water	-0.149 (0.001)***	-0.195 (0.018)***
Dwellings within 1600m	0.203 (0.002)***	
Distance to CBD	-0.013 (0.001)***	
Distance to secondary centre	-0.018 (0.001)***	
0 – 100m of a highway	- 5.6% (0.004)***	28.5% (0.041)***
100 – 200m of a highway	1.7% (0.003)***	32.3% (0.070)***
Distance to nearest freeway onramp (Km)	-0.018 (0.001)***	-0.025 (0.020)
Dwellings within 30min		-1.202 (0.095)***
Effective job density		2.843 (0.148)***
Adjusted R-Squared	0.863	0.839
No. of Land Parcels	128,136	1,214
Notes:		
<sup>1</sup> Figures in brackets report parameter standard errors. Significance at the 0.01 level is indicated by three asterisks, significance at the 0.05 level is indicated by two asterisks, and significance at the 0.10 level is indicated by a single asterisk.		
<sup>2</sup> Dummy Variables are presented as % change in Land Value, The continuous variables are presented as elasticities		

The allowable urban density (R-Code) elasticity is an important factor for the design and forecasting of integrated land use and TTIF modelling as there is an additional uplift from zoning land to allow higher densities as well, with each percentage change in R-Code (or dwellings per hectare) producing 0.112% change in land value. For the Mandurah Line catchment this creates a range of possible land value uplift scenarios (shown in Table 3).

*Table 3 Possible future residential density increase scenario - Mandurah Rail Line*

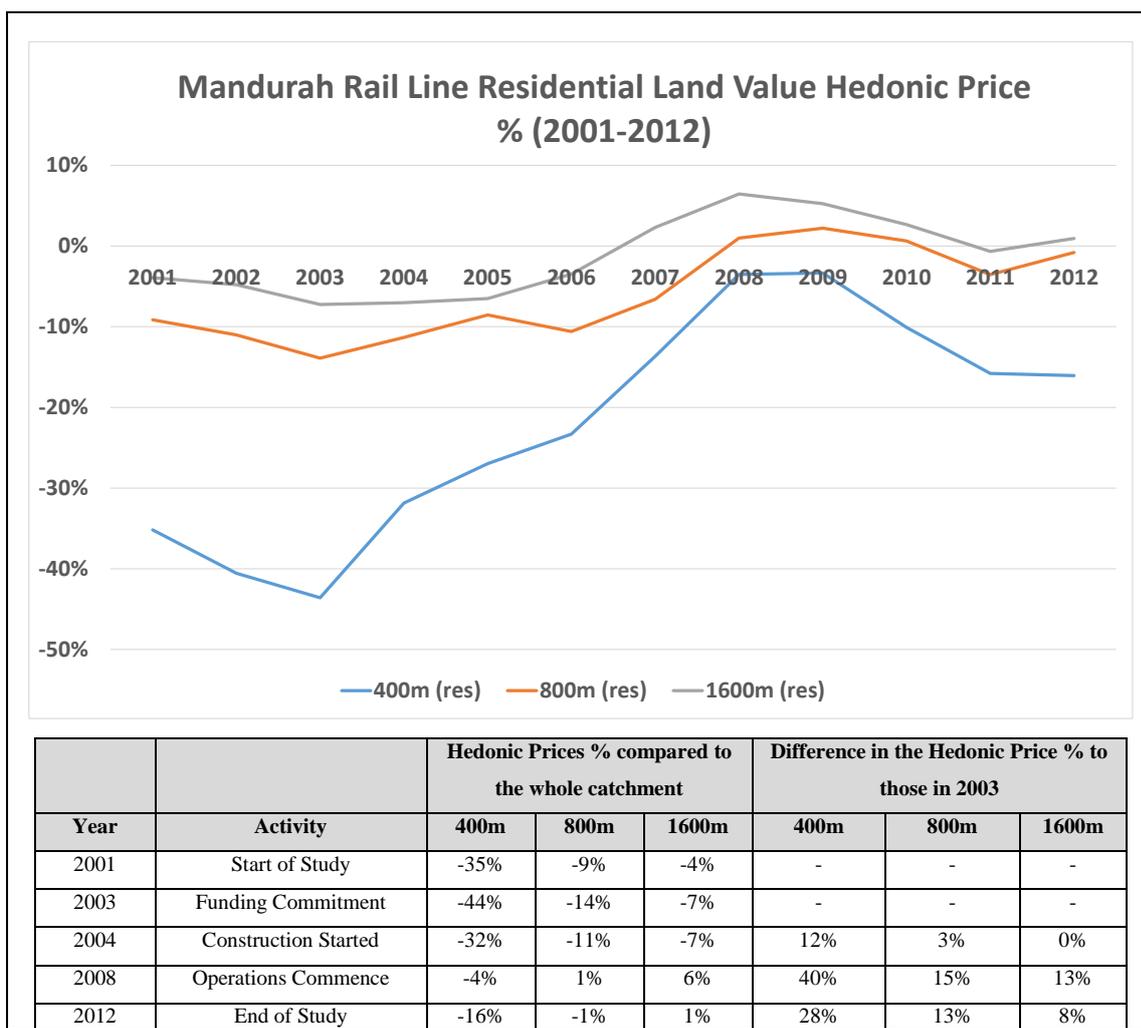
Existing R-Code	Possible future R-Code Scenario	% Change in R-Code	Catchment R-Code Elasticity	R-Code Scenario Uplift impact on the land value
20	40	<b>100%</b>	0.112	11.2%
20	60	<b>200%</b>	0.112	22.4%
20	80	<b>300%</b>	0.112	33.6%
20	100	<b>400%</b>	0.112	44.8%

#### 4.2.1.1. Mandurah Rail Line - Residential Panel Data Model (2001-2012)

Panel data modelling of the temporal variation in land prices over the period is important to understand the behaviour of land prices over time as many of the cross sectional variables are temporally non-stationary. The changes in the non-stationary variables can reflect: economic changes; technological changes; political shifts and cultural movements (i.e. gentrification); and spatial concentrations of urban renewal. The panel data HPM analysis was undertaken to determine the changes in the Mandurah rail line land market hedonic prices prior to construction, during construction and after the commencement of operations of the Mandurah rail line. A full description of the panel data hedonic price model is presented again by McIntosh et al. (2014).

The main increases in the land value hedonic price over the analysis period for the Mandurah Line's catchments result from funding commitment to the commencement of operations of the rail infrastructure. The graph of the Mandurah Line panel data HPM for

the period 2001 to 2011 (Figure 6) illustrates the hedonic prices of the station pedestrian catchments over this time when compared to the rest of the region’s catchments and forms the basis for forecasting land and property market impacts for future transit projects. Although the Mandurah rail line’s pedestrian catchments’ hedonic prices are still negative



with respect to the land parcels in the rest of the region (due to the negative externalities of being in the freeway median), the change in the hedonic prices is significantly positive.<sup>7</sup>

<sup>7</sup> The dip in the catchment’s hedonic prices after 2009 can be viewed as a delayed response to the Global Financial Crisis, and can be reasonably expected to correct back to the 2008 hedonic prices as has been achieved by the rest of the metropolitan region.

*Figure 6 (Top) Mandurah Rail Line residential panel data hedonic price (2001-2012) (Bottom) Hedonic prices for the Mandurah rail line's catchments (2001-2012)*

#### **4.3.Step 3 - Conduct TID financial analysis to forecast revenue generation and viability**

As demonstrated in the panel data hedonic price models, the 400m pedestrian catchment of the Mandurah rail line gained the greatest increase in hedonic price over the period 2001 – 2012<sup>8</sup>. These impacts on government taxation and charges were not forecasted at the time of project planning and as such did not appear in the project's financial cash flow analysis or business case, nor have they been documented in any ex-post analysis of the project.

Using the “Value Capture” financial model developed by the authors of this paper with the Western Australian Treasury Corporation (WATC), Figure's 7 and 8 compare the real present value calculation of the investment in the Mandurah Line with a hypothetical base case in which the Mandurah Rail line was never built. The increase in land values impacts Commonwealth Government taxes (Capital Gains Tax and GST<sup>9</sup>), Western Australian State taxes (Land Tax, MRIT, Stamp Duty) and Local Government (Council) rates on Commercial and Residential properties over the financial periods, 2007 – 2037. The panel data increase in the hedonic price of the residential land value are presented in Figure 6

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<sup>8</sup> This increase in real land prices (inflation adjusted using the Reserve Bank of Australia's inflation figures for this period) over the regional averages significantly impacted the existing taxation and charges for the three tiers of government.

<sup>9</sup> The GST calculation is for newly constructed non-primary and principle residence dwellings

and cross sectional analysis for the commercial land value uplift values (Table 3) for the 400m and 800m pedestrian catchments. The residential density elasticities presented in Table 3 were adopted for the 400m station catchments densification scenarios presented in Figure 8. Table 4 presents a summary of the inputs into the NPV calculations in the WATC model.

*Table 4 Summary of the inputs into the NPV calculations in the WATC model*

	Residential Model	Commercial Model
Land Valuations for the TIF	Parcel Level Valuations for each catchment from the GIS Model	Parcel Level Valuations for each catchment from the GIS Model
Discount Rate (Based on 10 year bond rate)	3.64%	3.64%
Inflation Estimate	2.50%	2.50%
Redevelopment Rate (Annual turnover rate)	5%	5%
Property Holding Period	7 years	7 years
Redevelopment Speed (years to complete)	1 year	1 year
New Titles per Redeveloped Lot (base case)	1.5	1.7
TIF Duration	30 years	30 years
Building to Land Ratio	0.32	1.0
Pedestrian Catchment uplift factors		
0 - 400m	28%	<b>40%</b>
400m – 800m	13%	<b>22%</b>
800m – 1600m	8%	<b>23%</b>
Value Uplift Period (Construction Period)	5 years	<b>5 years</b>
<b>Commonwealth Government</b>		
Capital Gains Tax	N/A	Applied in the model
Goods and Services Tax	N/A	Applied in the model
<b>State Government</b>		
Stamp duty	Applied in the model	Applied in the model
Land Tax	N/A	Applied in the model
Metropolitan Region Improvement Tax	N/A	Applied in the model
<b>Local Government</b>		
Council rates	Applied in the model	Applied in the model
Note: The structure of all the taxes and charges included in the WATC financial model are as follows:		
<b>Commonwealth Government Taxes</b>		
Capital Gains Tax: <a href="https://www.ato.gov.au/General/Capital-gains-tax/">https://www.ato.gov.au/General/Capital-gains-tax/</a>		
Goods and Services Tax on new non primary and principle dwellings: <a href="https://www.ato.gov.au/Business/">https://www.ato.gov.au/Business/</a>		
<b>State Government</b>		
Stamp duty: <a href="http://www.finance.wa.gov.au/cms/content.aspx?id=2053">http://www.finance.wa.gov.au/cms/content.aspx?id=2053</a>		
Land Tax: <a href="http://www.finance.wa.gov.au/cms/content.aspx?id=239">http://www.finance.wa.gov.au/cms/content.aspx?id=239</a>		
Metropolitan Region Improvement Tax: <a href="http://www.finance.wa.gov.au/cms/content.aspx?id=241">http://www.finance.wa.gov.au/cms/content.aspx?id=241</a>		
<b>Local Government</b>		
Council rates: <a href="http://www.dlg.wa.gov.au/Content/LG/RatingPolicies/Default.aspx">http://www.dlg.wa.gov.au/Content/LG/RatingPolicies/Default.aspx</a>		

The impact on the tax system of the investment in the rail line across the three tiers of Government is substantial in real terms (2007 dollars) and accounts for approximately \$506 Million dollars (in Real 2007 dollars) over a 30-year period, or 43% of capital expenditure (\$1.184B 2007AUD). This also equates to a 30% increase in the ad valorem tax revenue for the line's pedestrian catchments surrounding the Mandurah rail station precincts when compared to the non-transit base case. Whilst not all the tax increases presented in Figures 7 and 8 could be captured in a TTIF due to their multi-jurisdictional nature, they can be acknowledged and attributed in the project's financial business case and form part of the cost attribution negotiations between the different tiers of government (as per some of the options proposed previously). During the period 2001-2012 there was minimal, if any, residential land development around the Mandurah rail stations though some signs of development began around a few stations where government help was provided. The analysis presented in Figure 8 highlights the importance of undertaking significant land and property intensification integrated as part of transit projects, as it can add to a project's long term TID passive tax revenue streams. Urban densification could occur elsewhere away from transit though it would be more difficult as such developments require significant onsite car parking (thus reducing development density capacity), and so would put great stress on the surrounding road network leading to more problems than with development focussed around the rail infrastructure.

