

Curtin University Sustainability Policy (CUSP) Institute

School of Humanities

**Linking the knowledge economy, urban intensity and
transport in post-industrial cities with a case study of Perth,
Western Australia**

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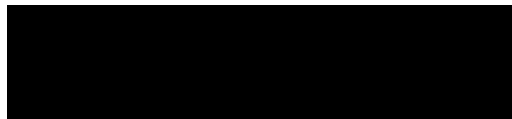
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Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature:



Date: 8/08/2016

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“An advanced city is not a place where the poor move about in cars, rather it’s where even the rich use public transportation”

— Enrique Penalosa, former Mayor of Bogota

Abstract

‘Linking the Knowledge Economy, Urban Intensity and Transport in Post-Industrial Cities with a Case Study of Perth’

As economies are transformed by growth in the knowledge-intensive economy, this thesis examines how urban intensification is impacting on post-industrial cities. While a global perspective is considered, a case study of Perth, Western Australia, is used. This thesis proposes that cities in post-industrial economies are characterised and driven by a multi-layered intensification of knowledge. This includes:

- intensification or agglomeration of knowledge economic activity;
- intensification of human capital knowledge; and
- intensification of the means of knowledge exchange i.e. Information and Communications Technology (ICT) systems and transport.

The research concludes that post-industrial cities such as Perth are, in respect of the growing knowledge-intensive economy, returning to a monocentric urban structure. This is because of a market demand for urban centres that both facilitate economic agglomeration by increasing tacit knowledge exchange through face-to-face interaction and provide scale and knowledge intensity in the urban labour and service markets.

The polycentric premise of accepted metropolitan planning is therefore questioned. An alternative urban structure is proposed for metropolitan scale cities, which includes a more targeted and focused polycentric approach. This is based on the intensification and densification of key urban centres around universities as the complementary centres for the central CBD.

The intensification in cities is also shown to be occurring with urban transport. Consistent with the worldwide trend away from spatially inefficient private motor vehicle use, Perth is seeing an increase in spatially intense forms of transport with knowledge-intensive professional workers. It is concluded that walking in dense urban centres is the fundamental means of creating face-to-face interaction. In a knowledge-intensive economy, reliant on scale in labour and service markets, capacity for dense centres is provided by high capacity spatially efficient transport, of which rail is the most spatially efficient.

This thesis is significant in that it suggests the need to rethink both the underlying premises for metropolitan spatial and transport planning in post-industrial cities.

Table of Contents

Part A: Thesis proposition and present nature of Australian cities

Chapter 1 – Thesis proposition and proposed theory

- 1.1 Thesis proposition
- 1.2 The structure of this thesis

Part B: Context literature review

Chapter 2 – Literature review on theories of knowledge and the knowledge economy

- 2.1 The knowledge economy - Understanding theories of knowledge
- 2.2 Knowledge transfer
- 2.3 The spatial context of knowledge spillover
- 2.4 Knowledge in the modern economy

Part C: The literature review on the three elements of knowledge intensification: ICT knowledge and infrastructure, human knowledge capital, and agglomeration of knowledge economic activity

Chapter 3 – Literature review on the intensification of knowledge economic activity

- 3.1 Spatial intensification of knowledge economic activity within cities
- 3.2 Economic urban agglomeration
- 3.3 Agglomeration, urban density and human capital
- 3.4 Networking of knowledge based agglomeration

Chapter 4 – Intensification of human (capital) knowledge

- 4.1 Intensification of human capital
- 4.2 Spatial intensification of knowledge workers within cities

Chapter 5 – Knowledge intensification of ICT

- 5.1 Knowledge intensification of modern ICT, the Internet and the link to the knowledge economy
- 5.2 The urban intensification of the physical infrastructure of the Internet
 - 5.2.1 Data intensification and data centres
 - 5.2.2 Spatial distribution of data centres
- 5.3 Spatial characteristics of Internet technology infrastructure in Australia

Chapter 6 – Part C Research into Perth and the secondary-questions on knowledge intensification

- 6.1 Characteristics of knowledge-intensive cities
- 6.2 Secondary question 1: Is knowledge economic activity intensifying in Perth, both in terms of an increase in knowledge-intensive industries and their spatial distribution?
- 6.3 Secondary question 2: Is human knowledge capital intensifying in Perth, both in terms of the labour market knowledge capacity and in terms of the spatial distribution?
 - 6.3.1 Methodology
 - 6.3.2 Human knowledge capital intensification research
- 6.4 Sub question 3: Is ICT knowledge intensification occurring in Perth, both in terms of the spatial distribution infrastructure and ICT enabled businesses?
 - 6.4.1 Methodology
 - 6.4.2 Spatial distribution of WA Internet Exchange participants
 - 6.4.3 Analysis of spatial location of WAIX participants
 - 6.4.4 Discussion of the spatial distribution of WAIX participants
 - 6.4.5 Spatial distribution of 'open' data centres in Perth
 - 6.4.6 Methodology
 - 6.4.7 Results and analysis on open data centres in Perth
 - 6.4.8 Discussion – Contrasting and comparing the spatial location of data centres and location of the Perth-based participants of the WAIX

Part D: City spatial planning for a knowledge-intensive economy:
Understanding Australia's and Perth's urban structures through capacity for
knowledge intensification

Chapter 7 – Literature Review – Spatial scales and urban structure

- 7.1 Spatial scales
- 7.2 Urban structure: System of cities – the national context
- 7.3 Knowledge intensification and urban structures of cities: monocentric, polycentric and/or dispersed
- 7.4 The evolution of urban structures in modern cities
- 7.5 Activity centres for knowledge intensification

Chapter 8 – Literature Review – Knowledge intensity and activity centres within Australian planning

- 8.1 Activity centres planning in Australia

8.2 Activity centre types and knowledge intensification

Chapter 9 – Universities as potential knowledge-intensive centres

9.1 Universities and knowledge economy intensification

9.2 Universities and human capital intensification

9.3 Universities and ICT intensification

9.4 Spatial concepts of universities as or within activity centres

9.5 Spatial development of Australian universities in the 21st century

Chapter 10 – Shopping centres as potential knowledge intensive centres

10.1 Shopping centres and knowledge economy intensification

10.2 Shopping centres and human capital intensification

10.3 Shopping centres and ICT intensification

Chapter 11 – Part D research on urban structures for knowledge-intensive cities

11.1 Methodologies

11.2 Australia's 'system of cities' and understanding Perth's urban structure

11.3 Perth's urban structure – mono, poly or dispersed?

11.4 Population growth and activity centre planning: a comparison with Sydney

11.4.1 Understanding Perth and Sydney through their labour markets

11.5 Perth's primary activity centres – a review for potential knowledge intensification

11.6 Alternative urban structure and activity centre strategies

Part E: The role of public transport in developing Knowledge Economy
centres: spatial intensification of urban transport

Chapter 12 – Literature review – urban transport systems for a modern knowledge-intensive
city

12.1 Cities, urban transport and knowledge intensification

12.2 Spatial characteristics of transport modes

Chapter 13 – Walking and knowledge intensity

13.1 Walking and active transport

13.2 Streets and roads – their impact on walkability in activity centres

13.3 Technology and personal mobility – extending walkability

Chapter 14 – Cars and knowledge intensification

14.1 Cars negatives and benefits

14.2 Parking

14.3 The technological revolution in road transport

14.3.1 Electric vehicles (EVs)

- 14.3.2 Car share and ride sharing
- 14.3.3 ITS (Intelligent Transport Systems for Road Infrastructure) and Autonomous Vehicles (AVs)

Chapter 15 – Public transport and knowledge intensification

- 15.1 Public transport modes
- 15.2 Public transport – accessibility and capacity
- 15.3 Public transport - flexibility and network effect
- 15.4 Public transport - circulation

Chapter 16 – Part E research into knowledge intensification of transport

- 16.1 Research methodologies
- 16.2 Research into knowledge intensity – Perth’s labour market and spatially intense commuting
- 16.3 Knowledge intensification of transport
 - 16.3.1 Implications of knowledge intensification on transport planning

Part F: Conclusion

Chapter 17 – Conclusion

- 17.1 The knowledge intensification of cities
- 17.2 Is knowledge intensification occurring in Perth? Yes.
- 17.3 The appropriate urban structure for a knowledge-intensive city
- 17.4 The appropriate transport strategies for a knowledge-intensive city
- 17.5 Areas of further research

List of Figures

- Figure 1 The three pillars of the Knowledge Economy
- Figure 2 The three knowledge pillars of the Australian mining industry (as adopted from Thierstein et al. 2006) based on the research from Tedeco and Haseltine (2010) and Martinez-Fernandez (2010)
- Figure 3 Educational Attainments: Highest Qualification of People in the Labour Force
- Figure 4 Number of workers in knowledge intensive industries in Sydney 2001-2011 with Global Competitiveness Index 2011 Local Government Area

- Figure 5 Proximity to CBD and knowledge economy place of residence and work for Melbourne
- Figure 6 The backbone density by bandwidth density for the United States
- Figure 7 Enplanements at large USA air traffic hubs 1975 and 1999
- Figure 8 Pan European fibre optic network routes planned or in place
- Figure 9 Historical evolution of backhaul capacity
- Figure 10 Availability of ADSL services in Australia (includes ADSL and ADSL2+ services), 31 January 2007
- Figure 11 Employment for Perth and Peel by sub-regions 2011
- Figure 12 Employed persons in the City of Perth 1961-2006
- Figure 13 Perth Industry Structure
- Figure 14 Mining and resource establishments in central Perth
- Figure 15 Maps of Local Government Areas (LGAs) of the Perth metropolitan area
- Figure 16 Knowledge intensification of Perth – per centage of labour force with university qualification versus no non-school qualifications
- Figure 17 Level of increase in education attainment 1991-2006 Bachelor degree and higher by residences for Perth metropolitan LGA
- Figure 18 Education attainment 1991-2011 Bachelor degree and higher by residences for Perth metropolitan LGA
- Figure 19 Distance from the WAIX of Perth WAIX participants 2010 and 2012
- Figure 20 Distance from the WAIX of all WAIX Participants 2010 and 2012
- Figure 21 Open use data centres – distance from the Perth GPO - 2012
- Figure 22 Remoteness areas and population distribution 30 June 2006
- Figure 23 Location of knowledge economy clusters for Melbourne
- Figure 24 Gazetted Activity Centres Hierarchy for Perth and Spatial Plan for Perth
- Figure 25 Map of WAPC planning subregions for metropolitan Perth
- Figure 26 Degree of primacy of Australia's state capital cities
- Figure 27 Agro-ecological zones of Australia
- Figure 28 Map of agricultural full equity profit 2005/2006
- Figure 29 The Australian 'system of cities' looking at regional population density, state capital city population and primacy (with NSW (with ACT) and Victoria combined into a core region)
- Figure 30 100 years of Australia population distribution by State
- Figure 31 Map of top ten Australian city pairs for air passenger movements year ending 2012
- Figure 32 Top ten Australian city pairs for air passenger movements year ending 2012
- Figure 33 Sub-regional flows of working residents to jobs 2011
- Figure 34 Sub-regional commuting patterns by occupations, absolute numbers 2011
- Figure 35 Sydney and Perth population comparison 1961-2051
- Figure 36 Sydney activity centres and metropolitan strategy map

Figure 37	Five Precincts in the Stirling/Osborne Urban Area
Figure 38	Proposed new Perth's urban hierarchy
Figure 39	Land space required by transport mode
Figure 40	Knowledge economy commuter zones for Melbourne
Figure 41	Operating capacities and speeds of different urban transit modes
Figure 42	Perth metropolitan area – Percentage of car commuting (as driver or passenger) as single method of travel by occupation from 2006 to 2011
Figure 43	Total number of commuters by occupation using spatially intense commuting modes for Perth metropolitan area 2006 and 2011
Figure 44	Spatially intense transport mode commuters by occupation
Figure 45	Proposed new urban network for post-industrial cities - with transport/education/economic contexts added
Figure 46	Knowledge Rail Network for Perth

APPENDIX

Appendix 1	Economic and Urban Structure Background to Perth, Western Australia
Appendix 2	Spatial characteristics of data centres
Appendix 3	List of WAIX Participants 2010 and 2012
Appendix 4	Perth Open Data Centre List
Appendix 5	Australian university types and spatial characteristics
Appendix 6	Knowledge intensification potential of Perth activity centres
Appendix 7	University Design Characteristics
Appendix 8	Rail network policy and infrastructure strategies for Perth

Part A: Thesis proposition and present nature of Australian cities

“It was the sort of idea that might easily decondition the more unsettled minds among the higher castes—make them lose their faith in happiness as the Sovereign Good and take to believing, instead, that the goal was somewhere beyond, somewhere outside the present human sphere, that the purpose of life was not the maintenance of well-being, but some intensification and refining of consciousness, some enlargement of knowledge.”

- Aldous Huxley Brave New World 1932

Chapter 1 Thesis proposition and proposed theory

1.1 Thesis proposition

As economies are transformed by the growth in the knowledge-intensive economy, this thesis examines how urban planning and transport strategies influence the economic growth of post-industrial¹ cities. Metropolitan Perth in Western Australia is considered as the case study (see **Appendix 1 Economic and Urban Structure Background for Perth, Western Australia**).

As in other increasingly post-industrial countries, Australia had seen, since the 1970s, the beginning of extensive changes in its industry composition and employment.² Output and employment in the service sector expanded considerably with declines in manufacturing output and employment, with the transformation being greater in Australia than in most other OECD countries (Productivity Commission 1998, Esposto & Abbott 2010). In 1975, the service sector accounted for just over 50 per cent of all jobs, increasing to almost 70 per cent in 2004 (Lewis 2004). By 2012, the service sector dominated the Australian economy, accounting for 75 per cent of the Australian economy (RBA 2012), with strong forecasted growth in knowledge-intensive service occupations into the future (Department of the Employment 2014). In contrast, manufacturing’s share of total employment halved over the

¹ Blackwell Dictionary of Modern Social Thought sees the *post-industrial society* as being marked by the change from a goods-producing to a service economy; occupationally, by the pre-eminence of the professional and the technical class; and in decision-making by the widespread diffusion of ‘intellectual technology’. Bell, particularly in *The Coming of Post-Industrial Society* (1974), defined the ‘axial principles’ of post-industrial society as the centrality of theoretical knowledge as the source of innovation.

² The rise in the modern knowledge-intensive economy in Australia can be dated back to the structural changes the Australian economy started undergoing in the 1970s (Productivity Commission 1998, Lewis 2004) and the modernising and internationalising of the national economy under the Hawke and Keating Federal Governments from 1983 to 1996 (Kelly 1992, 2009). Arguably the origins of Australia’s modern knowledge economy can be traced back further to the expansion of the university sector post World War II (WWII) under the Menzies Government (1949-1966) and then later under the Whitlam Government (1972-1975).

same period to less than 10 per cent by 2012 (RBA 2012). There were similar reductions in the relative share of jobs in the other 'industrial' sectors such as gas, electricity and water (Lewis 2004). With the extent of economic change, Australian cities provide useful examples for understanding opportunities and hurdles for would-be successful knowledge-intensive cities.

The knowledge economy, it is argued, requires an increase in the "knowledge intensity of capital, labour, products and services, particularly knowledge based services" (Lewis 2004, p.7). The changes to the Australian labour market arose from developments Lewis (2004) referred to as the 'new' or 'global knowledge economy'. Lewis (2004) contended that these changes emerged from two forces: the growth in technology; and the subsequent knowledge intensity of economic activities, including knowledge-intensive goods and services, and the globalisation of economic activity. Research from Lewis (2004), Spiller (2005) and Shah and Burke (2006), Esposto (2010), Department of Employment (2014) have all found clear evidence for an increase in knowledge intensity within the Australian labour market. This research found an on-going transformation of the Australian labour market with increasing knowledge intensification, skills deepening, and the proportion of people with qualifications over and above employment growth.

The knowledge-intensive economy has also been seen as part of a network model of innovation, dependent on the advanced business service sector from the likes of lawyers, business planners, design scientists and engineers and research institutes "*where the services in question require the application of significant intellectual effort or capital*" (Spiller 2005, p.1). Increasingly, these services are knowledge services which have a tendency to concentrate into relatively few cities, clustering within the core or centres of these cities (Spiller 2003, 2005, SGS 2012a). The economic function of centres and cities can be considered in terms of their trading or export-earning function.

Spiller (2005) argued that global or regional competitiveness is the only sustainable long-term source of new income for a regional community. Cities effectively need to earn more than they consume (a simple truth that ultimately applies to people and nations). Moretti (2012) classed economic functions within a city as being tradable or non-tradable (usually understood as tradable and non-tradable industries at the national level)³. The tradable industries relate to external markets, whether this is external to the city or the nation. A key

³ The tradable sector of a country's economy is made up of the industry sectors whose output, in terms of goods or services, are traded internationally, or could be traded internationally given a plausible variation in relative prices. Non-tradable goods or services are consumed in the economy in which they are produced, they are not exported or imported (ABS 1996b). The tradable sector of the economy has also been defined as being the sector of the economy that is subject to international competition. The non-tradable industries: industries where the majority of the output faces no international competition (Attewell & Crossan 2013).

aspect of the tradable economy, and in particular the innovation sector, is its strong multiplier effect on job creation. Every time a new job is created in the traded sector by a new business in a city or local economy, additional jobs are created in the local service sector (Moretti 2010). While the tradable industry sectors employ only a minority of workers, their effects on local employment are much larger. The multiplier effect is particularly large for jobs with high levels of human capital and for high-technology industries (Moretti 2010, Moretti & Thulin 2013). This is true across different economies and various labour markets; either flexible labour markets such as the United States of America (USA) or less flexible markets such as Sweden (Moretti & Thulin 2013). Moretti (2010, 2012) also noted that while industries such as retail⁴ have always had relatively low multiplier effects, the traditional industries with previously strong multiplier effect, such as manufacturing, have decreased in their multiplier effect.

The importance of service industries to the non-tradable sector has increased over the period considered, partly due to the increased output of the business services industry⁵. Bishop, Kent, Plumb & Rayner (2013) noted that the tradable economy has been, with the recent commodities boom, dominated by the resources sector (to the detriment of other parts of the tradable economy, particularly manufacturing). The understanding as to what economic activities the resources sector consist of has also developed. Rayner & Bishop (2013) argue that the tradable resources sector includes, in addition to resource extraction, resource-related activity. This resource-related activity included activities less obviously connected to resource extraction, such as engineering and other professional services (legal and accounting work) (see also Martinez-Fernandez 2010, Tedeco & Haseltine 2010).⁶

Notably, three of the service sector industries (health, education and retail) that were considered as part of the non-tradable sector now also operate in the tradable economy (see ABS 1996b)⁷. Education services as a tradable industry is notable in that, since 1990, it has shifted from being considered as part of the non-tradable economy to a key part of Australia's tradable economy, and there is now wide recognition of the significant growth in international education services (DFAT 2005, Lim & Saner 2011, Nyahoho 2011).

⁴ Exception being where retail and entertainment is part of a tourism precinct or industry such as with Las Vegas (Moretti 2012, p56).

⁵ Interesting the ABS (1996b), in what they indicated was experimental research of the (national) tradable economy; found that the tradable sector in Australia in the period from 1974 to 1990 consisted largely of resources and manufacturing industry sectors, while the non-tradable sector was dominated by the services sector, including health, education, retail and construction.

⁶ The blending of industrial sectors is not unique to mining and services, for example, the overlap between manufacturing and design services.

⁷ Nyahoho (2011) has argued that the internationalisation of education services can be linked to the internationalisation of trade arising from the 1994 conclusion of the 'Uruguay Round' on the General Agreement on Tariffs and Trade (GATT) which was notable for opening up trade in areas once considered domestic including in education and healthcare.

In 2013, international education activity contributed \$15.6 billion in export income to the Australian economy (Australian Education International, 2014).⁸

Bishop et al. (2013) forecast a time when demand for commodities in Asia would ease with the shift from consumption of goods towards services. This, they predicted, might impact negatively on Australia's tradable resource commodity industries, while the impact on Australian service industries – such as education, tourism, business and financial services – may be positive. Bishop et al. (2013) saw the potential benefit for an Australian tradable services sector, in part because of Australia's closeness to the Asian region relative to most advanced economies, and because of the well-developed and relatively open services sector. The dominance of resource commodities in Australia's economy somewhat obscures the transformation that Moretti (2012) identified in the USA – of the tradable economy moving from manufacturing to innovation services. In Australia, as identified by Martinez-Fernandez (2010) and Tedeco and Haseltine (2010), the productivity of the resources sector is underpinned by knowledge and technology service companies.

Notably the tradable industries, being the innovative and high-technology industries with higher level of human capital and strong multiplier effects, benefit from agglomeration and urban density (Spiller 2003, 2005; Knudsen et al. 2008; Rosenthal & Strange 2008; SGS 2008; Burger et al. 2009; Glaeser & Resseger 2010; Hu 2010; Abel et al. 2012). This is also evidenced in Perth with the spatial concentration of resource sector head offices and knowledge support services clustered in and around the CBD (Department of Planning, 2009; City of Perth, 2010a; Martinez-Fernandez, 2010; BITRE, 2012). Therefore high levels of human capital can be seen as essential for urban centres, enabling a range of innovative, high-technology industries.

In recent years, Australia's Federal Government has, from time to time, noted, in a number of key policy areas, that Australia's long term productivity, global competitiveness and improved social wellbeing relies heavily on both the productivity of its cities (including its urban transport systems) and the nation's capacity to engage in the global digital and knowledge economy (Cutler 2008, Bradley Review into Higher Education 2008, Infrastructure Australia 2009, Department of Broadband, Communications & Digital Economy 2009, Department of Treasury 2015). Infrastructure Australia (2009) has noted that Australia relies on its cities for national prosperity and that "our cities are hubs of economic activity that link Australia to the global economy". However, it was not until

⁸ Lim and Saner (2011) noted not only the significant growth in international services that has occurred, but in particular, the collective dominance of USA, United Kingdom and Australia in attracting 50 per cent of all students studying abroad.

2011 when the Federal Government's Major Cities Unit released the "Our Cities and Our Future Report -the National Urban Policy" (DIT 2011) that the Government sought to establish its first long-term national planning policy framework for Australian cities. The report noted that three-quarters of Australians live in just 18 major cities with populations over 100,000. These major cities generate around 80 per cent of Australia's gross domestic product and employ 75 per cent of the national workforce. Critically, it noted that Australian cities:

...are centres of economic activity where labour, industry and social institutions are concentrated. How efficiently our cities connect people, knowledge, businesses and markets—and how effectively our economic and human capital is utilised—directly impacts upon the economic performance of our urban and regional areas and their ability to contribute to national productivity growth (DIT 2011, p. 7).

The report stated that the then Australian Government's goal was to harness the productivity of Australia's people and industry, by better managing our use of labour, creativity and knowledge, land and infrastructure (DIT 2011). It also noted the benefits that accrued from agglomeration, including the greater opportunities for innovation, the sharing of knowledge and services, and more specialised labour markets. The report saw that the maximising of the economic agglomeration potential would occur with the (re)development of Australian cities. The Productivity Commission (2011, p.14) similarly noted that good planning can create the environment for efficient and effective cities, with land use planning being "essential to maintaining or improving the functioning of cities". However the Federal Government's interest in the economic role of cities and their planning has waxed and waned (and waxed again).⁹

Part of the lack of consistency in Federal Government interest in cities and land use planning is the strong role that Australia's state and territory governments have traditionally played. By 2009-10, all jurisdictions, except Tasmania and the Northern Territory, had capital city metropolitan strategic spatial plans, which set out state planning policy, defined land uses, and guided local government planning and development (Productivity Commission 2011).¹⁰ A key purpose of these strategic metropolitan plans was to manage

⁹ In September 2013 the Federal Government closed the Major Cities Unit (Planning Institute of Australia 2013). In the Federal Government's 2015 Intergenerational Report on Australia's future productivity despite a theme of innovation there was no discussions as to importance of cities for productivity, no mention of agglomeration or knowledge economy although digital economy opportunities were noted (Department of Treasury 2015). With the change in Australia's Prime Minister in September 2015 cities and public transport became matters of Federal interest again with the appointment of a Minister for Cities and Built Environment (Planning Institute of Australia 2015).

¹⁰ Perth's plan being *Directions 2031*, with a draft implementation strategy for the regional plan being, *Perth and Peel @ 3.5 million*. The previous regional plan was *Network City*; Melbourne being *Plan Melbourne – formerly Melbourne 2030*, Sydney - *City of Cities* and Brisbane's *South East Queensland Regional Plan (SEQRP)*; Adelaide being *The 30-year plan for Adelaide*

major change in the urban structure of metropolitan cities (Gleeson et al. 2004, Forster 2006, Dodson 2008, Bunker 2009, Davis 2016).¹¹ The nature of Australia's metropolitan regional planning schemes has, since the turn of the 21st century, focused not on economic outcomes of agglomeration and knowledge intensity, but on a broader concept of sustainability, with a particular focus on constraining metropolitan expansion with long-term or very long-term aspirational 'compact city' plans. With increasing population growth, mixed-use poly-centric activity, integration with transport planning and increased urban densities have all been key planning strategies of the compact city planning approach (Gleeson et al. 2004, Forster 2006, Black & Doust 2008, Dodson 2008, Bunker 2009, Holz & Kane 2015, Davis 2016).¹² These turn of the 21st century metropolitan planning strategies, based on neatly structured suburban development organised around centres and self-containment, have been described by Forster (2006) as inflexible and an over-neat vision for the future that, however well-intended, were inconsistent with increasing geographical complexity¹³ that emerged in Australian cities from the early 1990s. Now in the second decade of the 21st century, there is a lack of resolution as to the planning of Australian cities. Yigitcanlar and Martinez-Fernandez (2010) and Yigitcanlar (2014) have argued that modern planning doctrines have meant that the planning system has demonstrated an incapability to deal with 21st century socio-spatial changes. The drivers for the (assumed) economic and population growth have largely not been explored (except in the metropolitan planning schemes of *Sydney Cities of Cities 2005*, and more so recently with *Plan Melbourne 2014*, where knowledge intensification is recognised as a key driver, and to a lesser degree in *Perth and Peel @ 2031*). This could be said to make good policy, as it avoids economic faddism and industry favouritism. However, an understanding of the wider historic context of what is underpinning long term economic development could be argued to be essential.

Neither is the relationship between transport and knowledge economy intensification broadly understood in planning policy or action. In USA and Australian cities in the last decade, there has been a notably consistent decline in vehicle kilometres travelled (VKT) with a corresponding increase in public transport use and urban density, particularly around the

¹¹ Worldwide modern cities can be considered or understood by including their surrounding metropolitan area with both the number and populations of large metropolitan regions worldwide having increased dramatically during the last century (Heywood 2006). However these metropolitan regions, according to Heywood (2006) have not only failed to manage their own problems of growth, congestion, pollution and conflict, but also exert increasing dominance over the economic and political lives of the surrounding regions and nations.

¹² The focus on addressing population growth is not surprising. The Productivity Commission (2011) noted in examining the nation's planning system, Australia's population is projected to grow from over 22 million in 2011 to between 30.9 million and 42.5 million in 2056 (or according to the ABS's (2013b) projections, to increase to between 36.8 million and 48.3 million in 2061). The ABS (2013b) estimate that over 70 per cent of the forward population growth will be in Australia's capital cities with Perth and Brisbane having their population projected (under the ABS medium growth scenario) to more than double between 2006 and 2056.

¹³ Complexities arise from the interplay of issues such as increasing labour market diversification and specialisation, transport sustainability, centres and self-containment policies, housing unaffordability and land constraints, and how they should influence urban structure.

central urban cores. These intensification changes in urban structure and transport have occurred while the economy and labour markets have also (knowledge) intensified.

Therefore the primary question of this thesis is as follows:

If the nature of the urban economy has changed (and continues to change) towards knowledge-intensive activities, what are the appropriate urban and transport structures for post-industrial cities such as metropolitan Perth?

These questions form a key part of the thesis research as they provide the means of testing the knowledge intensification of Perth. This thesis argues that post-industrial cities are driven, and increasingly so, by an intensification of knowledge across multiple layers. This multi-layered theory of intensification of knowledge proposes that, in metropolitan cities, an increase in human knowledge capital and improved connectivity relative to a fixed population and metropolitan spatial size will result in an increase in knowledge economic activity. Therefore, economic agglomeration outputs are increased not necessarily by increasing population density or population scale alone, but also through increases in human capital of the given population and their level and speed of interconnectivity through communication and transport. Knowledge intensification, particularly as it relates to modern knowledge economic activity, should also be understood in the context of time intensification or social acceleration (see Rosa 2013). Rosa (2013) has argued that modern society is experiencing an economic, social and personal-time intensification or acceleration; effectively, a change in the tempo of modern human existence.¹⁴

The intensification proposes that where the spatial size of a metropolitan area grows unnecessarily, it will weaken the intensification, requiring an increase in human knowledge capital and/or improved connectivity. Essentially, urban sprawl, all other factors being unchanged, means lower knowledge intensification.

The more knowledge-intense cities therefore will be identified by a number of layers of intensification:

1. intensification or agglomeration of knowledge economic activity,
2. intensification of knowledge within human capital knowledge, i.e. increasing levels of knowledge within individual workers and their jobs and where those workers work and reside, and

¹⁴ Rosa (2013) identifies three types of intensification in time or changes in the tempo of modern social life: technological acceleration (transportation, communication, and economic production); social change (cultural knowledge, social institutions, and personal relationships); and acceleration in the pace of life for the individual (despite the expectation that technological change should increase an individual's free time).

3. intensification of the means of knowledge exchange, i.e. both within ICT and transport devices, systems and infrastructure (technological intensification), and with the spatial urban concentration or intensification of ICT and transport infrastructure and usage.

What is the use of the multi-layered theory of knowledge intensification? Can it add anything to thinking about city planning and design? This thesis argues that the benefit of knowledge intensification is that it creates or adds to the understanding of the economics of knowledge within a defined urban area and the relationship between the city population, size, density and stock of human knowledge, and the connectivity/ transport within that defined area. For example, it raises the understanding that an urban transport system in a post-industrial city is in fact transporting human capital more so than human labour and this can change the evaluation of public transport infrastructure projects. It further provides lenses through which to consider different modes of transport and how they could facilitate more spatially intensive concentrations of human capital and knowledge economic activity. It should lead to different approaches to how post-industrial, knowledge-intensive cities and their transport infrastructure are managed and planned compared to industrial or consumption-based cities.

To assist in answering the primary question, a series of preliminary secondary questions in respect to Perth, relating to these three elements of knowledge intensification (with transport as a means of connectivity addressed separately in the primary question), are proposed and addressed. These secondary -questions are as follow:

1. *Is knowledge economic activity intensifying in Perth, both in terms of an increase in knowledge-intensive industries and their spatial distribution?*
2. *Is human knowledge capital intensifying in Perth both in terms of the labour market knowledge capacity and in terms of the spatial distribution?*
3. *Is ICT knowledge intensification occurring in Perth, both in terms of the spatial distribution infrastructure and ICT enabled businesses?*

These questions form a key part of the thesis research, as they provide the means of testing the hypothesis that knowledge intensification is increasing in Perth. These secondary questions also go more broadly to the heart of the changing nature of the Australian economy. Fundamentally, the economy is increasingly driven by knowledge-intensive human capital and advancing technology in growing urban cities. This means economic and employment growth are increasingly linked to greater levels of agglomeration, but are our cities well managed or planned to facilitate greater levels of agglomeration? As per the

second law of thermodynamics (see Davis & Masten 2004) any system or machine which is creating an energy outcome suffers entropy. Similarly, cities seeking to achieve agglomeration benefits from intensification or densification can also experience some levels of dis-agglomeration. There are energy and urban dis-benefits or dis-agglomerations from intensification. Typically they are road congestion, housing unaffordability (as the real estate market 'heats up' near areas of high employment), or even the heat and energy costs expended by data centres' cooling servers with ICT systems – means knowledge intensification ultimately is about the good management or otherwise of cities. It raises the question: If we are seeing dis-benefits with density, then do we require a different system of management or infrastructure to lessen the entropy and instead deliver the beneficial agglomeration?