The level of funding generated by land value capture would appear to be much more than has been expected as no state government has looked to make use of such a mechanism. However the amount can be significantly increased if a simultaneous rezoning of land was carried out around stations to enable an even greater increase in land value. Using Schneck

and Diaz's (1999) TTIF impact variables, an integrated transit/urban renewal project for the Mandurah rail line could have been conducted around the stations by rezoning key tracts of underutilised government land to unlock the potential for new development. Given the significant growth in Metropolitan Perth since 2001, the urban intensification project would have created a lot of new development within the catchments.

Table 4 illustrates the impact of rezoning the existing catchments for more intense land uses. A series of intensification scenarios were developed in accordance with the results from Table 3 where the existing R20 residential density of (20 dwellings per hectare) is increased up to R100 (100 dwellings per hectare), which is roughly equivalent to the Subiaco TOD in Perth that has R-Codes ranging from R60, R80 and up to R110. The potential State Government TTIF revenue from Land Tax, the Metropolitan Region Improvement Tax (MRIT) and Stamp Duty for the Mandurah Rail Line as a result of urban intensification is presented in Table 5.

*Table 5 Potential impacts on the Total tax revenue, and a potential State Government based TTIF (Land Tax, MRIT, Stamp duty) with scenario for increases in catchment densities*

Possible R-Code Scenario	% Change in R-Code	R-Code Scenario Uplift & Transit impact in brackets	Combined Transit & R-Code Uplift factor	Net Total tax increase over <u>No Transit</u> Base Case (\$AUD 2007)	Net tax increase as % Capex (\$1,184M AUD 2007)	TTIF revenue over <u>No Transit</u> Base Case (\$AUD 2007)	TTIF revenue as % Capex (\$1,184M AUD 2007)
20 (current)	<b>0%</b>	0% (+28%)	28%	\$506M	43%	\$227M	19%
40	<b>100%</b>	11.2% (+28%)	39%	\$616M	52%	\$304M	26%
60	<b>200%</b>	22.4% (+28%)	50%	\$739M	62%	\$390M	33%
80	<b>300%</b>	33.6% (+28%)	62%	\$866M	73%	\$476M	40%
100	<b>400%</b>	44.8% (+28%)	73%	\$1005M	85%	\$563M	48%

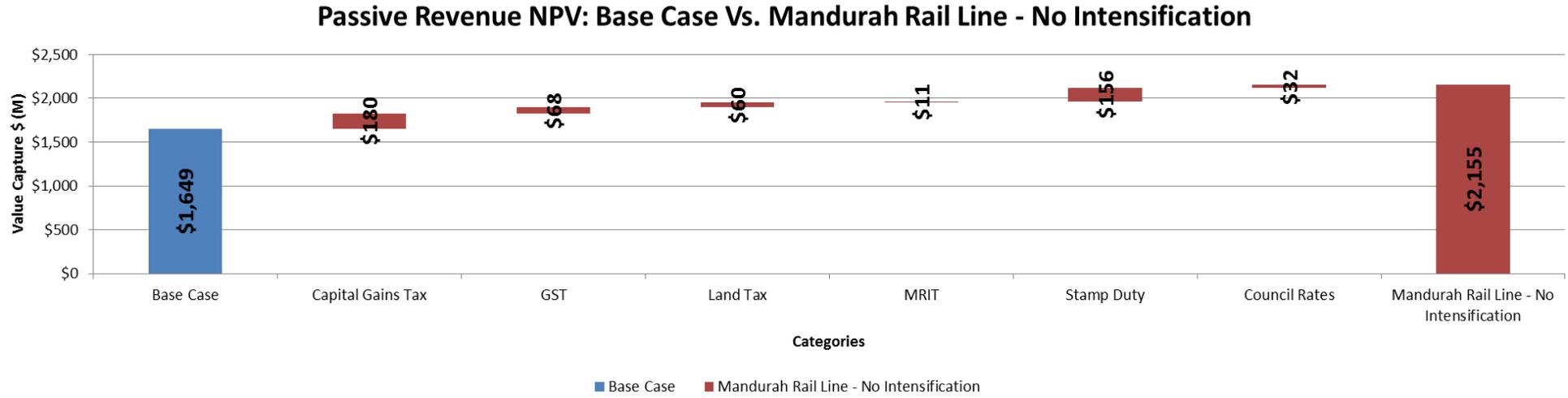


Figure 7 Net present value changes in ad valorem taxes in the Mandurah Rail Corridor 2001-2031 the base case to actual Mandurah Rail catchment taxes.

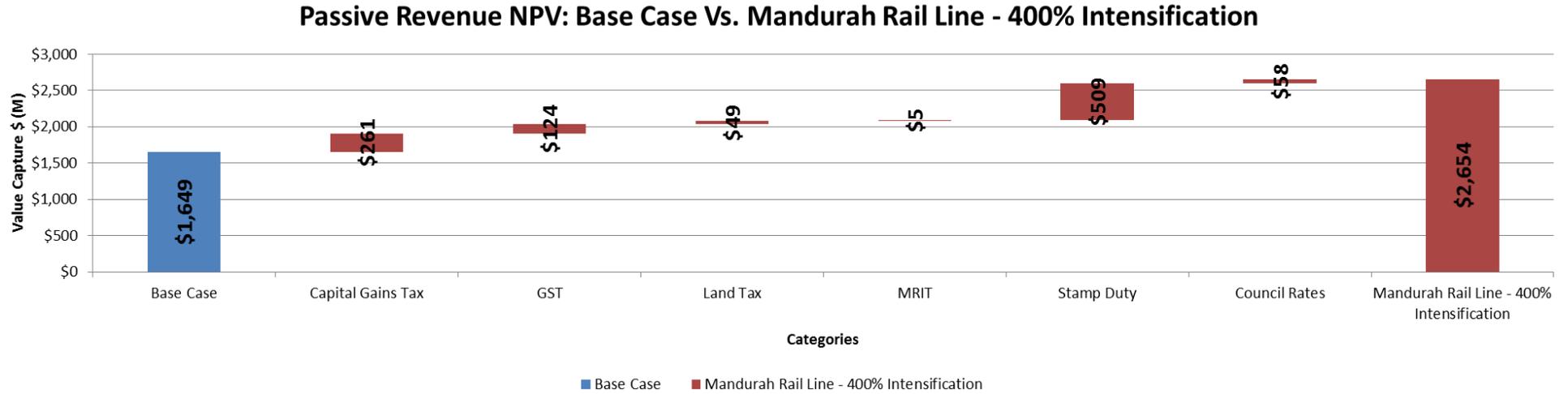


Figure 8 Net present value changes in ad valorem taxes in the Mandurah Rail Corridor over the financial periods, 2001-2031 tax revenue generated from the 400% alternative intensification scenario.

#### **4.4.Step 4 – Propose a project specific TTIF Implementation strategy**

Although TIF is yet to be implemented in Australia as a funding source for urban infrastructure, urban renewal, or for funding transit, the opportunities exist to tailor a TTIF for transit infrastructure. To facilitate the implementation of TTIF in Western Australia, the Western Australian State government would need to make a relatively easy legislative change to the Planning and Development Act surrounding the Metropolitan Region Improvement Fund (MRIF).

Western Australian Treasury would need to coordinate the revenue hypothecation and capture of the tax increment revenue as forecasted in Figures 7 and 8 to enable the capture of the revenue streams. Instead of the revenues entering the State's consolidated revenue, they would need to be forwarded to a TTIF facility in a fund such as the MRIF. The aim would be to create a coordinated TTIF facility to be managed by the Metropolitan Redevelopment Agency in conjunction with the Department of Transport, for example, for the appropriate state-based taxes (Land Tax, MRIT, and Stamp Duty) to be used for funding integrated transit and urban renewal projects in accordance with Table 4. Therefore the TTIF model for a large state government transit project such as the Mandurah Line could be structured in accordance with the options recommended by Sullivan et al. (2002) and Zhao et al. (2010) to:

- support a specific “Mandurah Line Transit TID” Bond;
- provide a “pay as you go” funding model, or payback of a state public infrastructure loan secured by the Western Australian Treasury Corporation;
- contribute to the service and availability payments of a Transit Contractor/Operator/Land and Property Developer Consortium Loan (design,

construct, own operate and transfer model for example, such as the massive North West Rail project in Sydney, New South Wales);

- use TTIF funds as a State Government contribution to federal or state grants for transit projects through a joint submission to a Federal/Commonwealth Infrastructure funding agency (Infrastructure Australia for example) clearly describing the calculation of increased tax revenues for the Federal Treasury; and
- form the basis for negotiation with the other tiers of government (local and Federal) to ensure equitable contributions from all the beneficiaries.

The use of the incremental increases in the existing tax base for a TTIF, even in low-density car dependent cities such as Perth, is likely to generate sufficient revenue to make a significant contribution for major transit projects. TTIF's should form part of the State's overall contribution towards project costs using any of the five TIF methods above. Having said this, if the TTIF is used in dense, integrated centres where the development opportunity is large, and the land surrounding the transit is up zoned appropriately, as is the case with Portland's MAX LRT, TIF could form the core project-funding model for the integrated land and transit project.

## **5. CONCLUSIONS**

This paper has demonstrated that a much larger funding source is available to help build transit in car dependent cities than has been considered in the past. The process of developing a TTIF implementation framework is multijurisdictional and complex and is dependent on the scale of the tax base for each tier of government, and to date is one of the key reasons why it is not implemented more widely internationally. This paper demonstrates a TTIF framework that could be adopted in car dependent cities like those in Australia, and other countries without a history of employing TIF to

help fund transit projects. It has also presented how a TTIF framework can be used to assess urbanisation alternatives and financial benefits as part of transit projects and improve decision-making around the provision of new transit systems. Therefore the key lessons for the implementation of TIF for integrated land use and transit projects in car dependent cities include the following:

- transit projects should be designed to maximise not only the transport benefits, but the land market benefits as well to induce maximum uplift in land and property markets;
- transit TIF can be used as a funding mechanism for private sector financing of urban transit projects and this opens the way for private sector involvement in the provision of urban transit,
- land use and transport integration is a key criterion for maximising the success of a Transit TIF project, with roughly equal importance placed on each, and focussing transit alignment on corridors with significant potential for fixing urban blight (like Portland, USA); and
- major land development/redevelopment should be implemented “in-project” to manage the flow of the land and property market TIF funds back into the project.

As with all aspects of planning for the introduction of transit into car dependent cities, the integration of land use and transport planning is important. However, with the funding of new transit systems becoming more difficult due to budgetary constraints, the use of a land value based funding scheme is likely to become much more common. The integration of land development will be essential for optimising this funding mechanism so that not only will the transit be built but the city shaping benefits can be derived as well.

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## FRAMEWORK FOR LAND VALUE CAPTURE FROM THE INVESTMENT IN TRANSIT IN CAR DEPENDENT CITIES

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**Keywords:** *Land Use, Transit, Accessibility, Hedonic Price Modelling, Value Capture*

### **Abstract**

Many car dependent cities have major transit projects stuck in financial and economic assessment due to inadequate links between land use, transport and funding. This has left most urban transport networks underfunded and requiring significant government support. During this widening transit funding gap, there has been an international increase in demand on transit systems, which is in part, a response to the global peak in car use per capita. This paper demonstrates to transit proponents and practitioners how to facilitate infrastructure projects by optimising induced and activated land use change.

A five-step framework for assessment is proposed that includes: an assessment of the regional and local legislation and regulations to determine what alternative funding opportunities are available; undertaking accessibility beneficiary analysis; analysis of the project-induced land value uplift; developing an alternative funding strategy to implement integrated land use and transport planning mechanisms; and the preparation of a procurement and delivery strategy. The proposed assessment framework enables transit business cases to extend project funding for integrated transit and land use projects, especially in car dependent cities. This is demonstrated through a case study in Perth, Western Australia.

### **1. INTRODUCTION**

Internationally, the funding of city and regional transit networks has traditionally been done by governments from consolidated taxation revenue and market rate loans. There are however, some exceptions such as in the US where there is a history of hypothecating parts, or all of specific local and regional taxes to strategic transit funding including the use of land value capture (Iacono et al., 2009; US EPA, 2013; Cervero1997). A growing number of jurisdictions are seeing the value in strategic land-based “producer charge” style levies similar to other utilities and infrastructure (e.g. Hong Kong, the UK, US and Japan). However, there is no clear framework for the use of land value capture and other alternative funding methods.<sup>10</sup>

US cities have used versions of ‘value capture’ for Tax Increment Financing in particular as well as other funding mechanisms (Iacono et al., 2009), but there is no clear framework to enable a mainstreaming of this approach. All other car dependent areas internationally (such as Canadian, New Zealand, Australian and even some European cities) there is no history of coordinated value capture assessment and implementation or indeed dedicated transit funding outside of relying on allocations of general tax revenue.

As transit has been mostly seen as a welfare item in state and regional governments’ budgets (especially in car dependent cities), new transit projects based wholly on general or consolidated revenue are often unable to be funded, due to the lack of a strategic fund or ongoing budget allocation, without the government exceeding lending limits. Though it has long been recognised that fixed transit infrastructure creates urban value in the

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<sup>10</sup> “Value capture” is a term used to describe the process of capturing the induced land market financial benefits created from an investment which can then be used to aid in its funding.

property and land markets (Smith and Gihring, 2006; Rodriguez and Targa, 2004; Cervero and Kang, 2010), there are few comprehensive assessment frameworks used to assess and capture the benefits that are created to assist this funding dilemma (Zhao and Larson, 2011). At the same time there is a need to integrate land use and transit systems to achieve a greater proportion of urban fabric that follows Transit Oriented Design (TOD) principles. When transit is just funded by traditional government funds there is usually no incentive for providing TODs (Renne and Wells, 2005) with the result that such integrated transit and land use just stays on the plans (Woodcock et al. 2010).

A new approach to funding urban transit infrastructure is needed in order to solve two problems simultaneously: creating a new funding source and assisting the integration of TODs into any new transit project. This is especially important for car dependent cities where there is a growing demand for transit with the peaking of car use (Newman et al., 2013; Goodwin, 2012), and TODs to support a transition towards more dense urban living (Newman et al., 2013).

This paper proposes a framework for assessing the transit accessibility and urban land market benefits created by investment in transit systems, and a method to capture these benefits to be used to help defray the cost of transit investment. At the same time it seeks to incentivise the provision of TODs. The gap in the published literature that this paper seeks to fill is in the development of an assessment framework for alternative funding options that are especially focused on capturing induced land and property market benefits for transit infrastructure projects in car dependent cities. The framework is needed to help with funding and also to help with integrating land use. Such a framework could also be

extended to emerging economy cities, such as in countries like India, that are also looking to expand their transit systems (Pucher et al., 2004).

## **2. BACKGROUND**

### **2.1. Car dependence and the role of urban transit**

Newman and Kenworthy (1989) first coined the term, “automobile dependence” in their book *Cities and Automobile Dependence*, which investigates 32 global cities whilst providing urban metrics for their analysis that include:

- gasoline consumption;
- public and private transport system modal split;
- automobile infrastructure provision (road supply and parking) relative to transit, and
- a measure of urban density and of urban centralisation.

The traditionally automobile (or car) dependent cities of North America and Australia are now investing substantially in the introduction and extension of urban transit systems (especially rail) in their cities to meet the demand for transit (Newman et al., 2013) and to reverse the issues created by the car dependence of their urban systems. Public transport, mass transportation or urban transit cover the terms most commonly used for fixed route, fixed schedule urban passenger transit, covering modes such as bus, bus rapid transit (BRT), light rail transit (LRT), heavy rail and commuter rail (Vuchic, 2005).

The focus of this paper is limited to fixed guide way services such as BRT and rail based transit, as it is the permanence of the transit infrastructure of these systems that tends to produce an impact on the land and property markets (Yiu and Wong, 2005; Debrezion et

al., 2007; Mohammad et al., 2013). In addition to the operational differences between modes, fixed guide way transit is attractive to developers due to its permanence; it offers surety for long-term land development investment and hence is an attraction to live or work near (Cervero et al., 1993; Cervero, 2004; Bartholomew and Ewing, 2011). Integrated bus and transit projects can also widen the accessibility benefits in a corridor and create a larger transit accessibility zone than transit's traditional pedestrian catchment (Cervero, 2004; Small and Verhoef, 2007; McIntosh et al., 2013).

## 2.2. Urban transit infrastructure value creation in land and property markets

The increased accessibility due to an investment in fixed transit infrastructure is monetised into its pedestrian catchment's land and property market values. This reflects a reduction in the generalised cost of travel, representing a "willingness to pay" (WTP) for a reduction in this economic cost (Batt, 2001; Ewing and Cervero, 2010). As indicated below in Figure 1, this effectively moves the property closer to employment and other services in terms of time, and up the bid rent curve (Alonso, 1964; Muth, 1969; O'Sullivan, 2012).

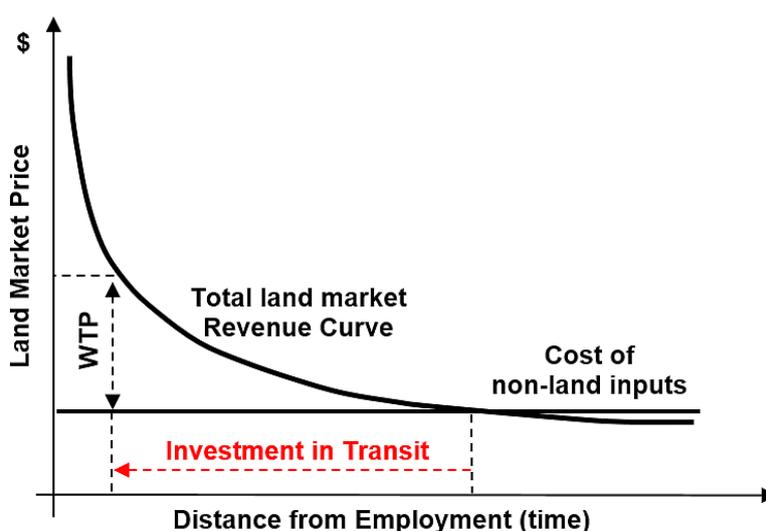


Figure 1 Land bid rent curve ( $\text{Land Bid Rent} = \text{Total Revenue} - \text{Cost of non-land inputs}$ )  
(Adapted from O'Sullivan, 2012)

Although studies into the residential property market response to the investment in transit tend to agree that proximity and accessibility to urban transit delivers a value premium, the observed magnitude of the uplift can vary depending on a number of factors (Ewing and Cervero, 2010). For one, these differences can be due to the assessment method used (different hedonic price modelling techniques for example). Some studies state that the variances in the premium rate recorded can include the type of property and type of transit service and its level of accessibility when compared to a competitive mode of transport (such as a car) (Duncan, 2008; Pan and Zhang, 2008; Zhang, 2010, Du and Mulley, 2006, Debrezion et al, 2007; Mohammad et al., 2013). Variances in land value uplift can also be due to service related operational issues such as noise, pollution and crime levels within close proximity to the station (Diaz, 1999; Hui and Ho, 2004; PB, 2001) as well as the transit station precinct's "Density, Diversity and Design" (Cervero, 2004).

Mohammad et al. (2013) also noted a higher uplift premium due to transit in East Asian and European cities compared to North American and Australian cities, and this is suggested as being due to high dependence on transit services in most of Europe and East Asia, and high car dependence in North American and Australian cities. It could also relate partially to cultural norms, where living in higher density precincts is more common in the Asian and European context. This is a reason why in North American and Australian environments, the total "lifestyle package" offered by new transit-oriented developments needs to be excellent, reflected mainly in high quality urban design of the public realm. Vancouver's sky train TOD's are a good illustration that it is not transit "hardware" (steel-wheel trains or rubber-tyre buses) that unlocks land use changes but rather the quality of service and the comparative travel-time savings of transit versus the

private car (Punter, 2003). Table 1 presents a selection of the numerous studies into the differences in the observed impacts in land and property markets between bus and rail transit.

*Table 1 Authors' compilation of the transit induced value uplift academic studies on the impact of differing types of transit on residential property and land market prices;*

	Author	Transit System	Value Measure	Catchment Area	Location	Premium Rate
<b>Bus Rapid Transit</b>	TCRP 90 Vol. 1 (2003)	BRT (South East Busway)	Property Value	Unspecified area	Brisbane, Australia	Up to 20%
	Mullins et al. (1990)	Transitway BRT	Property Value	Unspecified area	Ottawa, Canada	Limited
	Rodriguez and Targa, (2004)	TransMilenio BRT	Rental Premium	500m	Bogota, Colombia	6.8% to 9.3%
	Rodriguez and Mojica, (2008)	Trans Milenio BRT	Rental Premium	500m	Bogota, Colombia	13% to 15%
	Perk and Catala, (2009)	BRT - Martin Luther King, Jr. East Busway	Property value	Distance measure from BRT	Pittsburgh, USA	Significant and +ve
	Cervero & Kang, (2010)	Seoul BRT	Property value	90m to 300m of BRT stop	Seoul, South Korea	5% to 10%
<b>Light Rail Transit</b>	Al-Mosaind et al. (1993)	MAX LRT	Property Value	450m	Portland, USA	10.6%
	Weinstein & Clower (1999 & 2002)	DART LRT	Property Value	400m	Dallas, USA	-5.2% (1999), 13% to 18% (2002)
	Du and Mulley (2007)	Tyne and Wear light rail	Property Value		England, UK	- 42% to 50%
	Duncan (2008)	Light rail	Property Value	400m	San Diego, USA	5.7% to 16.6%
	Landis, (1995)	Santa Clara LRT	Property Value	275m & 400m	Santa Clara, USA	10.8% to 45%
	Garrett, (2004)	St Louis Metrolink LRT	Property Value	30m	Missouri, USA	32%
<b>Heavy Rail or Metro</b>	Sedway Group, (1999) TCRP (2004)	Bay Area Rapid Transit (BART)	Rental Premium	400m	San Francisco, USA	5% to 26%
	Wacher, 1971	Metro, London Victoria Line	Rental Premium	400m	London, UK	1% to 5%
	Laakso (1992)	Helsinki Metro	Property Value	400m	Helsinki, Finland	3.5% to 6%
	Bae et al. (2003)	Heavy Rail KoRail	Property Value	400m	Seoul, South Korea	0.3% to 2.6%
	Yankaya and Celik (2004)	Izmir Metro	Property Value	400m	Izmir, Turkey	0.7% to 13.7%

Commuter Rail	Gruen, 1997	METRA, Commuter Rail	Property Value	400m	Chicago, USA	20%
	Armstrong, 1994	Boston Commuter Rail	Property Value	400m	Boston, USA	6.7%
	Voith (1991)	Commuter Rail	Property Value	400m	Pennsylvania & New Jersey, US	3.8% to 10%

Therefore the key beneficiaries from transit infrastructure investment illustrated in Table 1 include:

- Land owners: due to increases in underlying land values.
- Property developers: potential increase in developed real estate values, faster sales rates, reduced holding costs, and lower construction costs due to reduced parking requirements.
- Transport system users: a more efficient, less congested transport system results in less time spent in transit, allowing more time for other activities and better transit experience.
- Business owners: increased economic activity due to improved customer and employee accessibility to their business, with workers arriving less stressed and more productive.
- Federal/State and Local Governments: due to increases in land property based revenue from existing levies and taxes from increased land and property values.

### 2.3. Capturing the value created by the investment in transit

The concept of capturing the value created by the investment in infrastructure (value capture) is not new internationally, with an early example being New York City in the US that implemented a Special Assessment District (SAD) in 1691 to fund the construction of the city's drainage and street pavement program (Zhao and Larson, 2011). Value capture mechanisms have been critical to investments in modern urban infrastructure in the US in the early part of the twentieth century (Cervero, 1994, Rybeck, 2004). Now in the US all states use special assessment districts to finance both the construction and operation of urban infrastructure (American Public Works Association, 2003). In 2008 special assessment districts and general value capture mechanisms comprised 0.26% of total state and local government revenue, with some state governments receiving over 2.0% (including sewer, water, roads and transit) (Zhao and Larson, 2011).