As Prud'homme and Lee (1999, p. 2) put it:

not all cities are equally well managed. Tokyo, the largest world city, is probably not too large, because it is reasonably well managed' There are other cities of the world, cities of 200,000 people which are definitely too large, because they are very poorly managed.

1.2 The structure of this thesis

Part A proposes a theory of knowledge intensification and its relevance to answering the primary question as to what is the appropriate urban structure and transport strategy for post-industrial cities with a potentially knowledge-intensive economy.

Part B provides a *Context Literature Review* of the theories of knowledge, how knowledge is transferred and the nature of the knowledge in the modern 21st century economy.

Part C considers the evidence of knowledge intensification worldwide and then primary and secondary research is undertaken to answer secondary questions 1, 2 and 3 as to whether knowledge intensification is also occurring in Perth, WA.

Part D addresses, through the different urban development scales (including the national, metropolitan and the urban centre), the spatial planning issues for knowledge-intensive cities. Part D then seeks to answer the primary question in terms of the appropriate urban structure for a knowledge-intensive Perth, with an alternative urban structure to the present statutory plan proposed for a knowledge-intensive Perth.

Part E addresses the appropriate urban transport strategy for knowledge-intensive cities. Modes of urban transport and their spatial characteristics are considered. Part E then seeks to answer the primary question as to the appropriate urban transport structure for a knowledge-intensive Perth, based on the preferred urban structure for Perth, as determined by Part D of this thesis.

Part F is the conclusion of this thesis, and where the answers to the questions are summarised.

Part B: Context literature review

Part B reviews the theories of knowledge, how knowledge is transferred and the nature of the knowledge in the modern 21st century economy.

“Fields and trees are not willing to teach me anything; but this can be effected by men residing in the city”

– Plato, Works (vol. III, The Phaedrus) 427-347BC

“Towered cities please us then, And the busy hum of men.”

– John Milton, L'Allegro 1645

Chapter 2 – Literature review on theories of knowledge and the knowledge economy

2.1 The knowledge economy - Understanding theories of knowledge

In trying to understand the knowledge economy and its spatial context, it is worth stepping back to consider the question: What is knowledge? Mankiw (1995) has defined ‘knowledge’ as the sum total of technological and scientific discoveries (what is written in textbooks, scholarly journals, websites, and the like). Knowledge has also been understood by its location – human (as in the human knowledge capital of individuals), organisational (the institutional knowledge capital of organisations held in databases, manuals, systems and patents) and social (the social capital knowledge embedded, accessed, and used by interactions amongst individuals through their networks) (Smith, Courvisanos, Tuck & McEachern 2011).

Importantly, the various locations of knowledge mean that the accumulation and distribution of knowledge differs as does the investment needed to facilitate the knowledge accumulation and distribution (Smith et al. 2011). In labour economics, knowledge is often understood in terms of ‘human capital’. Mankiw (1995) defined human capital as the stock of knowledge that has been transmitted from those sources into human brains via study. This definition is somewhat limited as knowledge can be developed through creative processes of the human brain (and not just learned) and then transferred into formal knowledge. Morone and Taylor (2004) argue that human capital creation can be seen as two separate processes – individual learning through traditional school or training and interactive learning which is everyday interactions be they at work or elsewhere.

Another way of understanding knowledge is to see it as codified or tacit. Codified knowledge is knowledge that is formalised, turned into data through operating manuals, blueprints, or

patents. Polanyi (1966) defined codified knowledge (or explicit knowledge as he referred to it), as knowledge transmitted using orderly formal languages, whereas tacit knowledge can be seen as knowledge that cannot be articulated by people. Similarly, Morgan (2004) proposed that tacit knowledge is personal and context dependent and therefore difficult to communicate other than through personal interaction in a context of shared experience. Polanyi (1966) saw tacit knowledge as personalised and defined it, as knowledge that indwells in a comprehensive cognisance of the human mind and body. Similarly, Fallah and Ibrahim (2004) saw tacit knowledge as embedded in the individual or group of individuals.

Tacit knowledge, as un-accessed knowledge, has been further categorised into socio-cultural (dispersed, never totally given), semantic (embedded into communities within language or practices) and non-epistle (inarticulated, the results of implicit learnings and what cannot be expressed by an individual) (Castillo 2002, Fallah & Ibrahim 2004). However, Morgan (2004) noted that it is generally accepted that tacit and codified knowledge are actually part of a continuum, with the real issue being the cost of conversion or codification. That is, when the pace and cost allow, knowledge is able to be standardised, valued and codified. However, when knowledge change is fast paced, then practical brain-held tacit knowledge, often acquired sub-consciously, becomes more critical. Tacit and codified knowledge can therefore be seen, when it comes to both creation and use, complementary (Johnson, Lorenz and Lundvall 2002). This duality in understanding knowledge is a key element for understanding the way knowledge impacts on the modern knowledge economy. In a fast moving, ICT enabled, efficiency focused economy where large amounts of complex data and knowledge are transferred quickly, tacit knowledge increases in importance.

2.2 Knowledge transfer

The transfer or spillover of knowledge is one of the key elements in the theory of agglomeration economics. Agglomeration theory, originally developed by Marshall (1920) provides for advantages arising out of companies and organisations clustering around geographic locations, i.e. cities or regions. Three advantages are provided: first, access to a relatively large skilled labour pool; second, economies of scale, in terms of access to, and availability of, resources, materials and inputs including services; and third, intensification of knowledge exchange between people, firms and institutions within close geographic proximity (Fallah & Ibrahim 2004). While agglomeration provides economic productivity, it is knowledge spillover that has been shown by a range of researchers and economists to provide innovation benefits (Fallah & Ibrahim 2004). Therefore, how knowledge transfer occurs and how the transfer can be positively influenced is an important economic and

planning issue. As spaces and places are key influences on knowledge transfer, spatial planning therefore has a critical role in enabling knowledge economy outcomes.

Knowledge transfer can happen in various spaces and places, be it two individuals in conversation, or formal or informal group situations such as meetings. The transfer can take place within workplaces, social situations and/or in institutional learning settings; again informal or formal. Evers, Gerke and Menkhoff (2010) argue that knowledge-based work needs teamwork and the existence of communities of practice, frequent social interaction and capacity building by direct face-to-face learning. Morone and Taylor (2004) noted that knowledge transfer can be positive as well as negative, particularly as it relates to social knowledge. Fallah and Ibrahim (2004) noted that knowledge transfer can be intentional and unintentional, arguing that the more knowledge is codified, the easier it is to transfer, while tacit knowledge is less easily transferred. Morgan (2004) argued that this tacit knowledge conversation is a difficult and demanding organisational exercise and places a huge demand on entire workforces, with large firms facing enormous problems creating and sustaining a 'shared language' throughout an organisation. Withholding knowledge within organisations is also problematic, as innovation and knowledge can leak out or spillover to other firms. Smaller firms without the same extent of formal R&D investments are often as innovative as larger firms (Smith 2000). One argument is that they are benefiting from unintended knowledge spillover within their firms or their industries (Fallah & Ibrahim 2004, Smith 2000). Nimbler, smaller organisations undertake informal R&D with the internal knowledge conversation being more effective because of higher levels of personal interaction among employees or industry participants (though often within smaller talent pools).

The value of tacit knowledge transfer is often in the conversion to codified knowledge. The conversion of tacit to codified knowledge is, however, often difficult and creates challenges for organisations (Evers et al. 2010). The importance of tacit knowledge, Lundvall, Johnson and Lorenz (2002) argue, is that it is often required to unlock or maximise the benefits of codified knowledge. The more explicit or codified knowledge is, Fallah and Ibrahim (2004) argue, the easier it is to communicate, meaning that well-codified knowledge can be understood away from its origin, thus allowing it to be more easily transferred over longer distances and maintained over a period of time. However, tacit knowledge transfer is more complex and where it is socio-cultural and semantic, for example, it is best transferred through absorption provided by shared experience (Fallah & Ibrahim 2004).

2.3 The spatial context of knowledge spillover

The transfer of tacit knowledge to codified knowledge within the Japanese corporate experience, according to Nonaka and Takeuchi (1995), is about the 'knowledge conversation', where tacit knowledge continues to be made more accessible through an intensely iterative spiral-like process of collective learning (see also Morgan 2004). This knowledge conversation has a people relationship context, with Nonaka and Konno (1998) adapting Kitaro Nishida's concept of 'Ba' (being the shared mental space for relationship interaction) to understand the mental space required for the creation of knowledge. Ba recognises it is the interaction of people that creates knowledge, and the spaces, places and technologies that best deliver human interaction will provide the most fertile ground for creation of knowledge.¹⁵ Tacit knowledge sharing space can be either a physical space enabling close physical communication or cyber place through electronic means. Nonaka and Takeuchi (1995) argue that because of the personal nature of knowledge sharing, the most powerful learning comes from face-to-face communication and from the use of the body rather than the mind. This supports the contention that while information communication technology can be seen as a key technological conduit for information transfer, physical human interaction is superior for the creation and transfer of tacit knowledge.

Successful places and place-making provide knowledge workers with day-to-day close encounters, and engagements in few, bounded communities of practice (Undheim 2002). This is important when considering the role of knowledge spillover in denser urban agglomerations. The place and personal focus of tacit knowledge exchange means it is referred to as being 'sticky' at the geographical urban scale – that is, supporting the building of relationships between people and organisations. Storper and Venables (2004) contend that there is a broad advantage to 'stickiness' and relevance of face-to-face contact, with quality contact being a non-substitutable means by which potential partners in knowledge or creative projects:

- overcome coordination problems
- minimise risk
- screen potential partners
- form cooperative groups
- provide for informal and intensified communication.

A key factor in tacit knowledge exchange (if not all knowledge exchange) is trust. The building of trust through direct face-to-face relationships expedites organisational learning,

¹⁵ The concept of 'ba' as knowledge sharing space has largely been understood in the organisational sense, however public and civic spaces equally provide opportunities to facilitate knowledge creation and exchange.

especially where reciprocity or further relationship activity is expected (Morgan 2004). Evers et al. (2010) note that a fair number of relevant studies have provided empirical evidence that proximity and face-to-face interaction indeed facilitate the transfer of tacit knowledge. Evers et al. (2010) argue this is because knowledge production is a social process that requires interaction, and while it may take place to a certain extent in cyberspace, innovation and discovery are also driven by emotions, fun and anger, excitement and frustration, which are best projected at persons in direct interaction. Castells (2005) has contended that, despite the increasing prevalence in communication happening in the global electronic space, people still assert a local culture and seek experiences in their localities. In this sense, tacit knowledge has strong tendencies towards the private and interpersonal.

The importance of urban spaces and places for knowledge transfer and the modern knowledge economy can be understood by considering the impact of the intensification of the human experience that occurs in cities. Simmel (1903) argued in his classic, *The Metropolis and Mental Life*, that the urban agglomeration of city life fundamentally intensifies the individual human experiences and changes the way individuals think and act. Metropolitan or urban living impacts the individual through an intensification of stimulation, which contrasts with more sedate rural existence. The intensification of metropolitan life not only provides heightened awareness and intellectual stimuli but, as a result, also requires a more rational, calculating and discriminating approach to life (as distinct from the more emotional and feeling-based relationship approach to rural existence).

Notably, for knowledge exchange (and its role in knowledge economic activity), Simmel (1903) argued that the metropolis, with its multiplicity and concentration of economic exchange, heightens the importance of the means of exchange, particularly with money. The money economy and the dominance of, and increase in the intellect or knowledge are, Simmel (1903) argued, intrinsically connected in urban existence. The modern metropolis, being both economically driven and intensely (and overwhelmingly) stimulating for individuals, sees an increasingly rational and calculating approach to all matters. This is partly driven by increased anonymity inherent with population scale, meaning that each party acquires “an unmerciful matter-of-factness” with the “intellectually calculating economic egoisms of both parties” being less impeded by personal relationships, which totally dominate rural existence (Simmel 1903, p.12). What this means is that urban existence has led to, or required, an increased need for calculability, punctuality and exactness when receiving stimuli or assessing new knowledge.

This is consistent with the work of urban psychologists, who have argued that human interaction in denser urban environments brings people together in closer interaction. This means other people become a more important stimulus (Freedman 1971, 1975). This is particularly true for creativity (Kristensen 2004) and for friendships and relationships where distance causes lapsing, unless relationships are rewarding enough to compensate for the spatial cost of their maintenance (Lee 1971).

The mechanics of linguistic change similarly provide a means of understanding the face-to-face nature of tacit knowledge exchange and the importance of dense urban environments. Physical environments, such as urban density, increase the amount of face-to-face interaction, which has an impact on linguistic change of local dialects and language (Bloomfield 1933, Labov 2001, Labov, Rosenfelder & Fruehwald 2013). Bloomfield (1933) saw that linguistically intense local differentiation was related to density because every speaker was constantly adapting their speech-habits to those of their interlocutors. Bloomfield's principle of density was based on interactional frequency, meaning that increased spatial density led to a higher likelihood of interaction. The frequency of interaction created a convergence of language. This is an important consideration for tacit knowledge exchange – a convergence towards 'shared language' aids trust and understanding and therefore knowledge exchange.

Lundvall and colleagues (2002) argued that the nature of the modern economy is fundamentally a learning economy, where innovation is increasingly dependent on complex, valuable tacit knowledge that is embedded in the individual, the firm, a network or a local context. Similarly Lucas (1988) emphasised that human capital accumulation is a social activity, involving groups of people in a way that has no counterpart in the accumulation of physical capital. This also means that human capital often exists as tacit knowledge within individual knowledge workers. This understanding – that the best mental relationship spaces for knowledge exchange are related to geographically close physical spaces – helps explain why information and communication technology is not leading to the end of the need for people to physically come together in urban spaces.

The role of tacit knowledge in knowledge economic development can be understood by seeing tacit knowledge as being held within the human brain, largely different from codified knowledge, which has now largely been uplifted in ICT systems. The locale of tacit knowledge in this sense has not changed over time and the human-held tacit knowledge continues to be effective in the modern new economy. Evers et al. (2010) argued that tacit knowledge is a major factor in the emergence of knowledge clusters. Amin

and Cohendet (2003, 2005) argue that tacit knowledge, or relational knowledge, is also important in maintaining links at distance, particularly between technopoles. However, there are strong arguments for concluding that tacit knowledge is more localised than codified knowledge, which is more immune to distance. The more important tacit knowledge is for production, the more localised production is likely to be. Again, this is to emphasise the links between knowledge accumulation, both at a firm or industry level and individual level, and the spillover effect through spatial location. Duranton and Puga (2003) make the point that, spatially, cities make it easier to find inputs (be it workers, intermediate goods, etc.) and customers, to experiment, and to discover new possibilities. Cities are likely therefore to be more important in uncertain and fast-changing economic environments.

Not all accept the primacy of local spatial impact on tacit knowledge. Amin and Cohendet (2003) have argued that knowledge is not fixed to particular sites and while it may have a spatial context, it is not related to a locally confined natural geographic advantage. The spatial context from the unique interactions and combinations of bodies, minds, speech technologies and objects crystallised in a set of local practices. It is the sense that tacit knowledge and relationships can be stretched and in some respects adapted in other places. The role of virtual clusters and ICT to replicate place with visual contact, mood and atmosphere is seen as attempts to address the benefits of local interaction. The local advantage is not seen as being spatially confined, and knowledge can be circulated and diversified by travel and ICT. Amin and Cohendet (2003) did not downplay the salience of local geographies in supporting economic dynamism and knowledge formation, but argue that the relationship between space and economy is always variegated, based on the simultaneous mobilisation of geography. Further Amin and Cohendet (2005) did not suggest that the nature and quality of near and distance relational links are the same. They argued that both local space and virtual global circuit are both interactive spaces conceived as circuits supporting relationally based knowledge. They concluded that while both spaces are important, the differences between local and trans-local may be an artefact of the nature and architecture of organisation rather than the qualitative differences in the nature of learning processes within each space.