Another long-term successful value capture program has been conducted by the Metropolitan Transit Railway Corporation (MRTC) in Hong Kong, which jointly develops its transit infrastructure with land development as part of the “Rail + Property” program (Cervero and Murakami, 2009) by selling the development rights around and over its stations. This program involving the private sector in land development around its stations covers the cost of transit investments (Hui and Lo, 2004; Zhao et al., 2009), thus making the strategic investment in transit a long-term cost-neutral decision for the government. However, strategic transport infrastructure rarely uses land-based beneficiary charging, with most car dependent cities preferring usage charges such as tolls.

Unlike the US, countries that do not have a legislative or regulatory history of direct land based beneficiary levies and taxes can make transit infrastructure beneficiary capture significantly more challenging. The US system of transit funding is also rarely presented with a complete framework of options for integrated transit/land use funding (Zhao and Larson, 2011), thus requiring a new assessment and capture framework to be developed.<sup>11</sup>

As shown previously, urban transit systems increase land value (McIntosh et al., 2011; Yiu and Wong, 2005; Debrezion et al., 2007; Mohammad et al., 2013) and the process of value capture is the quantification of these induced or activated benefits and the mechanism for returning them to defray the cost of infrastructure investment (Allen, 1987; Cervero, 1997; Smith, and Gihring, 2009; Iacono et al., 2009; Cervero and Duncan, 2002).

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<sup>11</sup> Value capture is simply a manifestation of the reverse concept of “betterment” which has been recognised since the infancy of town planning, but rarely enforced, probably for political reasons (Day, 1992).

Value capture provides a means to monetise a project's land and property market financial benefits as revenue that may either contribute (or be recognised and attributed) to infrastructure project costs. It also provides an understanding of the overall value created by a transit project, which allows:

- An understanding of the net cost of infrastructure;
- Development of options to offset the cost of the project;
- Support for cost sharing arrangements between stakeholders;
- Support for long term planning and integrated TOD policy development;
- Support for project affordability and funding analysis; and
- Development of a comprehensive project Value Proposition.

Whilst this seems difficult, value capture is merely an approach consistent with sound economic and tax principles (Batt, 2001). This captured value can be subsequently used to defray the capital cost of an infrastructure investment (Allen, 1987; Center for Transit-Oriented Development, 2008; Iacono et al., 2009, Zhao and Larson, 2011), or to contribute to its operating costs (Smith and Gihring, 2009; McIntosh et al., 2012).

Table 2 summarises the value capture mechanisms available, whether they are related to government or non-government property and whether the mechanisms passively generate revenue by impacting existing taxes and charges, or requiring active intervention.

*Table 2      Compilation of value capture mechanism implementation from academic studies, and operator and relevant government websites*

	Value Capture Mechanisms	Transit Project location (& transit mode)	Author	Notes
Government Property (Passive)	Sale of surplus property /development rights/air rights	<ul style="list-style-type: none"> <li>• Hong Kong, China (Metro)</li> <li>• Washington DC, USA (Metro)</li> <li>• Sydney, Australia (Heavy Rail)</li> </ul>	<ul style="list-style-type: none"> <li>• MTRC</li> <li>• WMATA</li> <li>• RailCorp</li> </ul>	Used when governments hold their property and receive a benefit when accessibility is monetised into their property values
	Sale of stations naming rights	<ul style="list-style-type: none"> <li>• New York, USA</li> <li>• Philadelphia, USA</li> </ul>	<ul style="list-style-type: none"> <li>• MTA</li> <li>• SEPTA</li> </ul>	
Government Property (Active)	Direct development of government property	<ul style="list-style-type: none"> <li>• Hong Kong, China (Metro)</li> </ul>	<ul style="list-style-type: none"> <li>• MTRC</li> </ul>	Mechanisms to capture increases in land values and economic prosperity
	Joint development	<ul style="list-style-type: none"> <li>• Tokyo, Japan (Metro)</li> <li>• Hong Kong, China (Metro)</li> </ul>	<ul style="list-style-type: none"> <li>• Tokyo Metro</li> <li>• MTRC</li> </ul>	

		<ul style="list-style-type: none"> <li>London, UK (Metro)</li> </ul>	<ul style="list-style-type: none"> <li>Crossrail Stns.- Canary Wharf &amp; Heathrow Airport</li> </ul>	that positively impact the value of state and local government property and land from transit
	Returns on government parking	<ul style="list-style-type: none"> <li>Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>Portland Streetcar</li> </ul>	
	Government property leasing	<ul style="list-style-type: none"> <li>Philadelphia (USA)</li> </ul>	<ul style="list-style-type: none"> <li>SEPTA</li> </ul>	
	Advertising revenue	International implementation		
Non-Government (Passive)	TIF & hypothecated taxes			Primarily focussed on increases in existing ad valorem taxes that result from increases in property and land value
	State Transfer Duty/Sales Taxes	<ul style="list-style-type: none"> <li>Atlanta, USA (Heavy Rail)</li> <li>Dallas, USA (LRT)</li> </ul>	<ul style="list-style-type: none"> <li>MARTA</li> <li>DART</li> </ul>	
	State Land / Property Tax	<ul style="list-style-type: none"> <li>Dallas, USA (LRT)</li> <li>Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>DART</li> <li>Portland Streetcar</li> </ul>	
	Local Government Rates/Taxes	<ul style="list-style-type: none"> <li>Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>Portland Streetcar</li> </ul>	
Non-Government (Active)	Benefit Area levies (or Special Assessment Districts) through State or Local Government Infrastructure cost recovery	<ul style="list-style-type: none"> <li>London, UK (Metro)</li> <li>Seattle, USA (Streetcar/LRT)</li> <li>Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>Crossrail Business Rate Supplement</li> <li>Seattle Streetcar</li> <li>Portland Streetcar</li> </ul>	Mechanisms to capture all or part of the increases in property and land values and economic prosperity that benefit non-government land and business owners
	Differential Rates, Specified Area Rates, Service charges	<ul style="list-style-type: none"> <li>Atlanta, USA (Heavy Rail)</li> <li>Dallas, USA (LRT)</li> </ul>	<ul style="list-style-type: none"> <li>MARTA</li> <li>DART</li> </ul>	
	Region wide transport levy	<ul style="list-style-type: none"> <li>Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>Portland Streetcar</li> </ul>	
	Existing Infrastructure Tax Hypothecation	<ul style="list-style-type: none"> <li>London, UK (Metro)</li> <li>Portland, USA (Streetcar/LRT)</li> </ul>	<ul style="list-style-type: none"> <li>Crossrail Community Infrastructure Levy</li> <li>Portland Streetcar</li> </ul>	
	Developer contributions	International implementation		
	Parking Levies / Bonds			
	<ul style="list-style-type: none"> <li>Development Parking levies</li> <li>Increased cash in lieu</li> <li>Metropolitan Wide Parking Levy</li> </ul>	<ul style="list-style-type: none"> <li>Portland, USA (Streetcar/LRT)</li> <li>San Francisco, USA</li> </ul>	<ul style="list-style-type: none"> <li>Portland Streetcar Inc.</li> <li>SFMTA</li> </ul>	
	<ul style="list-style-type: none"> <li>Density bonuses</li> </ul>	<ul style="list-style-type: none"> <li>New York, USA (metro)</li> <li>Curitiba, Brazil</li> </ul>	<ul style="list-style-type: none"> <li>NYC Department of Planning</li> <li>Rede Integrada de Transporte</li> </ul>	

The examples in Table 2 demonstrate the range of international implementation of the different value capture and alternative funding mechanisms available. The disparate nature of their implementation illustrates the difficulty in assigning one particular mechanism to a single project in one jurisdiction. The value capture framework proposed addresses these regional differences in an assessment methodology for international implementation.

### 3. FRAMEWORK FOR CAPTURING VALUE OF TRANSIT IN CAR DEPENDENT CITIES

The key strategic objective of the investment in transit in car dependent cities is to seek to address car dependence in the transport and land use systems, in the most economically

and financially efficient and effective way for as many people in the city as possible. This paper proposes a conceptual framework for the integration of strategic land use, transport and funding/financial planning analysis. This culminates in a value capture strategy to integrate all of a transit project's transport, land use/development and funding/financial components to optimise the project's integration benefits and thus enable implementation. To achieve this objective the proposed steps in the integrated land use, transport and funding assessment framework are:

- Step 1. Assessment of the relevant alternative funding legislation and regulations*
- Step 2. Accessibility beneficiary analysis*
- Step 3. Land and property market analysis of 'willingness to pay' for transit accessibility*
- Step 4. Analysis of the transit project value capture mechanisms and preparation of the integrated land use and transit project value proposition*
- Step 5. Procurement and implementation strategy through hypothecated transit fund*

The integrated framework and each of its assessment steps and their interactions is conceptually illustrated in Figure 2.

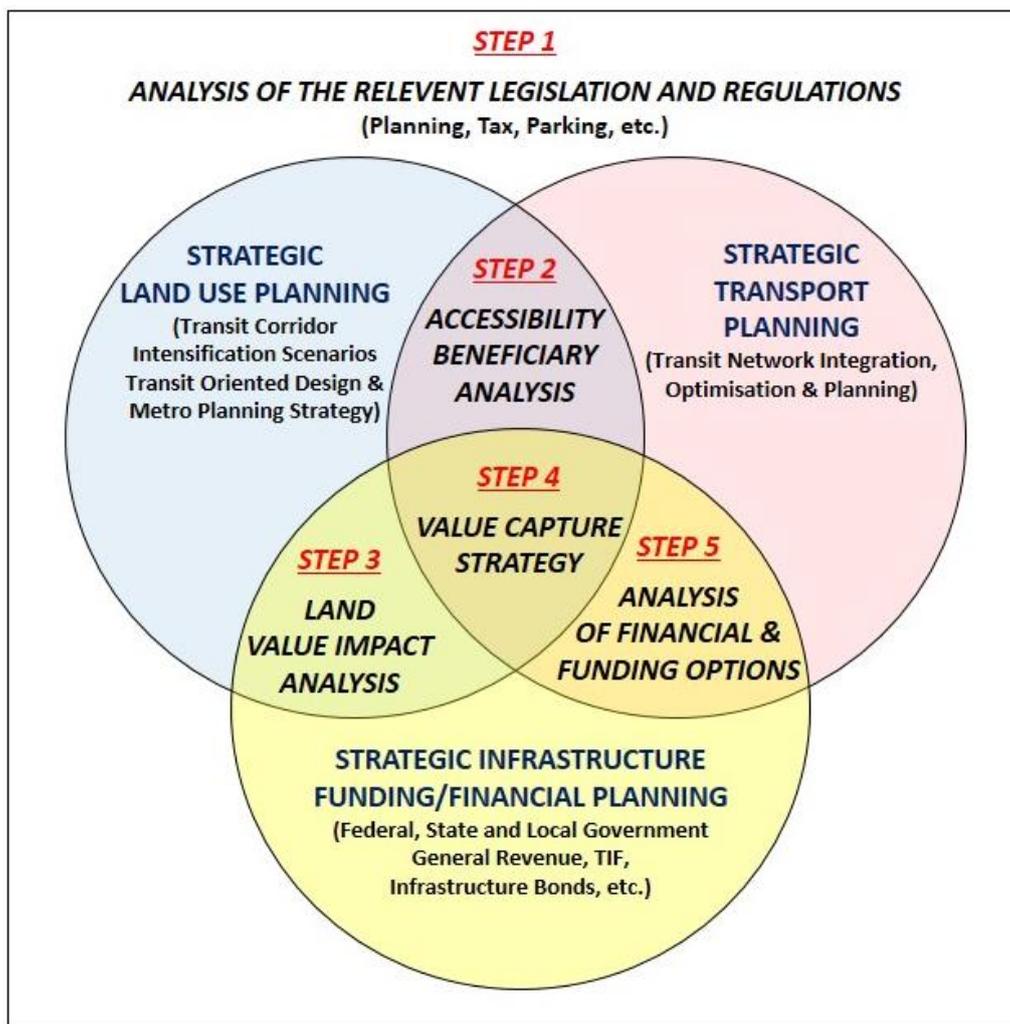


Figure 2 Conceptual value capture analysis framework for the integration of strategic transit land use, transport and funding/financial planning

### 3.1. Step 1: Assessment of the relevant alternative funding legislation and regulations

The first step in the integrated assessment methodology is to conduct a legislative review of the region's relevant government legislation and regulations, including:

- planning and development legislation (related to the ability to facilitate redevelopment),
- taxation legislation (state and federal government), local government rates, and
- parking regulations and legislation.

This stage is an important step in the methodology to ascertain what existing legislative opportunities are available and forms the regulatory basis for the value capture and alternative funding strategy. If there is a regulatory or legislative deficiency that would inhibit the introduction of the value capture framework, new or altered legislation and regulations would be proposed, such as the introduction of Tax Increment Financing (TIF) legislation.

### **3.2. Step 2: Accessibility beneficiary analysis**

Transport network accessibility is a critical aspect of metropolitan spatial and economic structures (Guiliano et al., 2010) and the role of transit accessibility is vital for cities to overcome car dependence (Newman and Kenworthy, 1999). Understanding the nature of the change in transit generated by a transport investment is vital in determining the distribution and size of the transport accessibility benefits that are delivered to the property and land market catchments. There are a number of transit accessibility metrics available including SNAMUTS (Scheurer, 2010) and AAM (Espada, 2010) but simpler methods such as calculating pedestrian catchments using a GIS system can also be employed.

### **3.3. Step 3: Land and property market analysis of the willingness to pay for transit accessibility**

The integration of the land and transport markets is one of the key drivers of the value capture framework, with the optimum value uplift and capture opportunities occurring where both their objectives are combined. Whilst the level of value uplift in the land and property markets can differ depending on the nature of the project, the significance of all the land market factors can be determined by undertaking hedonic price analysis of the

land values of commercial, industrial and residential properties (Small and Verhoef, 2007). In the meta-analysis of different studies into the impact of rail on land and property values, Mohammad et al. (2013) discuss the use of a range of estimation methods to determine the impact of the investment in rail transit on property and land prices, which include the following (with selected articles to refer):

- *Hedonic price modelling (cross section, panel data, time series) (Al-Mosaind et al., 1993)*
- *Geographically Weighted Regression (Du and Mulley, 2006)*
- *Average property/land values comparison (Sherry, 1999; National Association of Realtors, 2013)*
- *Direct differencing of land values (Fejarang, 1994)*

While dependent on data availability, the use of time variant panel data hedonic price modelling is likely to be the most effective for illustrating the impact of transit investment as it changes over different stages of its planning, construction and operation (Agostini and Palmucci, 2008; Bae et al., 2003; Mohammad et al., 2013). If there is insufficient data, or a lack of a comparable investment that has been implemented within a similar region, cross sectional analysis can demonstrate the value premium that the property and land markets place on in situ infrastructure (Al-Mosaind et al., 1993; Du and Mulley, 2007; Laakso, 1992; Voith, 1991). The estimation of the price premium in property and land markets forms the basis for the alternative funding framework, and is critical for communicating the benefits to stakeholders.

#### **3.4. Step 4: Analysis of the transit project value capture mechanisms available**

Based on the outcomes from Step 1 of the framework, an analysis of the different value capture mechanisms available to a transit project can be undertaken. There are many different types of value capture mechanisms (including both strategic and project focused

mechanisms). Table 3 proposes a value capture framework to assess and capture the value created by transit projects.

*Table 3 Value Capture Framework (adapted from McIntosh et al, 2011)*

<b>Property VC form</b>	<b>Value Created</b>	<b>Location / Region</b>	<b>Project Beneficiary</b>	<b>Assessment Methodology</b>	<b>VC Mechanism</b>	<b>Financial Return</b>
<i>Government Property (Passive)</i>	Increased value of Govt property	Transit regional beneficiary catchment	Govt. Land owners within the catchment	Value of property with and without project	<ul style="list-style-type: none"> <li>• Sale of surplus property</li> <li>• Hold property</li> </ul>	Increase in future sale price
<i>Government Property (Active)</i>	Govt property development	Stations along the alignment	Govt. Land owners within the catchment & Developers	Property development analysis	<ul style="list-style-type: none"> <li>• Property development</li> <li>• Parking returns</li> <li>• Rental returns</li> <li>• Joint development</li> <li>• Advertising</li> </ul>	Development returns, rental returns etc
<i>Non-Government Property (Passive)</i>	Increased value of non-Govt property	Transit regional beneficiary catchment	Private land owners within the catchment	Hedonic Price Modelling	<ul style="list-style-type: none"> <li>• Increase in existing ad valorem taxes</li> </ul>	Increase in earnings from current tax regimes
<i>Non-Government Property (Active)</i>	Increased value of non-Govt property	Stations along the alignment	Private land owners within the catchment & Developers	Hedonic Price Modelling & Property development analysis	<ul style="list-style-type: none"> <li>• Benefit area levies, special assessment districts</li> <li>• Developer levies/fees</li> <li>• Changes in duties and taxes</li> <li>• In kind developer contributions</li> </ul>	Increase in earnings from new tax regimes

Prior to the implementation of the value capture mechanisms into a transit project's Value Proposition, each mechanism should be evaluated against a policy evaluation framework (such as the one presented in Table 4). Externalities from poorly implemented funding mechanisms arise where there are divergences between social and private costs and are an example of a circumstance where the market acting alone will deliver poor outcomes (Allen Consulting Group, 2003). Funding options that allow the full economic, social and environmental costs to be accurately reflected in prices will, in general, be those that least distort economic activity and lead to the best community outcomes (Allen Consulting Group, 2003; TCRP, 2009; Litman, 2013).

*Table 4 Value Capture Mechanism Evaluation Criteria (Center for Transportation Studies, 2009, Allen Consulting Group, 2003; TCRP Report 129, 2009)*

<b>Evaluation Criteria</b>	<b>Explanatory notes</b>
<b>Revenue Yield</b>	Whether the mechanism generates adequate yield for the cost of implementation, and if the mechanism is stable over time.
<b>Cost Effectiveness</b>	Effectiveness is the central requirement of a funding approach to mobilise sufficient funds for investment in infrastructure, and to do so in a timely manner.
<b>Economic Efficiency</b>	Allocative efficiency is a longstanding concern of governments and measures which distort economic decision making with regard to investment or consumption patterns can lead to outcomes that shrink overall wellbeing.
<b>Equity</b>	Social justice concerns about sharing the burden of revenue raising fairly between individuals who have differing abilities to pay: it is generally deemed fair if people in similar economic circumstances are treated similarly (horizontal equity) and the amount paid varies in relation to the individual’s economic circumstances (vertical equity).
<b>Compliance Costs, Certainty &amp; Transparency</b>	Low compliance costs, and certainty is crucial in effective planning for businesses, with transparency being a key means of reducing uncertainty as it facilitates an understanding of the process and issues that need to be dealt with.
<b>Stakeholder Support</b>	Ultimately every funding approach requires making someone pay and governments are well aware this inevitably involves discontent from some quarter in the community, though this does not automatically preclude widespread support for a measure with the question of support often more about reasonableness and the outcome of a fair process, or trust in a fair decision maker and a “level playing field” or perception thereof on the part of the development community is critical. Any suggestion that one group or project can avoid such costs while another has to pay will be rejected.
<b>Technical Feasibility</b>	New technology is used in the collection of transport related taxes and revenue handling, and whilst these can be effective and accurate in allocation and collection of costs they can add another layer of complexity to traditional methods of funding collection.

The preparation of a transit project value capture mechanism assessment matrix (Table 5) acts as a cash flow statement that summarises the net financial revenues for each tier of government in a transit project as well as assessing the economic impacts of each of the proposed mechanisms.

*Table 5 Project Value Capture Mechanism Financial and Economic analysis matrix*

	<b>Revenue Yield (NPV \$) &amp; as a % of Project Cost</b>					<b>Qualitative Indicators (Evaluation Criteria -3 to 3)</b>						
	All cash flows	Net \$ Federal Govt	Net \$ State Govt	Net \$ Local Govt	Revenue Certainty	Cost Effectiveness	Economic Efficiency	Equity	Compliance Costs, Certainty & Transparency	Stakeholder Support	Technical Feasibility	Value Capture Mechanism Performance

<i>Government Property (Passive Mechanisms)</i>												
<i>Government Property (Active Mechanisms)</i>												
<i>Non-Government Property (Passive Mechanisms)</i>												
<i>Non-Government Property (Active Mechanisms)</i>												
<b>Total Value Capture Revenue</b>												

Each tier of government has demands on their limited resources and importantly the project’s value capture mechanism analysis matrix (as presented in Table 5) demonstrates the funding contributions required as they relate to their financial return. This illustration of project cash flow forms a critical component of the intergovernmental and community negotiations regarding the levels of project contribution from each party, as it enables each to weigh their level of contribution to the benefit they will receive.

**3.5. Step 5: Establish a procurement strategy through a hypothecated transit fund and implementation strategy**

The strategic funding for an urban transit network extends beyond the local area directly impacted by a particular project, as it will be providing accessibility impacts for the greater region. Thus a strategic value capture fund into which value capture financing can be directed should be established at a metropolitan region level. The fund’s hypothecated revenue stream would enable strategic funding of the transit network, and could be used to directly:

- repay transport infrastructure bonds,
- contribute to private sector financed infrastructure availability payments, or
- repay the directly incurred project infrastructure debt.

An important revenue stream for strategically funding transit is to collect passive tax increases related to property value uplift and use it as a basis for project financing, which is a process called Tax Increment Financing (Sullivan et al., 2002; Zhao and Larson,

2011). TIF is simply the term used by governments (especially in the US) for the way in which a debt financing facility is created against a secure revenue source (such as the transit fund proposed) utilising future taxes or levy revenue to repay debt incurred to finance public infrastructure (Allen Consulting Group, 2003).

Broad value capture TIF's could work by recognising and securitising the additional funds in the value capture framework from the induced increases in the existing tax base (i.e. stamp duty, land tax, etc.) or more actively from new taxes or levies, and these levies can be collected and securitised to raise finances that can help defray capital and operating costs of an infrastructure project. The infrastructure debt would be repaid over time by the transit fund using the hypothecated incremental tax cash flow. This *passive* increase in government property taxes will be received as long as the increased value in transit amenity continues to be monetised into land and property markets.

An implementation strategy could then be based on a completely public approach or it could involve a mostly private sector approach, or a mixture of the two. Innovative technologies and approaches to building around stations and operating the system, all become feasible with the use of the transit fund providing an on-going source to the financing of all aspects of the transit system.

#### **4. CASE STUDY: TRANSIT VALUE CAPTURING IN A CAR DEPENDENT CITY, PERTH, WESTERN AUSTRALIA**

Perth is the capital city of the state of Western Australia with a current population of 1.81 million people, making it the fourth most populous city in Australia and the most rapidly growing (Australian Bureau of Statistics, 2013). The Global Cities Database for 1995 (Kenworthy and Laube, 1999) shows Perth had the 10<sup>th</sup> highest total private passenger

Vehicle Kilometres Travelled (VKT) per capita of the cities reported (the first of the 84 cities outside of the United States), and the lowest transit mode share in Australia.

Metropolitan Perth has had rail transit since the late 19<sup>th</sup> century and increased its distribution in the late 20<sup>th</sup> and early 21<sup>st</sup> centuries under considerable political and community pressure. This is particularly evident in the provision of the Joondalup and Mandurah rail lines, which commenced operating in 1996 and 2007 respectively and were built deeply into Perth's car dependent suburbs down freeway medians. These lines have been very successful (against the predictions of many transport planners) as they were going into unexplored territory in terms of the usual land use associated with transit (McIntosh et al., 2013). This case study will investigate the value capture opportunities that could have been captured to fund the introduction of the Mandurah line in 2007.

#### **4.1. Step 1: Assessment of the relevant alternative funding legislation and regulations**

A review of Western Australian government legislation and policies identified that in addition to the existing land value capture legislative mechanisms there is legislation that has mechanisms that can facilitate alternative funding sources for transit infrastructure.

There are four main existing legislative Act's enabling value capture funding:

- Planning and Development Act, 2005
- Land Tax Act, 2002
- Perth Parking Management Act, 1999
- Local Government Act, 1995

These mechanisms were not initially planned to enable value capture but without any changes they can be adapted for this purpose (McIntosh et al., 2011). The presence of legislation that enables alternative funding mechanisms is important in the process to

facilitate value capture implementation, though it is unlikely that all jurisdictions have all the mechanisms required to assemble land, to capture land value taxes and hypothecate these revenues into a coordinated fund. Most cities, however, will have some of the necessary legislative base.