A number of studies show that, in specific contexts, distance is not necessarily a relevant factor in knowledge-related activities. Ponds, van Oort and Frenken (2007) in an analysis of knowledge spillover with collaborative university-industry science-based research, found that academic spillover occurs through geographically localised mechanisms and with collaborative research over distance, with levels of distance being addressed with varying spillover mechanisms. Chudoba, Wynn, Lu and Watson-Manheim (2005), in a study of Intel Corporation of virtual work groups – where discontinuities of geography, time zones,

culture, work practices, organisation, and technology where sought to be addressed – found that Intel had achieved virtual workplaces. Distance, itself, was not found to be a factor that impaired virtual collaboration and the effectiveness of a range of efficiency criteria. Chudoba et al. (2005) noted that many other similar studies found distance to be a significant hurdle to effective team communication, coordination and productivity. Physical and cultural factors were found to negate the argument that distance relationships can be developed to the equal of face-to-face relationships. Time separation and the number of time zones were found to have a negative impact on the coordination costs. While coordination efforts can resolve some issues, problems arise as more internal boundaries become present in a team (e.g. distance, time zones, culture, language), the benefits of coordination mechanisms and processes narrows, and the effort and delay incurred expand (Espinosa & Pickering 2006, Espinosa, Cummings & Pickering 2012).

The successfulness of virtuality in the Intel study in this sense has some limitations. It was within a single high-technology company, where considerable effort was made to adapt to remote work environments including having dispersed teams (where even geographically close teams relied on virtual conferencing technologies rather than using face-to-face). While the Intel study highlights an example of how distance can be removed in particular circumstances, not all knowledge transfer happens intra-organisationally within formal controlled organisational contexts. Often, it is different teams within organisations, or inter-organisational or individual to individual in formal and informal situations. Aubert, Rivard, and Tempier's (2009) research into 12 offshore business organisational relationships found that, in addition to geographic and cultural distance, perceived distance (related to the actual geographic distance) had a negative influence on the amount of effort required to conduct the relationship. The arguments negating the effect of distance – and therefore the benefits of geographical closeness play in creating relational networks –are not strong beyond a few well-controlled environments.

Other distance work, such as telecommuting and nomadic workers including field sales staff, have identified problems with distance from co-workers resulting in social isolation (Baker, Avery & Crawford 2007, Marshall, Michaels & Mulki 2007, Mulki, Locander, Marshall, Harris & Hensel 2008, Fay & Kline 2011). Chidambaram and Tung (2005) identify work isolation, referring to it as the “immediacy gap”, as an environmental condition that can appear with distance. The negative impact of isolation can be contrasted with the positive impact of workplaces as social places. Chiaburu and Harrison (2008) in examining 160 primary studies found that social support of co-workers was important in making workplaces work for a broad pattern of employee outcomes. The intensity of modern professional

careers has arguably further exacerbated issues of isolation and the need for face-to-face interaction in the workplace.

The strong relevance of face-to-face interaction to tacit knowledge is arguably the result of the biological and neurological nature of human beings. Social competence has multiple components with foundations in brain and biological systems; however, the physiological basis is only recently being understood (Frith & Frith 2001). Varela (1992, p. 340) has contended that “at the very centre of this emerging view is the belief that the proper units of knowledge are primarily concrete, embodied, incorporated – lived.” This means that those experiences that maximise the stimuli of the body are going to have greater impact. Neurologist Hanna Damasio (1994) argued that the brain is inherently embodied; phylogenetically programmed to operate a feedback loop between sense and thought, the body proper and the cognitive brain (interrelationship between flesh and thought with both constantly changing shape from synaptic firings, biochemical reactions and biological interruptions). However, human consciousness is largely unaware of the complexity of this subconscious feedback process.

A difference between the ‘lived’ face-to-face interactions and at-distance interactions is supported by research on people’s perceptions of distant related events and people’s interactions. Henderson and Wakslak (2010), in reviewing research on how people’s level of abstract thinking was related to distance, found that distant events are represented in more abstract, higher-level terms or stereotypical terms even when concrete information about them is available and reliable. The studies reviewed by Henderson and Wakslak (2010) held several variables (e.g. familiarity, similarity) constant and/or included measures to verify that the effects still emerged when statistically controlling such variables. The more distance, the greater the likelihood that abstractly represented behaviour is attributed to traits over contextual factors, resulting in greater correspondence bias (Henderson et al. 2006). This meant people expected events in distant locations to more strongly resemble prototypical events, which are relatively schematic and abstract. It was also found that research participants who perceived less physical distance increasingly thought about those closer members as unique individuals rather than interchangeable constituents (Henderson & Wakslak 2010b). Further Henderson and Wakslak (2010b) extended this logic to the domain of priming (being the influence on impressions by other factors), reasoning that when individuals form judgments of a close target they saw the target in a more localised manner, judging the target as an individual about which they have no a priori opinion rather than as a member of a category about which they already have a general impression of a group.

The impact of this research would clearly suggest that contextual relationships where bonding between individuals is important or where knowledge and scientific work was reliant on unbiased accurate observation of context would be negatively impacted by distance. It would also be consistent with the proposition that tacit knowledge creation is physiologically better at face-to-face (not that all applications of all tacit knowledge was reliant on face-to-face relations or situations). The face-to-face – body-to-body experience could be argued therefore to be a richer more immersed sensory experience, with interaction experiences being extended, in depth, both formal and informal sensory experiences aural, tactile, oral, and visual experiences. This is not to say on-line interactions cannot be stimulating, but they are not as rich or as complex or as nuanced as face-to-face interactions.

Distance, does however, provide advantages in other situations. Jia, Hirt, and Karpen (2009) found that more abstract, higher-level representations facilitated creativity, in that portraying a task as originating from a far (vs. close) location increased creative responses and led to better performance on a problem-solving task requiring abstract creative insight. This would suggest that reviewing codified knowledge or the codification process may be better if undertaken at distance. Work or projects may be a combination of codified knowledge and tacit knowledge and the work may take place both face-to-face and at distance. Architecture, engineering or urban design would be an obvious example of this, where the deep understanding of the design brief and the local context may occur face-to-face but the application of the codified knowledge is able to be applied at distance. The relational context for the further use of tacit knowledge at distance is created by the original face-to-face relationship. The above analysis of the role neurological factors play in human activity strongly suggest that Amin and Cohendet's (2003, 2005) contentions on the limited importance of local and geographical space for tacit knowledge transfer cannot be fully accepted. Where Amin and Cohendet's (2003, 2005) contentions are arguably still relevant and useful is that it would be true to acknowledge that tacit knowledge is not limited or bounded spatially, despite its inherent localised strengths. It is not, however, the evening out of local and distance but that tacit knowledge can be applied or maintained at distance more so as an extension of local relationships. This duality will be further explored in the consideration of agglomeration and network theory.

In examining the metaphysical concept of knowledge, the key conclusion is that the exchange of knowledge, being the process for driving the creation of new knowledge, is inherently physical. Tacit knowledge, in the context of the knowledge economy, is best exchanged in physical places because the exchange is inherently a mind and body process. This means that tacit knowledge exchange is subject to distance decay even with the advancements of ICT. This will be addressed further in subsequent sections. The

fundamental role that tacit knowledge plays in the knowledge economy, and its 'stickiness' and need for personal face-to-face interaction means that places and cities are also fundamental to the knowledge economy. An examination of the knowledge economy is inherently therefore an examination of people within cities.

2.4 Knowledge in the modern economy

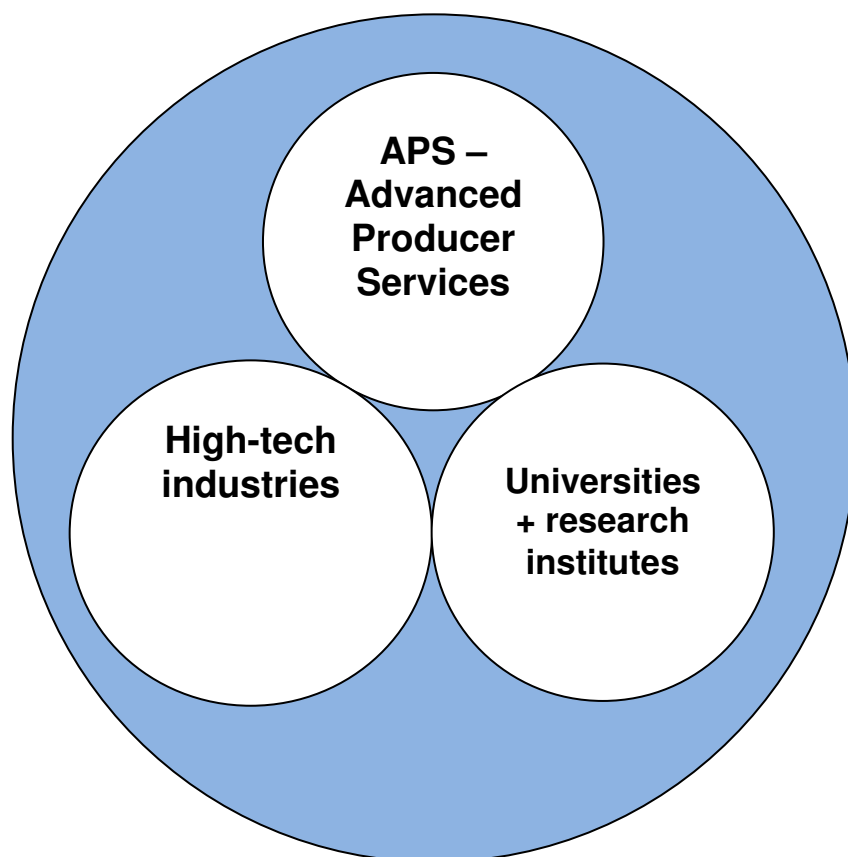
Knowledge, as embodied in human beings (as 'human capital') and in technology, has always been central to economic development (Kuznets 1971, Romer 1986, Lucas 1988, OECD 1996, Smith 2000, Mokyr 2002, 2005, OECD 2013). Knowledge development, such as demonstrated by the historical growth in literacy and formal education, has increased with levels of urbanisation, with literacy and education participation, and urbanisation increasing rapidly over the last 150 years (UNESCO 2006). Schleicher (2006) sees that there has, however been a fundamental shift in that the development of the modern knowledge economy reflects a transition from an economy more based on land, labour and financial capital to one where the main components of production are information and knowledge capital. In the OECD's (1996) seminal report, *The Knowledge-based economy*, it was concluded that economies were more strongly dependent on the production, distribution and use of knowledge than ever before with western industrialised economies now increasingly based on knowledge and information. According to the OECD (1996; 2013) knowledge had become the driver of productivity and economic growth, which led to a new focus on the role of information, technology and learning in economic performance. The term 'knowledge-based economy' stemmed from a fuller recognition of the place of knowledge and technology in modern OECD economies. It is also widely accepted in Australia and worldwide that modern economies, operating within increasingly global competitive markets, rely increasingly on innovation (Lewis 2004, Goebel, Thierstein & Luthi 2007, Montgomery 2007, Cutler 2008, Centre for International Economics 2009, Smith et al. 2011, OECD 2013, ATN 2015).

Innovation has been defined as the creative application of knowledge to increase the set of techniques and products commercially available in the economy (Courvianos, 2007). As the Cutler Report (2008, p.x), the Review of the National Innovation System, stated, "competing on innovation and knowledge is decisive to successful business performance for firms and to sustainable prosperity for nations". The process of innovation is preceded by the creation or redevelopment of new perspectives on existing ideas. Creativity is primarily understood as being an individual process and innovation as a group or organisational process to implement the creative idea (Smith et al. 2011). In this sense, creativity can be seen as

originating in tacit knowledge and transferring to codified knowledge through the innovation process to a final process or product. Knowledge is embedded in the entirety of the economic process for the development of new products and processes.

Conventz and Thierstein (2012) contend that, increasingly, Western economies are experiencing a shift from a natural resource production to a knowledge-based production, with knowledge being a key driver for innovation and economic growth. The knowledge-based economy has been defined by Goebel et al. (2007) as having a high proportion of research and development activities, a dependency on qualified workers and branches of activity linked to innovative processes and products. Central resources for these branches are information, knowledge and highly skilled people. Conventz and Thierstein (2012, p3), taking a German–western European perspective, identified that knowledge has become an integral part of those companies engaged in producer services and in advanced manufacturing, but also to firms in traditional industries. Thierstein, Kruse, Glanzmann, Gabi and Grillon (2006) and Conventz and Thierstein (2012) see the knowledge economy characterised by three important pillars: Advanced Producer Services (APS), high-tech industries, and knowledge-creating institutions such as universities and research establishments (see **Figure 1**).

Figure 1 **The three pillars of the Knowledge Economy** (Thierstein et al. 2006)



Smith (2000) has argued that many of the contentions about a distinct 'knowledge economy' are overblown and many so-called low-technology industries with low R&D spends are in fact highly advanced in terms of knowledge (and often have high knowledge spillover within their industries, which explains lack of formal company-led R&D). As Lucas (1988, p38) argued in his seminal text, Jacobs (1961, 1969) had rightly emphasised (and illustrated with hundreds of concrete examples) that much of economic life is 'creative' in the same way as 'art' and 'science' with "New York City's garment district, financial district, diamond district, advertising district and many more are as much intellectual centers as is Columbia or New York University". Smith (2000) and Carrillo et al. (2014) have similarly argued that knowledge has always been an element, an often significant element, in all forms of human society throughout human existence. That knowledge has always been a key component in economic activity is largely accepted and argued by economic historians such as Pred (1973, 1977, 1980) WD Smith (1984), Sharpin (1994) and Mokyr (2002, 2005).

Questioning the new knowledge based economy, Smith (2000) argued that knowledge accumulates over time, significantly changing the quality and quantity of outputs, but this does not mean society is entering a new form of society that is qualitatively different in terms of knowledge use. Simply knowledge, it is contended, has been and continues to be a core foundation of the economic process. However, Leamer and Storper (2001) have argued that a key part of the modern knowledge production process is the intellectual/immaterial activities which have greatly increased as a share of the value added, and are amenable to extremely fine and highly efficient divisions of labour that require more than a single firm to employ the range of specialists.¹⁶ This has led to outsourcing to specialist firms producing intellectual outputs (the advanced producer services as described by Thierstein et al. 2006 see also Fuente & Ciccone 2002, Gilli 2002, Spiller 2004, 2005, Goebel et al. 2007, Burger et al. 2009). Leamer and Storper (2001) see the geography of the Internet as being double edged, with tendencies towards specialisation and agglomeration with newer and complex products and transactions, while at the same time simplifying and codifying other services and products which allows for the dispersion of routine activities. This means more routine functions can be outsourced using communication technologies; however, complex and unfamiliar coordination of innovative activities require long-term relationships, closeness and agglomerations. This specialisation and increasingly fine division of labour is delivering the intensification of knowledge both in a spatial sense and a non-spatial immaterial sense (and creating demand for increasing knowledge intensity in employment, data intensity of ICT systems and infrastructure). The greater the specialisation, the greater the coordination required (Leamer & Storper 2001).

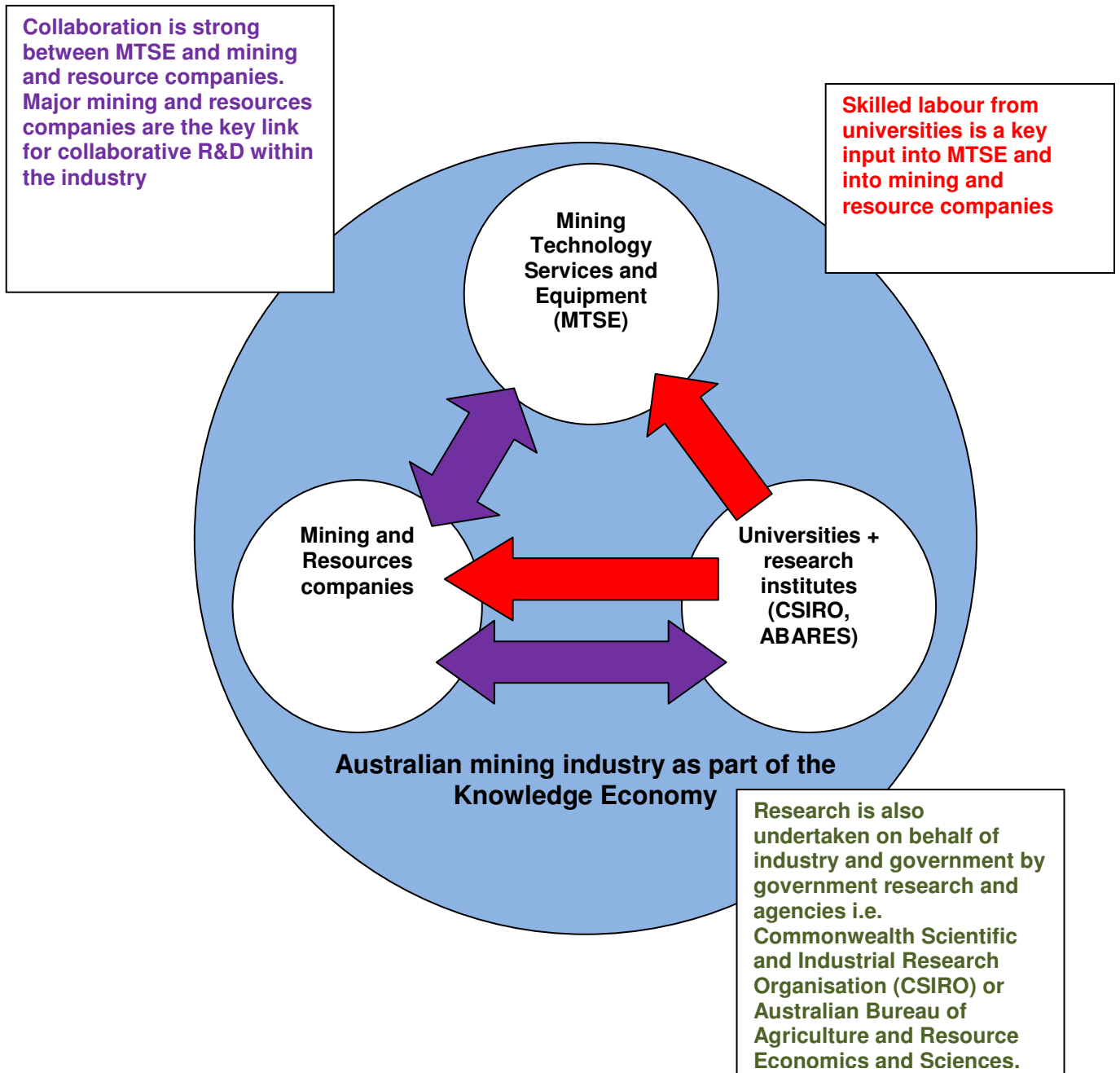
Changing economic environments obviously change and impact on traditional industries as much as they create new industries. Arguably, the 'high-tech' pillar of Thierstein et al. (2006) and Thierstein and Conventz (2012) can be substituted or interchanged, following the logic of Smith's (2000) argument that knowledge is embedded in and across many industries, by a number of productive traditional industries in the modern economy. The separatist view of traditional industries versus new knowledge industries in Australia was put by Houghton and Sheehan (2000) when they argued that the industrial economy relied on natural resources such as coal and iron ore and labour as the main resources. This they distinguished from the knowledge economy, where knowledge was the key resource, arguing that an economy built on knowledge is fundamentally different from one built on natural resources. This distinction between the old and new economy was however rejected even at the turn of the millennium, when the Hon. Mark Vaile (2000), then Australian Minister for Trade, argued that the old and new economies were not mutually exclusive and that the focus should be on the way in which ICT is helping to make 'old' industries like mining and

¹⁶ This is not to say Leamer and Storper (2001) argued that labour specialisation is new to the modern knowledge economy as they note specialisation appearing much earlier in economic history with the advent of industrialisation and cities but that the levels of specialisation have increased to a much finer level.

agriculture so efficient. Support for this argument, that knowledge is permeating all sectors of the Australian economy, comes from the Australian Bureau of Statistics (ABS 2002). The ABS (2002) identified that knowledge-based industries in Australia do not rely on a few high technology industries for growth and wealth production. Rather, elements of all industries are able to become knowledge intensive – even so-called ‘old technology’ industries like mining and agriculture, as well as traditional services such education and health.

There are strong arguments that the Australian mining and resources sector can be seen as a knowledge industry. The Australian resources sector, in extracting, transporting and selling minerals, has increasingly relied on knowledge, technology and innovation to increase productivity – though this has been built on generations of provision of good and services to the industry (Martinez-Fernandez 2010; Tedeco and Haseltine 2010). The knowledge economy’s incorporation into the mining industry can be best demonstrated by adapting Thierstein et al.’s (2006) three pillars of the knowledge economy approach through examining the relationships between the Advanced Producer Services (APS), the mining and resources industry (in lieu of the high tech sector) and Australian universities (see **Figure 2**).

Figure 2 The three knowledge pillars of the Australian mining industry (as adopted from Thierstein et al. 2006) based on the research from Tedeco and Haseltine (2010) and Martinez-Fernandez (2010)



The APS equivalent in the Australian mining and resources sector is the 'mining technology services' (MTS) sector or the 'mining technology services and equipment' (MTSE) sector. The MTS sector has been defined as comprising companies, institutions, associations and other organisations that receive a substantial portion of their revenue, directly or indirectly from mining companies for the provision of goods and services based on specialised technology intellectual property (IP) or knowledge (Martinez-Fernandez 2010). Tedeco and Haseltine (2010) has defined the MTSE as comprising establishments that supply goods and services that embody specialist technology, innovation, intellectual property or knowledge specific to the minerals industry. Universities are not considered by Martinez-Fernandez (2010) or Tedeco and Haseltine (2010) to be part of the MTS/MTSE sectors, which are comprised of small to medium sized companies employing 50 employees or less. The lack of previous prominence or recognition of the MTS/MTSE can be understood, because data on such firms is not specifically collected by the Australian Bureau of Statistics (Martinez-Fernandez 2010). The mining services sector has also grown significantly in the last decade or so (Martinez-Fernandez 2010; Tedeco and Haseltine 2010). This sector now makes a significant contribution to the Australian economy in its own right, with 2008-09 global (Australian and export) sales revenue for the Australian MTSE sector estimated at \$8.7 billion (or 0.7 per cent of GDP) with total research and development of \$985 million (Tedeco and Haseltine 2010). Export sales were partly driven by the modernisation of mining industries in Asia and Latin America, creating demand for sophisticated underground communications, remote-control systems and mine planning software (Martinez-Fernandez 2010).

The knowledge nature of the MTS/MTSE and its relationship to the other two pillars can be gauged from the surveys into the economics of the sector by Martinez-Fernandez (2010) and Tedeco and Haseltine (2010). Martinez-Fernandez (2010) analysed the role of knowledge-intensive service activities in innovation of the MTS sector by examining company case studies. Tedeco and Haseltine's (2010) study was a somewhat broader economic survey, which included research and development expenditure in the MTSE sector, skilled labour requirements, and issues relating to operating a technology business. Significant outcomes of the Martinez-Fernandez (2010) survey indicated that firm headquarters are clustered in business centres and inner city locations, with branches in big regional mining towns. Importantly, major cities and mine sites in particular are the centres of continuous innovation and collaboration (though not regional mining towns). Knowledge-intensive service providers strongly impact on innovation through both tacit and codified knowledge provision; although this is dependent on the quality and extent of the interaction between MTS firms and mining companies (84 per cent of firms build capability through

collaboration with major clients and multinational corporations). Tedeco and Haseltine (2010) found that formal R&D (54 per cent) in the MTSE was concentrated among a few large companies and research organisations in the technology application industries (as distinct from the equipment and machinery, consulting services, and contract services) with the majority of investment in R&D being spent in-house. The majority of companies in the MTSE, being small and medium enterprises (SMEs), had limited commitments and weak links to research and development in the university sector. The linkages between industry and universities are notably weak in Australia (Moodie 2004, OECD 2013, ATN 2015). Moodie (2004) argued that Australia has generally tended to concentrate its R&D in the public sector rather than in the private sector. More recently ATN (2015) has noted that Australia sits 29th out of 30 OECD nations in rankings for collaboration between the university sector and industry on innovation (OECD 2013).

Tedeco and Haseltine (2010) however found Australian mining companies viewed Australian MTSE as at the forefront of technology and innovation globally. In some respect, the larger mining companies took responsibility themselves for the collaborative R&D in the industry. Tedeco and Haseltine (2010) found the larger mineral companies were more active in setting up and funding public research centres on the basis that it was more productive to undertake collaborative research with a range of universities, public research centres and MTSE companies rather than with individual MTSE companies. Both Martinez-Fernandez (2010) and Tedeco and Haseltine (2010) found significant barriers to productivity and innovation related to the lack of skilled personnel (particularly engineers). The most important role universities provided to the MTS/MTSE sector was provision of skilled labour, although the lack of R&D linkages was also notable. The weaknesses in the R&D linkages between MTS/MTSE and universities are most likely due to MTS/MTSE largely being SMEs, although the absence of universities from the places of knowledge exchange (mine sites and CBDs) could also be a factor.

The example of the Australian mining and resources sector as a knowledge industry demonstrates that the knowledge is pervasive in the modern economy. Higher levels of knowledge are increasingly central to economic processes and exchanges. The knowledge economy therefore cannot be seen as a sector of the economy, as it increasingly defines the nature of the modern post-industrial economy.

Part C: The literature review on the three elements of knowledge intensification: ICT knowledge and infrastructure, human knowledge capital, and agglomeration of knowledge economic activity

In Part C, the evidence for the three factors of knowledge intensification is considered worldwide and then primary and secondary research is undertaken or used to demonstrate that knowledge intensification is also occurring in Perth, WA. The relationship between urban density and economic agglomeration, human capital and the knowledge economy is also demonstrated.

“What is the city but the people?”

- William Shakespeare, Coriolanus ~1605

“It is thus that through the greater part of Europe the commerce and manufactures of cities, instead of being the effect, have been the cause and occasion of the improvement and cultivation of the country.”

- Adam Smith, Wealth of Nations 1776

“In 2008, for the first time in history, more than half of the world’s population will be living in towns and cities.”

- United Nations Population Fund 2007

Chapter 3 – Literature review on the intensification of knowledge economic activity

3.1 Spatial intensification of knowledge economic activity within cities

Adam Smith (1776) in the *Wealth of Nations* was perhaps the first to articulate reasons for the economic advantage of cities. Smith (1776 p.III.4.18) identified that cities were a cause of the wider economic growth in society leading to development of new industry and accumulation of capital (p.III.3.12). Simmel (1903) argued that increased specialisation, focus on capital (or finance) and individualisation (with increased personal inner and outer freedoms) resulted from the larger scale of cities and the resulting higher levels of anonymity and competition. The complexity and diversity of urban existence, resulting from the agglomeration of so many people with their competing intertwined interests and activities,

inherently led to increased personal and economic specialisation and variation. The economic and psychological need to stand out in the crowded agglomeration, of needing to be sufficiently (and constantly) different and noticeable, was also linked to the “brevity and rarity of (individual) meetings” in the large-scale competitive city (Simmel 1903 p.18). This contrasted to the more socialised and culturally established organised nature of rural living. Simmel’s (1903) observations on the need to stand out amongst the scale of competing activity and making the most of opportunities from relatively rare and brief face-to-face meetings, helps explain, despite increased electronic communications, why humans economically (and psychologically) continue to inherently agglomerate in cities. For Simmel (1903) the essential nature of urban life is one of specialisation, competition and commodification.

The history of economic geography with the on-going advantage of cities and increasing urbanisation, Leamer and Storper (2001) have similarly argued, is the story of two opposing forces – commodification (the transformation of complex transactional tasks into routine tasks which are price sensitive and thus pushed to cheaper and more remote locations or removing the need for occupations and jobs completely) and agglomeration (where new activities require high levels of complex and unfamiliar coordination)¹⁷. Previous rounds of transport and ICT development have always had a double effect: dispersing routine activities while concentrating or agglomerating complex and time-dependent activities (see Rosa 2013 for time intensification). In many ways, the histories of ICT and transport technologies, that are crucial to knowledge exchange, have been interwoven with the advantage of cities. Economic progress over the last three centuries has therefore come with an increasingly fine division of labour: physical in the 19th century and intellectual activities in the 20th century (Leamer & Storper 2001).

Automation and computers take the debate on commodification and the division of labour, particularly with the continuing advancement of both the Internet and artificial intelligence (AI¹⁸), to a new level. A number of writers, notably Susskind (2008, 2013), Frey and Osborne (2013), Brynjolfsson and McAfee (2014), and Susskind & Susskind (2015) have argued that the Internet and AI automation will have a much broader and more fundamental impact on employment and society than previous technological changes and that they will also impact on traditionally highly skilled and knowledge intense professional employment. In this debate on the impact on employment¹⁹ there has been minimal attention on the impact on cities or

¹⁸ Artificial intelligence (AI) refers to the ability of a machine and its software and hardware to perform both logic and abstract functions including communications between differing systems. This includes the capacity to perceive and retain knowledge to assist in problem solving strategies (Nilsson 2014, Otieno 2015).

¹⁹ In Chapter 5 the debate of the impact of Internet and ICT on distance and spatial form is addressed.

the spatial economy, though the impact can be extrapolated from the reasoning of Leamer and Storper's (2001) iterative knowledge production model.

The extent of or the potential rate of change has been questioned by others who argue that the case is overstated and not proven by evidence of even recent technological change (Remus & Levy 2015, Bessen 2016). Susskind's (2008, 2013) focus has been on the legal profession, where he argued that technology would allow most of the work undertaken by legal firms to be commodified and delivered more efficiently by specialist systems and technologies. Remus and Levy (2015), while agreeing with the thrust of Susskind's (2008, 2013) arguments, contended that the possible extent of legal system automation was far more limited and therefore more immune to commodification. This was because of a number of factors, including the additional coordination required with complex automation, the induced greater demand that automation would create for complex legal services and the extent of complex work not suited to automation.

Brynjolfsson and McAfee (2014), in examining expected impacts of computerisation on the USA labour market, found, in terms of jobs at risk of being replaced due to computerisation and relationship to wages and educational attainment, 47 per cent of existing jobs in the USA were at high risk of being lost. They also found that low wages and educational attainment were linked to the probability of job loss (in logistics and transportation, office and administration, and production occupations). While the jobs at greatest risk were more rule-based activities, big data based algorithms were rapidly impacting on jobs with non-routine cognitive tasks across a range of service occupations (Brynjolfsson & McAfee 2014, p.44). The work that was most non-susceptible to computerisation, according to Brynjolfsson and McAfee (2014), were tasks requiring creative and social intelligence. The conclusion reached by Brynjolfsson and McAfee (2014) is not inconsistent with the Leamer and Storper (2001) knowledge production model.

There are limitations of a methodology with an over-focus looking at the impact of technology on explicit jobs, rather than work and tasks that could be bundled into new types of jobs. Bessen (2016), in rejecting computers and AI as a source of significant *net* (*emphasis added*) technological unemployment or job polarisation, has argued that while old jobs disappeared new jobs were created. Looking at the relationship between computer technology, occupations and employment since 1980 in the USA, Bessen (2016) found that occupations that used computers grew faster, not slower. This was true even for highly routine and mid-wage occupations. Following the Leamer and Storper (2001) model, Bessen (2016) found computing removed commodified skills and tasks but this (similar to Remus &

Levy 2015) led to or induced new tasks and roles requiring new skills and jobs. Notably, consistent with Leamer and Storper (2001) knowledge production model, Susskind (2008, 2013) accepted that new opportunities for legal workers would evolve with a greater focus on intellectual/immaterial strategic and consultancy activities (see also Johnson & Donnelly 2013 and also noted by Remus & Levy 2015). These however were unlikely to be within traditional legal commercial models. In Susskind and Susskind (2015) the arguments of Susskind (2008, 2013) were extended to a range of specialist professions, where it was argued that print based industrial society expertise was being opened to broader society. This removed the advantageous position of many specialist professions as being gateways to expertise. This professional expertise could now increasingly be commodified and brokered by other professions and systems.

Ultimately this question is not answerable with research on what jobs have been or could be created or destroyed by technology. The key lays in the question of whether there will ultimately remain any new intellectual/immaterial work of complex and unfamiliar coordination (as per Leamer & Storper 2001) or, similarly, whether technology through artificial intelligence will continuously narrow the new work opportunities to effectively nil. In this scenario, taken to its extreme, at some point the broad engagement of humans in the knowledge economy will narrow to render major knowledge intense cities unnecessary. While a comprehensive answer to this question is not within the scope of this thesis, it is a question, with this century's rapid technological change, that needs to be considered.