#### **4.2. Step 2: Accessibility Beneficiary Analysis**

Public transport accessibility assessments were conducted for Perth using both SNAMUTS (Scheurer, 2011) and AAM (Espada, 2011; Espada and Luk, 2011) and the results are presented in Figure 3. While the two measures use different accessibility assessment methods and are presented at differing scales, as one might expect they both report similar results with accessibility highest in the central areas. The implications of these analyses are that the higher the level of transit accessibility provided to the benefiting land catchments, the higher the level of benefit perceived, and subsequently the greater the level of “willingness to pay” for transit accessibility. For the purposes of this research only the SNAMUTS model was used.

##### **4.2.1. Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS)**

Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) is a GIS-based tool that assesses the relationship between transit network configuration, performance and service standards and the geographical distribution of clustering of land use activities across a metropolitan area (Scheurer, 2010).

SNAMUTS is based on a supply-side analysis of land use-transport interaction and has been designed to facilitate decision-making about transit service and infrastructure improvements as well as the location of land use intensification measures. The greatest value of the use of SNAMUTS is the delineation of the accessibility impact of discrete

transit projects, as well as land development projects on their localised neighbourhood. In addition to this it also highlights the variation in public transit accessibility across the metropolitan region’s transit network as a whole.

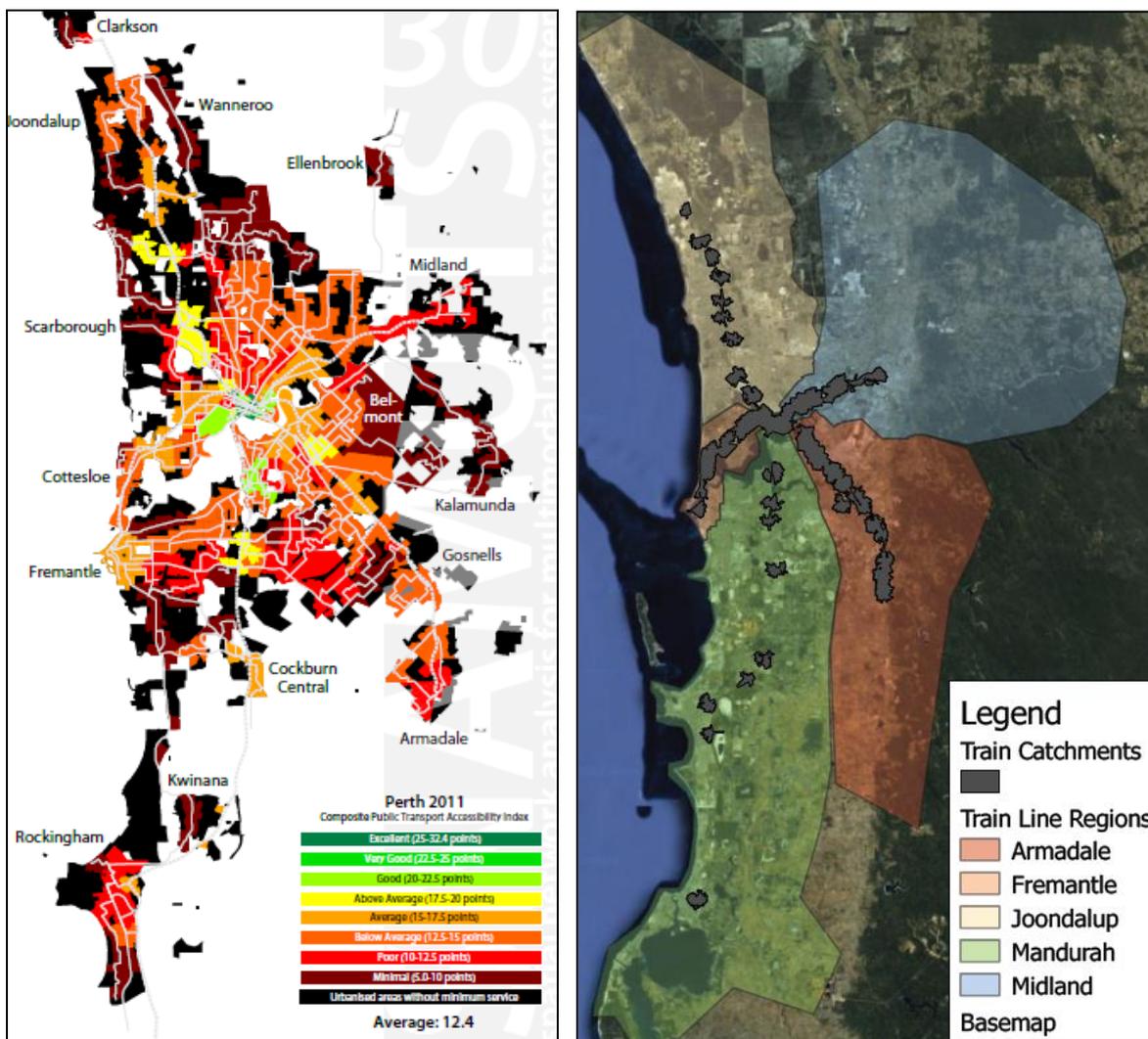


Figure 3 (Left) SNAMUTS public transit accessibility model for Perth, 2011 (Scheurer, 2011), (Right) Perth rail pedestrian catchments

### 4.3. Step 3: Land Value Impact Analysis

A panel data Hedonic Pricing Model (HPM) was developed for the rail transit catchments in metropolitan Perth (shown in Figure 3) in order to predict the impact in property values from rail infrastructure over time, in particular over the time period of the introduction of

the Mandurah rail line. Land value per square metre was modelled for 462,476 residential land parcels across metropolitan Perth (see the descriptive statistics in Table 6). The residential land models included 400m, 800m, and 1600m proximity bands to rail stations (road network service areas) and they reflect the 5, 10 and 20-minute rail station pedestrian catchments. The models also included SNAMUTS indicator values to control for transit network level-of-service and capture the accessibility benefits outside the rail catchments that are generated by feeder-bus services and the rest of the general bus network. Table 6 presents a full set of descriptive statistics for the HPM.

In the Log-Log functional form of the estimated hedonic models, the parameter estimates for the continuous variables are interpreted as elasticities (i.e. the percentage change in land value due to a 1% change in a continuous explanatory variable while those for dichotomous variables (or dummy variables) are interpreted as uplift percentages (i.e. the percentage change in land value due to a unit change in a dichotomous explanatory variable).

The dichotomous variables included the three train station catchment dummies and the two highway proximity bands while the rest of the variables in the residential and commercial models were continuous. The majority of the control variables in the models were of expected sign and magnitude, and importantly the evidence of land value uplift as a result of proximity to rail was very compelling (and consistent with the data compiled in Table 1). These uplift values are relative to all properties further than 1600 metres from a train station, which is considered to be well beyond the acceptable pedestrian accessibility to transit (further than a 20 minute walk). The individual train line models reveal

interesting trends relating to how passenger rail access impacts land values to a different extent in different regions.

Panel data modelling of the temporal variation in land prices is important for understanding the behaviour of land prices over time. Many of the cross sectional variables are non-stationary in a temporal sense and can reflect a number of factors such as:

- economic changes;
- technology changes;
- political shifts; and
- cultural movements (gentrification, etc.)

In addition to these factors, a panel data HPM was estimated in order to validate theories of how accessibility benefits are monetised into land values, prior to, during construction as well as after the commencement of operations of a rail line. The panel data modelling method employed time dummies as well as pooled data time variant terms with the rail line pedestrian catchments over the period 2001 to 2011. The annual datasets were then stacked to form a single complete panel dataset containing all the residential land valuations over the 11-year period.

*Table 6 Descriptive Statistics for the Residential HPM for 2011*  
*(1) Fremantle, (2) Armadale, (3) Midland (4) Mandurah and (5) Joondalup*

Explanatory Variables	Mean or Percentage Values					
	All Regions	(1)	(2)	(3)	(4)	(5)
Land Value/m <sup>2</sup> (no view) (AUD\$ 2011)	590.69	1646.59	366.95	425.29	542.88	632.00
Log Land Value/m <sup>2</sup> (no view) (AUD\$ 2011)	6.121	7.306	5.692	5.714	6.103	6.336
Number of Land Parcels	462476	28487	85108	67761	128136	152974
<b>Transportation Proximity</b>						
<b>400m train catchment</b>						
number of parcels	5300 (1.2%)	1913 (6.7%)	1401 (1.6%)	1440 (2.1%)	224 (0.2%)	321 (0.2%)
(% of total catchment number of parcels)						
[Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011]	[1044.03]	[1885.62]	[473.19]	[701.85]	[325.27]	[556.69]
{Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	{6.65}	{7.46}	{5.99}	{6.47}	{5.67}	{6.28}
<b>800m train catchment</b>						
number of parcels	15998 (3.5%)	4643 (16.3%)	5068 (5.9%)	4000 (5.9%)	890 (0.7%)	1396 (0.9%)
(% of total catchment number of parcels)						
[Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011]	[1002.33]	[1930.44]	[466.18]	[770.63]	[588.45]	[789.61]
{Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	{6.62}	{7.50}	{5.96}	{6.57}	{6.16}	{6.52}
<b>1600m train catchment</b>						
number of parcels	51388 (11.1%)	6797 (23.9%)	15749 (18.5%)	7424 (11.0%)	9238 (7.2%)	12179 (8.0%)
(% of total catchment number of parcels)						
[Ave. Catch. LandVal./m <sup>2</sup> AUD\$2011]	[768.32]	[1961.71]	[403.95]	[800.36]	[555.87]	[713.54]
{Ave. Catch. Log LandVal./m <sup>2</sup> AUD\$2011}	{6.35}	{7.48}	{5.84}	{6.55}	{6.09}	{6.47}
0 – 100m of a Hwy # of parcels (% of total)	17811 (3.9%)	1306 (4.5%)	3746 (4.4%)	2585 (3.8%)	4753 (3.7%)	5420 (3.5%)
100 – 200m of a Hwy # of parcels (% of total)	26215 (5.7%)	2355 (8.3%)	5365 (6.3%)	4566 (6.7%)	7108 (5.5%)	6820 (4.5%)
200 – 400m of a Hwy # of parcels (% of total)	48942 (5.7%)	4105 (14.4%)	9643 (11.3%)	8106 (12.0%)	13784 (10.8%)	13302 (8.7%)
Distance to nearest freeway onramp	8.63	6.89	13.54	17.41	5.52	4.94
<b>Transportation Accessibility Measure</b>						
SNAMUTS score	6.62	11.02	7.34	5.58	6.98	5.56
# of Dwellings within 1600m of parcel	4680	5772	4228	3880	4404	5314
Distance to CBD (km)	17.422	12.16	17.97	18.37	18.76	16.56
Distance to secondary centre (km)	4.80	2.44	5.10	6.78	5.33	3.75
<b>Property and Locational Attributes</b>						
Area (m <sup>2</sup> )	1746	688	2067	4072	1488	942
R-Code	20.98	21.11	21.56	18.81	20.52	22.36
Senior high school rating	5.52	17.34	7.33	2.80	4.88	7.05
Socio Economic Index For Areas (SEIFA)	58.641	87.49	42.39	51.88	60.89	63.43
Distance to water (km)	3.17	1.15	5.01	4.08	2.13	3.00

The results of the panel data Log-Log HPM study are shown in Table 7, with the majority of the models reporting strongly with Coefficients of Determination (or adjusted R-Squared values) over 70%, which is the suggested minimum level of explanatory power for hedonic models in predicting land values (Hannonen, 2009; McCarthy, 2001). The

cross sectional model highlights the counter-intuitive negative Joondalup and Mandurah rail coefficients which were due to the negative externalities of proximity to the freeway. The panel data model was adopted for forecasting as this highlighted the impact of the relative change in accessibility and hedonic price, which is a truer representation of the value uplift in land markets the study was seeking to address.

The panel data model demonstrated that the hedonic price change between funding commitment and transit opening for the Mandurah Line was in the range of 40% for the 400m catchment to 13% for the 1600m catchment. This is a significant difference in land values due to the new rail system accessibility.