A means of addressing this question is through a consideration of what is uniquely human and what distinguishes humans from computers and AI (therefore providing the opportunity of human only knowledge tasks). The argument for unique human knowledge has been made for human brain embedded tacit knowledge²⁰ and therefore the limitations of AI (Fetzer 1990, Lowney 2011). This argument goes to the limitations of AI, logic and programming, in that not everything (action or event) can be reduced to programmable language or instruction (Fetzer 1990), and key aspects of tacit knowledge relate to evolving or newly created language conventions, emotions (Fetzer 1990), human interpretation, moral decisions, and socially complex contexts requiring abstract and or judgemental interpretations (Fetzer 1990, Lowney 2011, Trubody 2013, Remus & Levy 2015). Trubody (2013) and Mondal (2014) have both argued that interpretation and human creativity is reliant on human existence or a state of 'being in the world'; effectively an understanding of one's own existence and interests. This was not to deny AI cognition and its potential superiority but to distinguish machine cognition from human cognition.

²⁰ What exactly is tacit knowledge is subject to a somewhat endless debate of varying distinctions and abstractions—see Polyani 1958, Gouraly 2002, Collins 2009, 2010, Lowney 2011, Trubody 2013.

Others have argued that AI is capable of cognition (thinking) which can be continuously adapted and improved to include further tacit knowledge capabilities (Fenstermacher 2005, Rapaport 2012, & Sanchez 2013). Computer cognition is increasingly being enabled by the Internet and utilisation of other computer systems. Rapaport (2012) has argued that computing can possess minds, while different from human minds, which undertake mental processes governed by cognitive algorithms. This means that computers, through algorithms, can be affected by emotions, attitudes and individual histories. Perhaps the distinction lays in the depth and types of human cognition that cannot be programmed through language, marks or notations, and mathematical reasoning or logarithms. What uniquely makes humans human is an issue addressed by evolutionary psychologist Robin Dunbar (2008)²¹. Consistent with the on-going opportunities in the world of computerisation and AI for increased coordination of knowledge process (Leamer & Storper 2001) and creative and social intelligence (Brynjolfsson & McAfee 2014), Dunbar (2008) outlines a hypothesis of the natural development of the social brain. Dunbar proffers that primate sociality and cognition increased, as human societies were forced to expand in size and complexity during the course of our evolution over the past 5 million years. This created a unique human state of existence. Dunbar (2008) essentially argued what distinguishes human cognition is that we are able to live in a virtual world; of imagination and spirituality. This creates a capacity for story-telling, empathy and moral beliefs, as well as a capacity to bond, organise and socialise with numerous other humans in complex communities. These capacities, located in the frontal lobes of the brain, do not just relate to brain size and its computing efficiency. In this sense the arguments for AI, based on increased computer efficiency and system integration, do not ultimately challenge human cognition.

Any argument that computerisation, Internet and AI technology will have a fundamental impact on the future of the work *as well as* remove the benefit of cities is not strong. Leamer and Storper's (2001) iterative knowledge production model of competing centrifugal (commodification and deurbanising) and centripetal (immaterial specialisation with urban agglomeration) forces, appears robust. There have been numerous cycles of technological change destroying particular jobs and generating new jobs with increasing immaterial knowledge coordination functions. Evolutionary psychology provides a possible explanation as to this iterative process. Therefore the increasing need for cities would seem consistent with past trends of increasing urbanisation and agglomeration based on the increasing need for coordination of immaterial knowledge activities.²²

²¹ Dunbar (2008) distinguishes human cognition from other primate cognition, however the arguments are arguably equally applicable to distinguishing human cognition from computer and AI.

²² The greater negative consequence of computerisation and AI is possibly more to do with the social and economic polarisation and its spatial representation. This would be the dividing of populations between high knowledge value, high agglomeration and economically weak, low agglomeration outer metropolitan areas. Brynjolfsson and McAfee

3.2 Economic urban agglomeration

A consideration of why the world's economy has been spatially intensifying leads to a discussion of economic agglomeration. Cities can be understood as operating at and within broad economic and spatial scales, including at the international, national, regional, urban metropolitan and urban centre scale. These scales provide for differing economic agglomeration drivers (Fujita, Krugman & Venables 1999, Schmutzler 1999, Arnott 2011). 'New economic geography' provides a framework for understanding regional, national and international agglomeration (Fujita, Krugman & Venables 1999, Krugman 1999, Schmutzler 1999). The 'new economic geography' approach emphasises interactions between increasing returns, transportation costs, and the movement of productive factors applied in the broadest economic sense across various spatial scales, including urban, regional, and international economic growth (Schmutzler 1999, Arnott 2011). This approach identifies the existence of large economic agglomerations at the various spatial scales. It also recognises that there are, at these various scales of economic activity, agglomerative or centripetal forces of external economies of scale and dis-agglomeration or centrifugal forces of transport costs (Arnott 2011). In particular, Fujita, Krugman and Venables (1999) identified that cities operate within a system of cities, which emerges as population increases. Bouhol, de Serres and Molnar (2008), in investigating the impact of distance and proximity on GDP in OECD countries, found substantial impacts on GDP from distance/proximity to major markets, particularly where proximity was to denser economic markets. While transport was a factor, proximity was thought to have a greater favourable impact on productivity through greater scales of economies for product and labour markets. This was because market proximity saw greater competition from access to denser economic activity, with its greater scale and higher levels of movement of goods and people.

The benefits of agglomeration at the urban scale and its links to urban density have been noted by the World Bank (2009), which contends that geographic places do well when they promote:

- higher densities as cities grow,

(2014) have argued an optimistic view of the future in terms of economic growth, however a negative perspective with the intensification of wealth (i.e. the spread of wealth and employment in society will become narrower). This is consistent with the arguments of Rosen (1981) and Perri (2014) where, as technology increases the size of the market that is able to be served by a skilled or unique offering single person or firm, small differences in skills are shown to lead to large differences in economic returns and a 'winner take-all economy'. Therefore this technology efficiency decreases employment and economic opportunities of other parties. This, as Moretti (2012) has demonstrated in the USA, has a stark spatial conclusion.

- shorter distances as workers and businesses migrate closer to density, and
- fewer divisions as nations lower their economic borders and enter world markets to take advantage of scale and trade in specialised products.

The World Bank's argument is that the transformations along the dimensions of density, distance, and division are essential for development and are to be encouraged. Urban agglomeration is the spatial concentration of economic activity in cities and, as cities increase in size, agglomeration tends to increase (Strange 2008, SGS 2012a). Urban agglomeration has been understood to occur because of access to:

- the scale of economies for the supply of goods and services,
- the concentration of large and skilled labour pools or markets, and
- knowledge spillovers being the efficient diffusion, sharing and adoption of new ideas and technologies (see Strange 2008, Beenstock & Felsenstein 2009).

It is fair to say that there is evidence of both industry specific agglomeration (also known as 'localisation'), particularly in new and growing industries (Marshall 1920, Romer 1986, van der Panne 2004) and more general urban agglomeration spillover from industry to industry and into the wider urban economy (Jacobs 1969, Scherer 1982, Glaeser et al. 1992).

Agglomeration in the knowledge economy is not generalised across all urban areas, occurring in particular regions and parts of cities (Spiller 2003, 2005, Burger Oort, Frenken & Van Der Knaap 2009, Meijer & Burger 2010), including within Australia (Johnson 2010, Hu 2010, Martinez-Fernandez 2010, Spiller 2003, 2005, Rawnsley & Szafraniec 2010, SGS 2012a).

Globally, urban concentrations of intellectual and immaterial production can be demonstrated by looking at the spatial concentration of patents. According to the OECD (2008) patent-based statistics reflect the inventive performance of countries, regions and firms, as well as other aspects of the dynamics of the innovation process (e.g. co-operation in innovation or technology paths). Hasan and Tucci (2010) found that both the quantity and quality of inventive activity is associated with economic growth and that, crucially, countries with higher levels of patenting activity – as well as those whose patents are filed primarily in the US – tend to have higher growth rates. In this sense, patenting activity can be seen as an economic marker of the knowledge economy and, therefore, any spatial characteristics of patenting are key indicators of spatial characteristics of the knowledge economy. OECD (2008) data since the 1990s shows patenting activity is concentrated in a set of countries (e.g. the United States, Japan, Germany, Korea, France and the United Kingdom). At the regional level, indicators on patenting show that patenting activity is even more highly concentrated than population in most OECD countries. In the USA, four regions out of 179 contributed to 34 per cent of patents filed under the Patent Cooperation Treaty (PCT) by US

residents in 2003-05 (and 12 per cent of all PCT filings). These regions are located in California and the northeast. Over the same period, Tokyo led in the patenting of Japanese inventions (28 per cent). The regions of Seoul and Gyeonggi-do in Korea ranked fifth in 2003-05. In the European Union, patenting activity is distributed between France (the Ile-de-France region), Germany (Stuttgart, Oberbayern), the Netherlands (Noord-Brabant) and the United Kingdom (south east of England).

Kerr (2010), examining the links between patents and the distribution of immigrant engineers and scientists, found that US cities with higher prevalence of breakthrough innovations increased their share of US patenting to about 35 per cent. In addition, the growth differential was driven by the mobility of the technology's labour force, particularly immigrant scientists and engineers. Effectively, breakthrough inventions fostered a growth and a spatial concentration in patenting through attracting science and engineering immigrants to locations with the breakthrough technologies, thus reinforcing concentration of patenting performance. Bettencourt, Lobo and Strumsky (2007) also found a spatial concentration with new patents being granted disproportionately in larger US urban centres, thus showing increasing returns in inventing activity with respect to population size. This, they found, was due, not to the higher productivity of inventors in larger cities, but because of their higher concentration in such cities. Turk-Bicakci and Brint (2005) found in USA that successful industry/university technology partnerships tended to be concentrated in the larger major research universities. Not all institutions were found to have the ingredients for success, which were defined as good technologies, well developed regional high tech infrastructure, national reach and dedicated skilled technology transfer staff. Another example of the increasing concentration and specialisation of knowledge-intensive industries within major cities is with New York and its increasing role as a specialist financial centre. Glaeser (2005, 2012), in his examinations of the economic history of New York, noted that New York's modern economy is characterised by specialised finance related and professional industries²³. Glaeser (2005) pointed out that in Chinitz's (1961) analysis of New York, Manhattan was notably then more economically diverse. Glaeser (2012) later argued that New York's over specialisation places it at risk and called for greater economic diversification.

Understanding what drives urban economic specialisation has been described as a classic unresolved issue, with many research areas remaining open and empirical work lagging the theoretical frontier (Holmes & Stevens 2003). Similarly, Duranton and Puga (2003) argued that the concept of urban agglomeration economies is robust to many different specifications and microeconomic mechanisms, but empirically identifying and separating these

²³ In 2002, the four top industries 'security, commodity contracts and like activity', 'business, scientific and services', 'credit intermediation,' and 'company management' accounted for 56.6 per cent of employees in Manhattan, though the high concentration in financial industries has declined after the global financial crisis following 2008.

mechanisms becomes very difficult. In the UK, the Eddington Transport Study (2006) commissioned reports on the relationship between agglomeration and productivity, which found that agglomeration economies do exist and that they are substantial in some industries, particularly the knowledge services sector (D. Graham 2005). In particular, high agglomeration values were found for business services and management, consultancy, financial services and public services. Similar conclusions were reached in Australian agglomeration research (Rawnsley & Szafraneic 2010, Hensher, Truong, Mulley & Ellison 2012)²⁴. Fujita and Thisse (2002) argued that technological progress brings new types of innovative activities that benefit from being agglomerated. This leads to more prosperity and to the development of prosperous and competitive clusters of specific industries, as well as to the existence of large diversified metropolitan areas. Chatterjee (2006) calculated that agglomeration in the US (based on the year 1999 spatial distribution of employment) is substantial and accounts for just under half the observed concentration of employment. More generally, the importance of agglomeration economies ranges between 40 to 50 per cent of observed spatial concentration but importantly, agglomeration is not the only factor driving economic activity in cities (Chatterjee 2006, Hensher et al. 2012).

The links between spatial concentration and growth are not necessarily simple, ubiquitous or regular (Brulhart and Sbergami 2009). The effect of spatial concentration on economic growth may be non-linear and conditional on other factors (Brulhart and Sbergami 2009). These other factors that lead to the spatial concentration of economic activity may vary and can include natural locational advantage, city amenity (Glaeser 2009) including climate, and government policies such as regional government taxation and/or industrial relations policies (Holmes and Stevens 2003, Kohlhase and Ju 2007). At a national level, with an aggregate of all economic activity, the benefits of urban agglomeration are arguably limited or irrelevant, especially in industrialised countries, although these aggregate patterns mask considerable heterogeneity across sectors. Looking beneath the national level aggregate data, Brulhart and Sbergami (2009) recognised the mounting evidence that local clustering economies may well be as strong as ever in developed and developing nations alike; noting for example the growth effects of the financial sector with agglomeration.

3.3 Agglomeration, urban density and human capital

More recent studies on agglomeration have identified links between urban density and human capital (Rosenthal & Strange 2008, Knudsen et al. 2008, Glaeser & Resseger 2010, Abel, Dey & Gabe 2012, SGS 2012a, Kelly & Mares 2013). Glaeser and Resseger (2010)

²⁴ Industries found by both Hensher et al (2012) and Rawnsley and Szafraniec (2010) to have a statistically significant agglomeration elasticities were Financial & Insurance Services, Education and Training Services, Health Care & Social Assistance.

found a correlation between per worker productivity and city size where there were higher levels of human capital (which they surmised as evidence of knowledge agglomeration). Rosenthal and Strange (2008) found that proximity to college-educated workers drives much of the urban wage premium typically found with spatial concentration of employment. Abel et al. (2012) identified new estimates of the magnitude of agglomeration economics in US metropolitan areas using a model of urban productivity that explicitly incorporated the complementarity between cities and skill. It was found that the productivity of a metropolitan area was primarily determined by population density, the human capital stock, and other factors that vary by region. Based on a comprehensive sample of 363 US metropolitan areas during the period 2001-2005, the analysis showed that a doubling of density increased productivity by an average 2-4 per cent. Abel et al. (2012) crucially found, consistent with knowledge spillover theory, that the higher a metropolitan area's human capital stock, the higher productivity benefits. Doubling the density in metropolitan areas with human capital that was one standard deviation above the mean saw productivity double the average. The average effect of urban density and density of human capital was highest among knowledge-based industries – such as professional services, arts and entertainment, and information and finance. These are the industries where the exchange of knowledge and sharing of ideas are important parts of the production process. For a metropolitan area with human capital that was one standard deviation below the mean, no productivity was gained. There was a net negative agglomeration or dis-agglomeration effect where there was low human capital. This suggests the negative costs of density, such as congestion, overcomes any positive spillover effect in unskilled places. The productivity enhancing effects of the density of human capital was found to be an important factor in understanding the aggregate output for the 50 most productive metropolitan areas, which produce 60 per cent of USA GDP. Abel et al. (2012) confirmed the findings of Rosenthal and Strange (2008) who found the positive effect of agglomeration is really due to the presence of human capital.

As noted previously, knowledge spillovers are not immune to distance as tacit knowledge is through the process of social interaction (van der Panne 2004). With greater distance, Karlsson and Johansson (2006) contended that knowledge flows are affected by friction costs because of geographic or other communication distances. With greater complexities of knowledge, the greater the friction in its transfer. As Glaeser, Kallal, Scheinkman and Shleifer (1992, p.2) noted, intellectual breakthroughs must cross hallways and streets more easily than oceans and continents. This means that cross-fertilisation of ideas across industries speeds up economic growth, with increased growth of cities being one manifestation of this phenomenon. Indeed, as the modern economy becomes increasingly based on complex and time dependent knowledge transmissions, the importance of cities increases.

The evidence of agglomeration benefits now abounds in the international literature, but this understanding has had limited impacts on cost-benefit analysis and appraisals of Australian infrastructure investments. Nor has it, in any measurable way, been introduced into urban planning for Australian centres (Trubka 2009, Rawnsley & Szafraneic 2010). This had changed at the Federal level under the Rudd and Gillard Governments for transport infrastructure funding guidelines (Infrastructure Australia 2009). It has also been noted that academic modelling research within Australia on urban agglomeration of Australian cities is still very much in its infancy (Trubka 2009, Rawnsley & Szafraneic 2010, Hensher et al. 2012, SGS 2012a, Legaspi et al. 2015). This has meant that Australian cities have continued to sprawl without effective policy intervention as to the inefficiencies and economic costs associated with this form of spatial organisation (Trubka 2009). Trubka (2009) estimates that agglomeration economies in Australian capital cities provide between a 3.5 per cent and 7.4 per cent increase in productivity when an area's employment density is doubled, which remains consistent with findings from international examples. Rawnsley and Szafraneic (2010) also note the link between the size of the city and its spatial organisation, arguing that labour productivity can be achieved by ensuring that agglomeration is maximised within the city's existing structure. In particular, it could be affected by providing high-density employment space, building on existing employment hubs (outside the CBDs) that already experience high agglomeration. Rawnsley and Szafraneic (2010) argued that policies that support an over-supply of non-manufacturing employment land outside the CBD providing low-density development result in employment sprawling and missed agglomeration and productivity. Instead, centres should be encouraged to build upwards, similar to CBD environments.

Importantly, the nature of an industry or urban density is not the only consideration in understanding agglomeration. There is also an inherent relationship between transport and agglomeration (Prud'homme and Lee 1999, Graham, D 2005, Eddington 2006, Trubka 2009, Rawnsley & Szafraneic 2010, Hensher et al. 2012, SGS 2012a, Kelly & Donegan 2014, Legaspi et al. 2015) and between spatially concentrated ICT and transport (Moriset 2003, Kane 2010, Maeng & Nedovic-Budic 2010). The spatial concentration of firms is dependent on the nature of transport provision and costs. This is because it is transport that provides access for workers into the large metropolitan city labour markets and their spatially concentrated workplaces. Fujita and Thisse (2002) argue that agglomeration happens provided that transport costs are below some critical threshold. Congestion in highly urbanised locations diminishes returns to agglomeration, meaning that some industries impacted by congestion favour a more dispersed economic geography (Brulhart & Sbergami 2009, Accetturo 2010). However, as Prud'homme and Lee (1999) noted that congestion can be not so much an indication of city size, but the lack of good city management and insufficient transport investment. This is supported by Graham, D (2005) and Eddington

(2006), who argue that the economic benefits of agglomeration can be demonstrated as wider economic benefits of transport investment beyond the benefits accounted for in standard cost-benefit appraisals (see also Hensher et al. 2012, Legaspi et al. 2015). The type of transport investment however could be critical, in that it may be logical to argue that more knowledge intensive industries that benefit from densification and agglomeration would also benefit from transport infrastructure that intensifies human activity (i.e. public transport). Industries that benefit from disaggregated urban forms would correspondingly benefit from road transport investment. This can be demonstrated by looking at the varying carrying capacity of transport infrastructure. For example, the proposed underground Bligh Government version of the Cross River Rail project in Brisbane was forecast to carry 120,000 passengers in and out of the city during the morning peak, with the rail lines in two proposed bored rail tunnels being equivalent to a 30-lane motorway in passenger capacity (Bligh 2010).

3.4 Networking of knowledge based agglomeration

Castells (2005) argued that the prevalence of knowledge in the modern economy is because ICT technology has allowed the dominance of networks. This was because, while knowledge and information had always been central in all historically known societies, what was new was the microelectronics-based, networking technologies that had provided new capabilities to an old form of social organisation – networks. The effectiveness of networks were limited in the past, in that they were limited to projects under a certain size and complexity of the organization required to perform the task. This meant networks were focused on the private life, while the world of production, power and war was occupied by large, vertical organisations, such as states, churches, armies and corporations that saw the marshalling of vast resources by a central authority. However, digital networking technologies enable networks to overcome their historical limits. This rise in the prevalence of networks has led to autonomy and multi-directionality and a continuous flow of information.

Devriendt, Derudder and Witlox (2008) argued that there is a trend towards city-to-city digital city networking and interrelationships between key cities creating digital hubs. Castells (2005) referred to the 'new economy' as the 'network economy'. The networked nature of the economy allowed new, efficient forms of organisation of production, distribution and management. This was the reason for the substantial increase in the rate of productivity growth. Increasingly, knowledge economy services are provided by a network of providers and innovators outside major company or government structures in organisations with less hierarchy, and where workers are more specialised and provided with more autonomy

(Leamer & Storper 2001, Fuente & Ciccone 2002, Spiller 2004 & 2005, Goebel, Thierstein & Luthi 2007, Burger et al. 2009).

Smith (2000) contended that modern innovation is often linked to the external networked environment of the firm and their interactions. While knowledge can be firm-specific or product specific there are also industry or product knowledge bases that are open and rely on the sharing of knowledge across industries, involving industry bodies and institutions. It is argued that this network of decentralised human capital or knowledge is becoming increasingly dominant, reflecting a shift from large corporate organisations to a more organisationally dispersed network of companies. The organisational dispersement of knowledge and the critical role that knowledge plays is consistent with the proposition of the role knowledge plays in an economy. In F.A. Hayek's (1945) seminal paper, *The Use of Knowledge in Society*, it was argued that the most current and useful knowledge for price setting was organisationally decentralised and that not all knowledge could be reduced to statistical values for central planning purposes. In this sense, while certain types of knowledge can be organised from bureaucratic rationally planned centres (be these governments or corporations), ultimately the best use and development of knowledge is by organisationally decentralised sources. Hayek (1945) proposed that the economic problem of society is mainly one of rapid adaptation to changes in the particular circumstances of time and space that could not be resolved by communicating knowledge centrally. This leads to a conclusion that the maintenance of current and ready-to-use knowledge is difficult to centralise in an organisational sense. This suggests a highly knowledge enabled economy should be disaggregated organisationally with a network approach to communications.

The need to have a knowledge advantage means that a party requires constant access to knowledge at least equal to or superior to their competitors. The complexity and timeliness of what is knowledge in an economic context means knowledge is difficult to ascertain and fully understand or manage. Fabricant (1976), in reviewing the work of F.A. Hayek, and his fellow 20th century Austrian economist Ludwig Mises, on the complexity and changeability of knowledge in a capitalist economy, noted the importance of use by individuals of particular pieces of (tacit) knowledge. Individual people – and only them – possessed tacit knowledge with which to adapt most economically to the incessant changes in a dynamic world. Similarly, Lavoie (1985) noted the entrepreneurial market process generated a continuously changing structure of knowledge, with knowledge being created in a decentralised form and dispersed through the price system to coordinate the market's diverse and independent decision makers (see also Yeager 1994). Paradoxically, this timeliness and variability of knowledge requires participation within market networks, so as to have some understanding of what information and knowledge is current and relevant. The

need to have a knowledge advantage means there is a need to optimise problem solving to efficiently realise knowledge outcomes. This is increasingly difficult in economies and societies subject to time or social acceleration (Rosa 2013). However, Morgan (2004) observed that problem solving capacity is not abundant but scarce, idiosyncratic and unevenly distributed within networks between individuals, firms and regions. Effectively, this means that obtaining a knowledge advantage is an intensive, on-going and constant competition between firms and individuals. This competitiveness, while time related, also has a spatial or distance context, as distance can add a time and quality of information or knowledge disadvantage. This leads to one of the paradoxes of the networked knowledge economy in that it has spawned greater uncertainty, especially at the firm level, with real difficulties measuring and enhancing intangible assets (such as R&D, proprietary know-how, intellectual property, brand, workforce skills, organisational competence, network of customers and suppliers and goodwill) (Morgan 2004). This in return has increased the importance of face-to-face knowledge exchange.

Johansson and Quigley (2004) considered a parallel development of agglomeration and networks economies, and ultimately a convergence. Within an agglomeration, physical and ICT networks among players exist to deliver benefits such as knowledge spillover. It is also the case that networks extend beyond agglomerations, aided in the modern economy by high-speed, high-capacity ICT. Johansson and Quigley (2004) see that where co-location is undesirable (or not possible), external networks can substitute (to an extent) for agglomeration with modern ICT. In part, the capacity for networks to overcome distance, Johansson and Quigley's (2004) have contended, is partly dependent on technology permitting goods and services to be standardised. Malecki (2007) similarly notes that while some cities are creative and innovative, some are not, and the reason why this is so has often been focused on internal characteristics. However, this internal competitive focus often omits one of the most overlooked characteristics of knowledge creativity – the network links (channels or pipelines) to global sources of knowledge. Leamer and Storper (2001) provide an example of this in that cultural networks can overcome distance to a degree, pointing to the cultural ties and the economic success over time of remote Commonwealth English-speaking countries such as Australia and New Zealand. Similarly, as previously noted by Chudoba et al. (2005) and Ponds et al. (2007), it would seem that well-organised cultural or organisational networks can be, with appropriate mechanisms or infrastructure (in part at least), a substitute for distance. It is the creation of a network link – a 'knowledge gateway', be it using ICT or economic, cultural or organisational links – that allows agglomerated centres to become effectively part of a wider network. Historically, these knowledge gateways have been ports such as New York, Amsterdam or London, where the port led to commercial, cultural, political and administrative links and ultimately to the first information

systems, including business newspaper publishing and telecommunications infrastructure links (Smith, W.H.1984, Glaeser 2005)²⁵.

The modern network–agglomeration convergence approach is supported by Banister and Hickman’s (2006) vision of ‘technopoles’ – urban concentrations connected through ICT – and with Devriendt et al.’s (2008) concept of a future with ‘cyberplaces’ – Internet enabled physical places, and ‘cyberspace’ – the virtual, immaterial world where distance did not matter. The link between the agglomeration and networks which enabled the convergence was arguably the intensification of knowledge in dense urban spaces highly connected to other dense urban spaces. Major urban centres had capacity to overcome distance in part because their density and size provide economic, cultural, political, and/or infrastructure links or knowledge gateways to other dense urban centres they were economically and socially connected to. Knowledge gateways also operate at a more fine-grain scale than the metropolitan city. This author (Kane 2010) proposed that within cities, some centres can be seen as ‘ex-spatial’ in that they had relationships or networks with other distant (i.e. not spatially associated) cities or centres. CBDs, airports and universities, for example, exchange knowledge and people with other distant places in a way that more suburban centres (such as shopping centres) do not.

The intensification of economic knowledge activity is happening concurrently with the urban intensification of ICT knowledge, both in terms of the increasing data capacity of ICT systems and the spatial concentration of ICT physical infrastructure in high-demand urban agglomerations. This digital development has enabled cities and centres to be efficiently networked to other cities. The continuing demand and supply of more intense ICT arises from the economic activity of dense agglomerated cities. This provides a link between network theory and agglomeration in that they share a connection relating to urban density and knowledge intensification within it.

²⁵ This port knowledge transfer is also evident in Asian ports such as Malacca (Lee 2008), pre-Meiji Nagasaki (Gordon 2013) and Cochin (Nandy 2006) particularly in terms of progressive and secular thought, diversity, and openness.

Chapter 4 – Intensification of human (capital) knowledge

4.1 Intensification of human capital

It has been argued that what distinguishes the new knowledge economy is the intensification in human knowledge through increased education and skill levels within labour markets. The changes in information technologies, as a result, are making educated and skilled labour more valuable and unskilled labour less so – effectively, labour markets are becoming more knowledge-intensive (OECD 1996 and 2013, Smith 2000, Fuente and Ciccone 2002, Castells 2005, Scleicher 2006, ABS 2013d, Australian Education International 2014, ATN 2015). Castells (2005) contended that societies in transition to the new economy found the divisions between users and non-users of technologies, such as the Internet, were greater and tended to make that utilisation more a question of the generation to which one belongs: the younger the generation and the higher the education level, the greater the use. Smith (2000), a somewhat knowledge economy sceptic, accepted that what was changing was the increasing relevance of education (with the growing employment categories being those with higher education qualifications).

The increase in the economic productivity of human capital is the result of the investment by humans in accumulating knowledge either through education or on-the-job training. Becker (1993, p.16) defined human capital as:

... expenditures on education, training, medical care, [to] produce human, not physical or financial, capital because you cannot separate a person from his or her knowledge, skills, health, or values the way it is possible to move financial and physical assets while the owner stays put.

The link between knowledge accumulation through education and its association with economic growth is now well established. The two main branches of the new growth theories on economic development were pioneered by Lucas (1988) and Romer (1990), who both proposed a link between human capital and economic growth. It is also well recognised that knowledge spillover benefits arise from the clustering of human capital (Lucas 1988, Rosenthal & Strange 2008, World Bank 2009, Glaeser & Resseger 2010, Abel, Dey & Gabe 2012). Human capital has a spatial context in the sense that its intensification in cities and urban areas produces economic benefits. DeVol, Shen, Bedroussian and Zhang (2013, p.2) examined the GDP performance of 261 USA metropolitan areas finding that “the overall explanatory power of the relationship [between higher education and GDP per capita] is

strong and robust". More than 70 per cent of the variation in real GDP per capita across the 261 metropolitan areas from 1990 to 2010 was explained by higher education attainment. In particular, they found a significant correlation between the percentage of the population aged 25 or older with a university degree and metropolitan GDP per capita.

The evidence of a positive contribution of ICT to the productivity of workers, establishments, and industries is also well established (Fuente & Ciccone 2002, Echeverri-Carroll, Ayala, Kshetramade & Murthy 2007, Cutler 2008, OECD 2013). Fuente and Ciccone (2002), in reviewing the literature on the economic return from human capital investment, contended that the wider benefits or spillover from increased knowledge and skills through education occurred because of their complementarity with technology. They also noted that knowledge and skills accumulated through education were also a crucial input for the development of new technologies, and necessary for their adoption and efficient use. This increased employability also provides for higher income levels for individuals and increased economic productivity and growth (Fuente & Ciccone 2002, Scleicher 2006, OECD 2013, ATN 2015). In Australia, the productivity successes of the 1990s were built on successful innovations, based on the adoption and adaptation of new computer and communication technologies by service-oriented industries, made possible by the strong growth in educational achievement over the previous decades (Cutler 2008).

Arguably, the intensification of knowledge and its links to modern technology, while clearly apparent in the 'new economy', has been increasing since the industrial revolution. Mokyr (2005) contended that the short answer to why the West was so much richer today than two centuries ago was that, collectively, Western societies 'know' more than they once did. This cannot be merely explained by individual people on average knowing more than their immediate ancestors (based on the increased education and training investment in individual human capital). Increased individual human capital investment has continued since the industrial revolution. Importantly, societies know more collectively, with "greater specialisation, professionalism, and expertisation", meaning that the total amount of knowledge that society controls is vastly larger than ever before (Mokyr 2005, p.287). This resulted, Mokyr (1990) argued, in the knowledge capital society being international (if not global) by the 19th century.

Mokyr (2002) claimed that the most successful economies in the second industrial revolution in the late 19th century were those in which these connections were the most efficient. This led, in the USA, to the growth in practically minded research communities cooperating with industrial and commercial organisations. This in turn saw, in the 20th century,

institutionalised research and innovation – teams of people interacting (rather than the individuals more common in the 18th and 17th centuries). Mokyr (2002) proposed that the total proportion of a society's knowledge held by any one person has decreased. As complexity increased so did the collective effort, which meant that tacit knowledge sharing among teams became more important. Modern economic and research activity handles vast outpourings of commercial, scientific and technical knowledge, which makes the individual mastering of the total body of knowledge impractical. It is no longer possible for individuals to solely process, understand, identify or discover potentially significant relationships between data. Mokyr's (2002) argument is supported by changes in academic authorship. Prior to the 1920s, sole authorship was the norm, whereas the trend in recent decades has been to shared authorship, which is now the most common form (except within the humanities) (Greene 2007). Shared authorship, particularly in the sciences, can now mean the number of authors run into the hundreds. This is attributed to scientific experiments being so complex that they require massive collaboration and specialisation of multiple individual scientists although, arguably, it also reflects to a degree the recognition given to lower-level contributors who were previously not recognised (Price 1986).