The historic data examination of the introduction of the rail line within the Mandurah subregion therefore tells a substantially different story to the one portrayed by the cross-sectional analyses for 2011, and is a critical aspect of the analysis of the rail transit accessibility and value capture potential. Instead of having a minimal impact on land value (due to the freeway the train runs down) there is indeed a rapidly growing land value increase of up to 40% which is as high as most other studies have shown. The potential for the Mandurah Line to impact government revenue and the attractiveness of transit oriented land development is large, despite it being in a highly car dependent corridor.

The increase in real property prices over the regional averages shown in Table 6 has significantly impacted the existing taxation and charges for the three tiers of government. These impacts on government taxation and charges were not included in the forecasting at the time of the investment in the Mandurah Line and as such did not appear in the project's financial cash flow analysis or business case. These passive increases could have

been financially modelled and included in the project business case, and subsequently could have been used to defray the cost of the project.

*Table 7 OLS Panel data (Log-Log) HPM of Residential Properties (2001 – 2011)  
(1) Fremantle, (2) Armadale, (3) Midland, (4) Mandurah and (5) Joondalup*

<b>Explanatory Variables</b>	<b>All Regions</b>	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>	<b>(5)</b>
Const	6.048 (0.006)***	9.010 (0.022)***	6.223 (0.010)***	6.877 (0.010)***	-1.124 (0.02)***	4.113 (0.011)***
ln_area	-0.516 (0.000)***	-0.412 (0.001)***	-0.535 (0.001)***	-0.558 (0.001)***	-0.390 (0.0001)***	-0.375 (0.001)***
ln_rcode	0.024 (0.001)***	-0.023 (0.002)***	0.013 (0.001)***	0.055 (0.001)***	0.102 (0.001)***	0.334 (0.001)***
train400	0.235 (0.005)***	0.228 (0.007)***	-0.142 (0.007)***	0.071 (0.007)***	-0.337 (0.002)***	-0.269 (0.018)***
train800	0.176 (0.003)***	0.252 (0.005)***	-0.123 (0.004)***	0.093 (0.004)	-0.094 (0.001)***	-0.050 (0.009)***
train1600	0.074 (0.001)***	0.180 (0.004)***	-0.130 (0.002)***	0.148 (0.004)***	-0.034 (0.003)***	-0.008 (0.003)***
ln_snamuts	0.003 (0.000)***	-0.006 (0.0001)***	0.007 (0.0001)***	0.011 (0.0001)***	-0.009 (0.0001)***	0.010 (0.0006)***
ln_seifa_adv_di	0.304 (0.000)***	0.166 (0.002)***	0.202 (0.0004)***	0.205 (0.001)***	0.283 (0.0004)***	0.281 (0.0005)***
ln_shsrate11	0.058 (0.000)***	0.171 (0.001)***	0.055 (0.0001)***	0.023 (0.0001)***	0.030 (0.0001)***	0.045 (0.0008)***
ln_dist_water	-0.183 (0.000)***	-0.241 (0.001)***	-0.053 (0.0004)***	-0.094 (0.0004)***	-0.214 (0.0003)***	-0.200 (0.0003)***
ln_dwell_1600	0.157 (0.000)***	-0.165 (0.002)***	0.173 (0.001)***	0.125 (0.001)***	0.206 (0.0007)***	0.175 (0.0001)***
ln_dist_cbd	-0.028 (0.000)***	-0.012 (0.001)***	-0.001 (0.0003)***	-0.023 (0.0003)***	-0.004 (0.0003)***	-0.041 (0.0003)***
ln_dist_ctr_non	-0.034 (0.000)***	-0.062 (0.001)***	0.025 (0.0003)***	-0.009 (0.0004)***	-0.004 (0.0003)***	0.005 (0.0003)***
hwy0_100	-0.077 (0.001)***	-0.165 (0.002)***	-0.075 (0.001)***	-0.107 (0.002)***	-0.053 (0.0001)***	-0.015 (0.001)***
hwy100_200	0.006 (0.001)***	-0.062 (0.002)***	-0.018 (0.001)***	-0.025 (0.001)***	0.041 (0.001)***	0.049 (0.001)***
ln_fwyonramp	0.026 (0.000)***	0.021 (0.001)***	-0.013 (0.0004)***	-0.089 (0.001)***	0.015 (0.0001)***	0.032 (0.0003)***
dt_2002	0.067 (0.001)***	0.081 (0.003)***	0.018 (0.001)***	0.047 (0.002)***	0.058 (0.001)***	0.082 (0.001)***
dt_2003	0.18 (0.001)***	0.164 (0.003)***	0.101 (0.002)***	0.163 (0.002)***	0.178 (0.001)***	0.210 (0.001)***
dt_2004	0.367 (0.001)***	0.301 (0.003)***	0.259 (0.002)***	0.317 (0.002)***	0.374 (0.001)***	0.419 (0.001)***
dt_2005	0.549 (0.001)***	0.428 (0.003)***	0.464 (0.002)***	0.505 (0.002)***	0.598 (0.001)***	0.565 (0.001)***
dt_2006	0.769 (0.001)***	0.577 (0.003)***	0.730 (0.002)***	0.765 (0.002)***	0.796 (0.001)***	0.781 (0.001)***
dt_2007	1.187 (0.001)***	0.869 (0.003)***	1.175 (0.002)***	1.216 (0.002)***	1.165 (0.001)***	1.23 (0.001)***
dt_2008	1.315 (0.001)***	1.070 (0.003)***	1.319 (0.002)***	1.387 (0.002)***	1.314 (0.001)***	1.318 (0.001)***
dt_2009	1.24 (0.001)***	1.015 (0.0003)***	1.258 (0.002)***	1.348 (0.002)***	1.247 (0.001)***	1.217 (0.001)***
dt_2010	1.25 (0.001)***	0.994 (0.003)***	1.273 (0.002)***	1.349 (0.002)***	1.234 (0.001)***	1.252 (0.001)***
dt_2011	1.323 (0.001)***	1.071 (0.003)***	1.355 (0.002)***	1.409 (0.002)***	1.297 (0.001)***	1.324 (0.001)***
<b>Congruence Statistics</b>						
No. of Observations	4431363	297855	795028	595669	1200898	1541913
Adjusted R-Squared	84.60%	81.98%	91.12%	92.16%	87.20%	80.32%
Std. Error of Reg.	0.336	0.250	0.239	0.311	0.280	0.243

*Notes: Figures in brackets report parameter standard errors. Significance at the 0.01 level is indicated by three asterisks, significance at the 0.05 level is indicated by two asterisks, and significance at the 0.10 level is indicated by a single asterisk. Interaction terms between time dummies and train catchments are omitted here for brevity but the annual uplift estimates can be seen plotted below in Figure 16.*

#### **4.4. Step 4: Analysis of the Value Capture mechanisms available**

In partnership with the WATC, a detailed financial model was created to analyse the present value calculation of passive and active value capture mechanisms for the investment in the Mandurah Line compared to a hypothetical base case in which the Mandurah Rail line was never built. The results for both the passive and active mechanisms are presented in Figure 4.

##### 4.4.1. Passive Value Capture Mechanisms

The impact of the increase in land values translates to the Commonwealth Government taxes (Capital Gains Tax and GST), Western Australian State Taxes (Land Tax, MRIT, Stamp Duty) and Local Government (Council Rates) over the financial periods, 2001 – 2031. The modelled impact on the tax system of the investment in the rail line was substantial and accounts for approximately \$506 Million dollars (or 30%) of capital expenditure (2013 AUD). This equates to a 30% increase in the ad valorem taxes for the primary 400m pedestrian catchment surrounding the Mandurah rail station precincts compared to the non-transit base case.

##### 4.4.2. Active Value Capture Mechanisms

In addition to the passive tax benefits from the investment in the Mandurah Line, a scenario was developed supposing some active value capture mechanisms were put in place within the existing 800m pedestrian catchments that included:

- 10% differential increase in local government rates,
- \$100 annual specified area Levy/property,

- \$100 annual service charge/property,
- 5% density bonus on post title sale proceeds for extra permitted floor area, and
- 50% reduction in new development car parking, with bay costs to be taken as cash in lieu.

These mechanisms are presented individually and are not designed to be implemented together (though they can be). As there was minimal, to no intensification within the 800m pedestrian catchment since the commencement of the rail line, and the only intensification to merely develop up to the permitted low density, with no increase in zoning, the development based mechanisms will be of little impact compared to an intensification based scenario.

However, if further rezoning of the land around the stations to facilitate intensification of the land uses were to occur to further facilitate land and transit integration, this would lead to even greater uplift in the land values around the stations (represented in the R-Code Elasticity in Table 5) and importantly increase the amount of development within the catchments to be impacted by the passive and active mechanisms. To illustrate the impact of intensification, a 400% increase in residential density in the 400m pedestrian catchment land catchment scenario was run, with the results presented in Figure 6. Although this increase could be interpreted as excessive, it merely raises the residential density to the levels of the Subiaco TOD in Perth, which is now being exceeded by new significant government TOD projects at two of the Mandurah line stations.

The passive and active mechanism revenue for the “no intensification” scenario was substantial at just over \$750 Million (AUD 2013), but with the intensification scenario this increased to over \$1.7 Billion (AUD 2013). These are significant project-induced revenues, which equate to 60% and 132% of the capital cost of the Mandurah rail line,

respectively. While not all of these revenues are able to be captured (i.e. Commonwealth Government taxes), or in some cases actually economically efficient (i.e. developer contributions), they form an important part of the development of the project's financial performance over a thirty-year project operating period.

Each of the value capture mechanisms proposed in the “no intensification” scenario are assessed in an evaluation matrix<sup>12</sup> (presented in Table 8) and this enables a transparent analysis of each of the mechanisms proposed, although it is worth noting that a weighting for each of the assessment criteria would be conducted with the relevant stakeholders as part of the assessment process.

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<sup>12</sup> The evaluation matrix proposed highlights both quantitative and qualitative metrics and enables the analysis of financial and economic factors together.

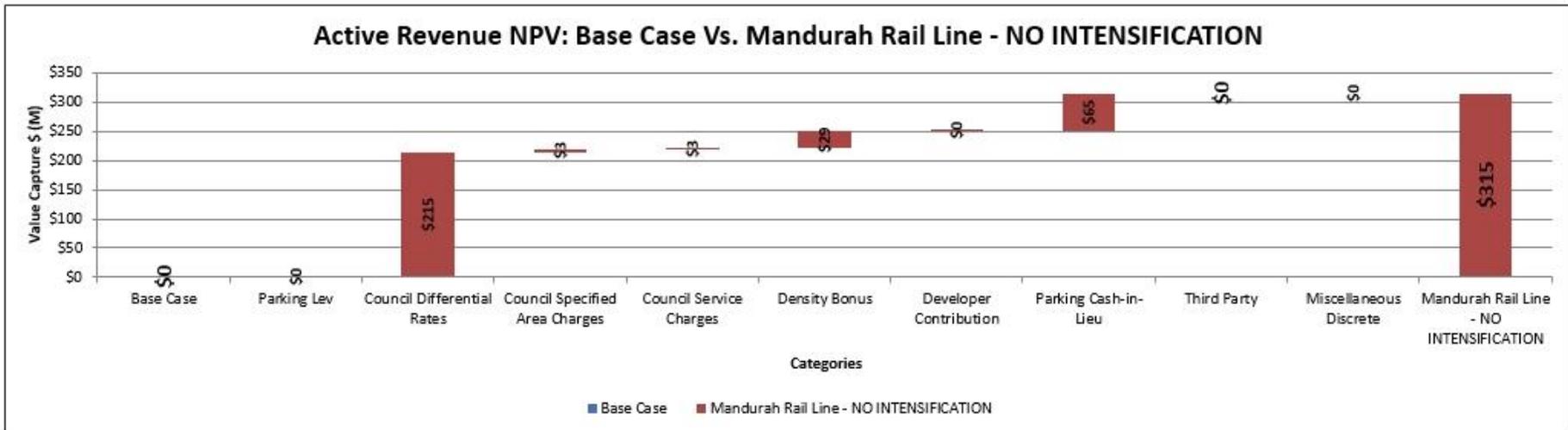
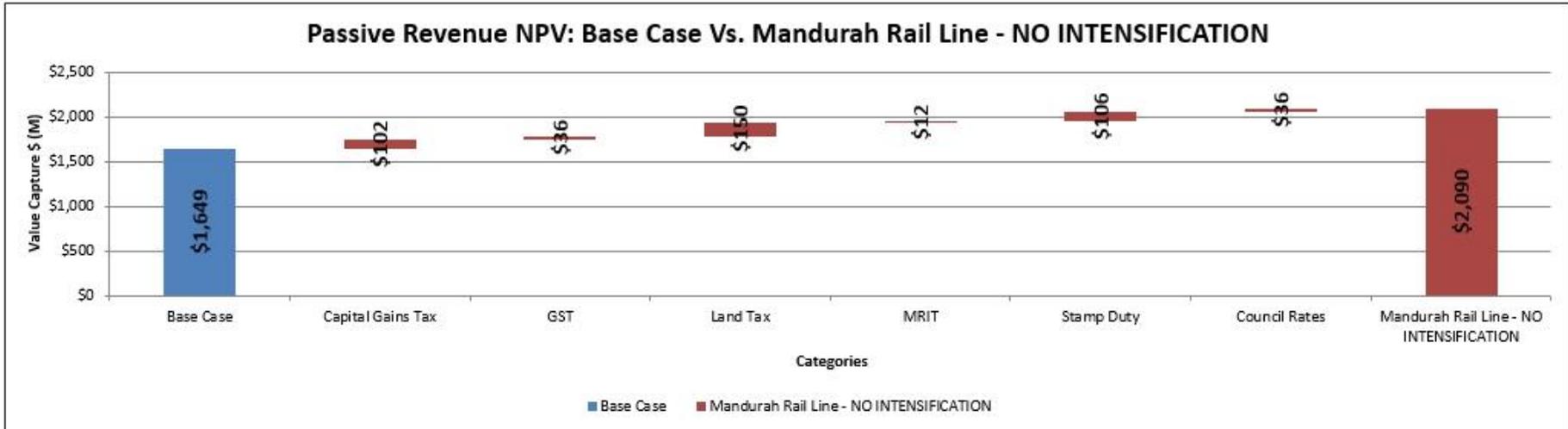
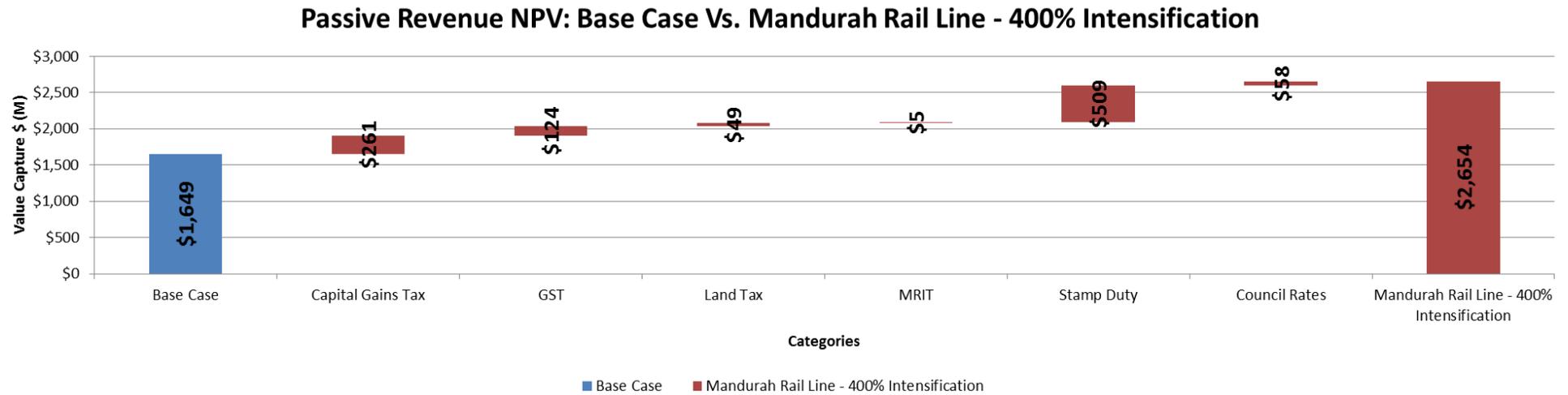


Figure 5 Net present value changes in the existing ad valorem taxes in the Mandurah rail corridor over the financial period, 2001-2031. (Top) the base case to actual Mandurah rail catchment taxes, (Bottom) the potential present value performance of the active value capture mechanisms for the “no intensification” scenario.



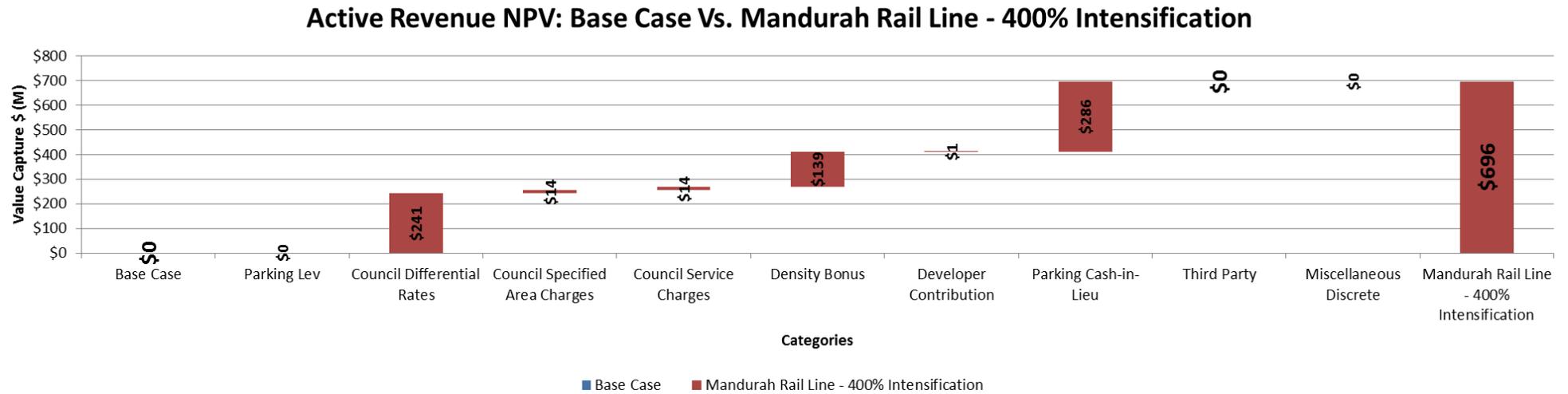


Figure 6 Net present value changes in the existing ad valorem taxes in the Mandurah rail corridor over the financial period, 2001-2031. (Top) the tax revenue generated from a 400% alternative intensification scenario, (Bottom) potential present value performance of the active value capture mechanisms.

*Table 8 An unweighted Transit Project Value Capture Mechanism Analysis Matrix for the no intensification base case*

	Value Capture Mechanisms	Revenue Yield Present Value (\$M AUD2013) for 2001-2031				Qualitative Indicators (Evaluation Criteria -3 to 3)						
		Federal Govt \$(M)	State Govt \$(M)	Local Govt \$(M)	Revenue Certainty	Cost Effectiveness	Economic Efficiency	Equity	Compliance costs, & transparency	Stakeholder support	Technical Feasibility	Total Qualitative Score
Govt. Property (Passive)	Sale of surplus property /development air rights	-	-	-	1	1	3	3	3	3	2	16
	Sale of naming rights to stations	-	-	-	1	3	3	3	2	3	3	18
Govt. Property (Active)	Direct development of Govt. property	-	-	-	2	1	1	2	1	3	1	11
	Joint development	-	-	-	2	3	3	3	1	3	3	18
	Returns on government parking	-	-	-	3	3	3	1	1	2	2	15
	Government property leasing	-	-	-	2	2	2	0	1	3	0	10
	Advertising revenue	-	-	-	2	3	3	3	3	3	3	20
Non-Govt. (Passive)	Federal Govt. Capital Gains Tax	\$102	-	-	2	3	3	0	-3	0	-3	2
	Federal Govt. Goods & Services Tax	\$36	-	-	2	3	3	0	-3	0	-3	2
	State Transfer Duty/Sales Taxes	-	\$106	-	2	3	2	1	2	1	2	13
	State Land / Property Tax	-	\$150	-	2	3	3	2	2	2	2	16
	Metropolitan Region Improvement Tax	-	\$12	-	3	2	2	2	3	2	2	15
	Local Government Rates/Taxes	-	-	\$36	2	3	3	2	2	2	2	16
Non-Govt. (Active)	Benefit Area levies State or Local Government Infrastructure cost recovery • Differential Rates, Specified Area Rates, Service charges	-	-	\$218	3	3	-1	1	0	-2	2	6
	Corridor transit levy	-	-	\$3	3	3	2	1	1	1	1	12
	Developer contributions	-	-	\$0	3	2	-3	0	1	1	2	7
	Parking Levies / Bonds • Development Parking levies, Increased cash in lieu, Regional Parking Levy	-	-	\$65	2	3	3	2	2	2	2	16
	Density bonuses	-	-	\$29	2	3	3	3	2	2	2	17
<b>Total Revenue for each tier of government \$(M)</b>		<b>\$138</b>	<b>\$268</b>	<b>\$351</b>								
Notes:												
1. Not all the mechanisms were applicable to the Mandurah rail line and hence were not financially assessed, though they were all qualitatively assessed for application suitability. Lack of information on the nature and amount of Government property in the corridor inhibited this assessment, though this could be rectified for future assessments of the corridor.												
2. <u>Qualitative Indicators Evaluation Criteria</u> 3 (Strong Performance), 1 (Modest Performance), 0 (Marginal Performance), -1 (Moderately Poor Performance), -3 (Very Poor Performance)												

**4.5. Step 5. Establish a Procurement Strategy through a fund to hypothecate all value capture funds for project financing and an Implementation Plan.**

As the Mandurah Line has been built, the estimated revenue that could have been raised suggests it would have been enough for the construction and even part of the on-going operations of the line if the project had been developed using a value capture framework. We suggest a value capture fund called the *Metropolitan Region Transit Fund* (MRTF) could have been established and that the transit fund could have captured project-based *active* value capture benefits and passive taxes through hypothecated funds from existing legislative tools, and then facilitated by a TIF. In fact, any value capture fund could facilitate the creation of a loan mechanism to fund the capital costs of the investment in transit infrastructure.

The creation of a value capture fund requires all levels of government to agree to its terms of reference, an integrated land use and transportation focus, and importantly the development of a delivery agency to manage the investment of its funds. The significant outcome of creating transit oriented land uses has been given a considerable boost through this kind of process but to optimise implementation a delivery agency will need to focus on these outcomes as well as building the transit (Renne and Wells, 2005; Cervero et al., 2002).

An implementation strategy for the next stages of Perth's rail system could be based on a completely public approach, involve a mostly private sector approach, or involve a blend of the two as with Western Australia's Metropolitan Redevelopment Authority. It is possible for Perth to implement a largely private rail project based on the above value capture analyses, as this enables private sector involvement and

capital required to facilitate innovation in building and operating a new rail system, and in development around highly valuable sites along the route. The alternative funding framework could be applied to any car dependent urban system looking to create a way out of its car-based dilemmas.

## **5. CONCLUSIONS**

This paper presents the merits of bringing metropolitan region strategic land use and transit planning together with strategic funding mechanisms to enable implementation of transit infrastructure and re-urbanisation. Most car dependent cities such as those in the US and Australia are attempting to rebuild in this way. The paper has outlined a value capture framework that in five steps can determine the potential to use value capture to fund a new transit system.

The process will necessarily involve all tiers of government to help distribute the project cost equitably and use the different powers available. The Perth case study shows that substantial funds could have been generated with the government mechanisms currently available. The reality is that most if not all the funding could have been obtained by this mechanism. It also shows that the funding could have enabled private sector involvement and would have achieved significantly more TODs with many more people therefore having easy access to the transit line. Whilst there may be challenges in setting up these value capture mechanisms, not doing so would mean that cities, especially car dependent cities, would be more poorly placed socially, environmentally and economically. The global turn to transit and re-urbanisation has left many cities without the funds to support the finance required to

enable the investment in transit infrastructure and TOD, and this paper proposes a framework to enable this.

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