Over the 20th century, improvements in transport and ICT have allowed geographic fragmentation of production with a global trade in intermediate inputs. Glaeser and Kohlhase (2004) estimated that the real cost of transportation in the USA declined by 95 per cent over the 20th century, yet agglomeration of producers remained common (if not in the older, yet to be transformed, manufacturing cities).²⁶ The larger and more globally linked metropolitan areas are enjoying stronger economic growth – and are reinforcing their positions as the major centres of the economy – with the core agglomeration characteristics of creative and cultural functions, tourism, finance and business services, science technology and research, and power and influence (both private and government) (van Winden & van den Berg 2004). Effectively, the value of human capital is increased in the centre of the urban environment. This is because of the role of the city centre for tacit knowledge exchange, specialised, complex and diverse labour activities, and face-to-face, trust-dependent activities.

The advantage of the knowledge intensification of jobs and people is increased by the spillover of knowledge with the clustering of people within cities. Lucas (1988) suggested a spatial link for human capital being the driving force for the central role of cities in economic life. As previously noted, Rosenthal and Strange (2008) and Abel et al. (2012) concluded that the positive effect of urban agglomeration was ultimately due to the presence of human capital. Duranton and Puga (2003), noting Jovanovic's (1997) finding that modern economies devote more than 20 per cent of their resources to learning, contended that

²⁶ See also BITRE 2014a for an Australian perspective on the decrease in transport costs over the 20th century.

learning is not a solitary activity taking place in a void: instead, it involves interactions with others and many of these interactions have a 'face-to-face' nature. Cities, by bringing together a large number of people, may thus facilitate learning – or, as Fujita and Thisse (2002, p.9) eloquently put it: “the propensity to interact with others is a fundamental human attribute, as is the tendency to derive pleasure in discussing and exchanging ideas with others”.

Distance is an impediment to such interactions, and thus cities are ideal environments for the development of social contacts. Jacobs (1969) claimed that knowledge was generated by cities facilitating, through diversified urban environments, search and experimentation in innovation. Duranton and Puga (2003) contended that, essentially, it is the proximity to individuals with greater skills or knowledge that facilitates the acquisition of skills, and the exchange and diffusion of knowledge. It can therefore be said that the predominant view in the literature is that cities positively affect labour productivity, because spatial proximity facilitates the transfer of ideas, which in turn makes workers more productive (Echeverri-Carroll et al. 2007). Human capital within the knowledge economy therefore needs to be seen in its spatial context, i.e. knowledge-intensive human capital, connected and working in urban density, produces higher economic value and output than the same human capital disconnected and dispersed.

The Australian Government's recent reviews into primary, secondary and tertiary education – the Bradley Review into Higher Education (Bradley et al. 2008) and the Review of Funding for Schooling (Gonski et al. 2011) both noted the importance of a population's education and knowledge capital for the nation's economic performance in a globalised economy. Competence-based skill formation in a vocational tertiary education system is also important, with Smith et al. (2011) supporting Tether et al.'s (2005) arguments that all levels of skill are important, with a sound basic education the foundation upon which all adaptable, innovation-related skills are based.²⁷ Innovation and economic development are therefore dependent upon a broad public education and training system (Smith et al. 2011, ATN 2015).

The Bradley Review (2008) noted that many countries accept the strong links between national productivity and the proportion of the population with high-level skills. As the Bradley Review's Executive Summary (Bradley et al. 2008, pxi) stated:

²⁷ See also Smith 2000, ABS 2002, Toner 2011, Esposito and Abbott 2011, for discussions on knowledge underpinning more parts of the economy than is often considered.

... as the world becomes more interconnected and global markets for skills and innovation develop even further, it will be crucial for Australia to have enough highly skilled people able to adapt to the uncertainties of a rapidly changing future.

In this sense, the education of the knowledge workers of the future will precede their advent into the workplace. The education of knowledge workers will not only be at the university tertiary sector. The changes in the Australian economy in the past few decades demonstrate the importance of the knowledge intensification of human capital. Shah and Burke (2006) noted that the number of people employed in Australia increased by 19.7 per cent between 1995 and 2005, while the number with qualifications increased by 44.7 per cent. The reasons for this was skills deepening²⁸, more so than new employment growth (Shah and Burke 2006). Skills deepening has been driven by the structural shift in industries, occupational change within industries, and an increase in part-time work – requiring more workers to be trained for a given amount of work – and an overall rise in the level of skills and qualification requirements within occupations. This skills deepening, as described by Shah and Burke (2006), is effectively individual worker knowledge intensification, in that individual workers are intensifying their levels of knowledge and skills. Assuming these trends continued, the estimated proportion of employed people with qualifications in 2016 would be 71 per cent compared with 58 per cent in 2005, with increasing numbers achieving qualifications at higher levels (Shah and Burke 2006).

The increase in formal educational attainments in Australia has notably risen since the 1970s. As can be seen from **Figure 3**, the proportion of the labour force that is formally qualified rose from around one quarter in 1976 to around two-thirds by 2007/ 2008 (Esposito and Abbott 2011).

²⁸ Skills deepening is the increase in the proportion of people with qualifications over and above that due to employment growth.

Figure 3 Educational Attainment: Highest Qualification of People in the Labour Force

Year	Higher education '000	VET '000	Total '000	Total % of labour force
1976/76	189.0	1352.7	1541.7	24.9
1980/81	445.1	2192.0	2637.1	38.9
1985/86	602.9	2552.3	3155.2	41.6
1990/91	986.1	3635.3	4621.4	55.1
1995/96	1545.2	3545.6	5090.8	56.0
2000/01	2296.1	3934.9	6231.0	63.3
2007/08	3037.2	4434.9	7472.1	66.4

Source: Esposto and Abbott 2011 from ABS data

The higher levels of knowledge intensity are not only demonstrated through a consideration of increasing levels of qualifications, with a broader analysis of the Australian labour market over the past three and a half decades also demonstrating knowledge intensification (Sheehan & Esposto 2001, Langworthy 2008, Esposto 2010, Esposto & Abbott 2011).

Esposto and Abbott (2011) further observed, using Census data from 1971 to 2006, that the composition of the knowledge intensity of Australian occupations has changed over the long term. Using the USA's Occupational Information Network (O*NET) occupational classification system²⁹ with measures of knowledge and Australian employment data, they obtained a broad understanding of how occupational knowledge intensities and the human capital requirements of the Australian economy have transformed over time. To describe changes in the knowledge intensity of Australian occupations, Esposto and Abbott (2011) used a weighted average knowledge intensity index to measure changes in the intensity of knowledge in occupations across the whole labour market. This provided a comparison of changes in the composition of knowledge in terms of job types and allowed a determination of whether knowledge in a given job type had increased or changed because there had been either:

- a growth in occupations requiring a higher level of knowledge intensity;
- a decline in the number of jobs requiring lower levels of knowledge intensity; or
- both an increase in occupations requiring higher levels of skills or knowledge intensity and a decline in those that needed lower levels of knowledge or skills intensity.

²⁹ In the O*NET 33 knowledges are classified into different categories. Some of these categories are general and regarded as being essential elements in the successful performance of occupational tasks. Others are narrower and can only be applied to a fine range of occupational groups or are occupation-specific.

While incorporating measures of formal education in its evaluation, Esposto and Abbott's (2011) analysis uses measures of skill and knowledge developed to incorporate a far broader concept of the acquisitions of skills/knowledge, including through workplace and other skills acquisition. It demonstrates how knowledge and human capital has changed in much of the Australian labour market over the longer term. These researchers found a rise in the indices of knowledge intensity for full-time employment – for both men and women and for female part-time employees – indicating that job growth in the Australian labour market was geared towards occupations that require higher levels of knowledge intensity. This analysis demonstrates a steady and persistent growth in the knowledge intensity of Australia's labour markets. This growth intensity, however, has not been consistent across all employment groups and differs, for instance, between full-time and part-time work.³⁰ For men in full-time work, growth in knowledge intensity (as identified in the indices of knowledge intensity) generally occurred in the top three deciles of knowledge intensity, but declined in most others. The strong increase in knowledge intensity in the top three deciles indicates increased relative demand for occupations that require high levels of knowledge intensity in full-time work.

The intensification of knowledge in the Australian economy can also be gauged by looking at different levels of demand for knowledge required for the challenges of a rapidly changing labour market. Predictions for the skills and knowledge requirements of the Australian labour market suggest a continued increase in demand for higher skilled and knowledge workers (Bradley Review 2008, Access Economics 2009, Esposto 2010, Gonski Report 2011, Department of Education 2014). Esposto (2010), using the O*NET, and applying it to the Australian labour market context using the Monash Forecasting System (MFS), developed detailed labour market 'knowledge' forecasts.³¹

All ten categories of knowledge in employment were found to have experienced significant increases historically and in terms of forecasts. Esposto's (2010) analysis showed a major change in the knowledge intensification of employment in Australia and predicted it will continue to intensify into the future with the increasing demand for knowledge intensity in employment. However, 'Manufacturing and Production' experienced the least historical knowledge growth with Esposto (2010) suggesting this trend may be closely tied to a strong

³⁰ The increasing knowledge role of women within the workforce is consistent with the predictions of Daniel Bell in *The Coming of Post Industrial Society* (1973).

³¹ MFS uses macroeconomic scenarios derived from the Access Economics Macro Model (looking at the economy of our trading partners and the state of the global economy), industry-specific information from Australian Bureau of Agricultural and Resource Economics (ABARE) and the Tourism Forecasting Council (TFC), information from the Productivity Commission and finally, the MFS incorporates the Structure of Technical Change generated by Monash University's Centre of Policy Studies (CoPS). From these scenario models the MFS makes a labour market extension by providing employment forecasts for the 340 four-digit occupations of Australian Standard Classifications of Occupations (ASCO) and this was then connected to the O*NET to obtain employability skill forecasts or employability skills for the future.

decline in employment in the manufacturing sector in Australia, accompanied by a corresponding shift towards the service sector.

4.2 Spatial intensification of knowledge workers within cities

The importance of labour markets to their cities cannot be underplayed. Without labour markets cities do not exist. It is widely accepted that larger labour markets are more efficient than smaller ones (Baumgardner 1988, Prud'homme & Lee 1999, Glaeser & Ellison 1999, Bettencourt, Lobo, Helbing, Kuhnert & West 2007, Bleakley & Lin 2012, Kelly & Donegan 2014). For knowledge industries, the density of human capital is also fundamental to the efficiency of the urban labour market (Knudsen et al. 2007, Rawnsley & Spiller 2010, Abel et al. 2012, Hensher et al. 2012, SGS 2012a, Kelly & Mares 2013, Kelly & Donegan).

Therefore, it can be said that knowledge industries will have an advantage in larger cities where there are highly skilled and qualified workers operating within larger labour markets. The increasing intensification of knowledge is therefore occurring not only within human minds or within jobs, but spatially through the concentration of knowledge workers within urban areas (in terms of their employment and the residential locations).

Labour markets in USA and Australian cities, however, have been dispersing from denser traditional city centres since at least the 1960s, though this has stabilised since the 1990s (Houghton 1981, Glaeser et al. 2000, Glaeser & Kahn 2001, Kneebone 2009, 2013, Meijers & Burger 2010, Raphael & Stoll 2010, BITRE 2010, 2011, Davies 2011, Frey 2014). The dispersement was driven by the advent of the reduced cost of transport, particularly with the private motor vehicle, but also by consumption based employment following population growth, and cost advantages to industries from lower land and access costs (which are also linked to lower transport costs) (Glaeser et al. 2000, BITRE 2010, 2011, Davies 2011, Meijers & Burger 2011). The industries that have driven the suburban growth have been in the population-driven employment sectors such as retail, community and health services, primary and secondary education, real estate and housing construction. These sectors have all seen employment growth in suburban areas though with lower density employment patterns compared to the inner urban core (Houghton 1981, Raphael & Stoll 2010, Davies 2011, Kneebone 2013). There have been exceptions to this. Kneebone (2013) noted that in a minority of US cities with major job decentralisation, such as Chicago and Detroit, now have concentrations of many of their jobs in dense locations outside the urban core. In the USA, denser employment centres occur within polycentric cities and mega regions (where two or more metropolitan areas overlap) and 'edge cities' have developed (Glaeser et al. 2005, Meijers and Burger 2010).

Job decentralisation has followed the suburbanisation of US and Australian cities, with jobs following people (Davies 2011, Raphael & Stoll 2013,). This occurred in almost every US city and in almost every industry (Raphael & Stoll 2013). However Kneebone (2013) noted that as a result of the global financial crisis (GFC), that job losses were greater in the most decentralised industries such as retail, construction and manufacturing. These steep job losses in the GFC stalled the decentralisation of jobs that characterised previous decades in the USA (Kneebone 2013). This resulted in the percentage of inner city jobs slightly increasing compared to slight declines in the middle ring and outer ring employment. In Australia the decline in CBD and inner city employment turned around with growth in inner city employment from the mid 1990s, although this only matched the continued growth of dispersed suburban jobs (Spiller & Rawnsley 2010, BITRE 2010, Davies 2011, BITRE 2012, Kelly & Mares 2013). Spiller and Rawnsley (2010) saw this turnaround of inner city employment as the result of the internationalisation of the Australian economy with a movement away from protected low knowledge industries such as manufacturing to more intense knowledge service industries.

The evidence is that knowledge-intensive workers are more likely to be based in metropolitan cities, but there are two key questions: firstly, whether knowledge-intensive workers are distributed unevenly *amongst* cities and secondly whether they are distributed unevenly *within* cities. In considering the spatial distribution of knowledge workers, one can consider the occupation of the worker or the industry of the employer. Johnson (2010) and Hu (2010), for example, used industry in their examination of Melbourne and Sydney, while occupation was examined by Florida (2002a, 2002b, 2002c) for the USA, or by Lorenzen and Andersen (2009) and Boschma and Fritsch (2009), for Europe.³²

Florida (2002a, 2002b, 2002c), in the USA, and Lorenzen and Andersen (2009), Boschma and Fritsch (2009) and Lee (2014), in Europe, have analysed the spatial distribution of knowledge industries and creative workers across regions and in particular cities. Florida's (2002a, 20002b, 2002c) research found that the creative classes were unevenly distributed across cities or regions. Similarly Lorenzen and Andersen (2009) found strong empirical evidence that creative workers were unevenly distributed across European cities and regions. The creative class's distribution suggested that smaller cities have a greater

³² The two methods have their advantages and disadvantages according to Johnson (2010) who noted that in many respects defining the knowledge economy by a worker's occupation rather than industry of employment was easier and arguably more accurate. Using employee's industry however provides the capacity to explore the spatial distribution of particular industry subsets. Florida (2004) used definitions of creative occupations using three categories - the *creative core*, *creative professionals*, and *bohemians* (as did Lorenzen and Andersen (2009) and Boschma and Fritsch (2009) in their European studies). The creative core being those found in science and engineering, architecture and design, education, arts, music and entertainment whose economic function is to create new ideas, new technology and/or new creative content (Florida 2004).

diseconomy. Two reasons were suggested for this phenomenon: the consumer preferences and job preferences of the creative class; and larger markets provided greater creative amenities and services for the creative class's specialised consumer preferences. Lorenzen and Andersen (2009) also found a strong correlation between the distribution of the creative class and specialised jobs, with job preferences influencing the creative urban hierarchy, because labour market thresholds for creative jobs were greater in larger cities. In particular, a dramatic drop-off in high-technology workplaces was identified in smaller cities, which had too few members of the creative class to constitute viable labour markets for high-technology jobs. The decline in high-technology jobs coincided with an equally sized decrease in the presence of the creative class. These findings are consistent with Leamer and Storper's (2001) assertion that larger knowledge-oriented cities are driven by specialisation and complexity.

In addition to spatial concentration, the urban density of knowledge workers is also relevant. Knudsen, Florida, Gates and Stolarick (2007) examined the role of (occupational) density and creativity on urban innovation. They hypothesised that the higher densities of creative individuals promoted and facilitated face-to-face interactions, creating knowledge spillover and innovations. Their hypothesis was supported when the joint and separate effects of population density and creativity on innovation for 240 metropolitan areas in the USA was examined. It was found that creativity-density was positively and significantly linked to patents. In particular Knudsen et al. (2007, p 25) asserted that proximity and intellectual human capital worked together to power innovation, concluding that *"it is the geographic concentration of people with expertise, knowledge that powers the exchange and spillover that precede innovation."* Abel et al. (2012) also established a link between urban density and the density of human capital across US cities with higher economic output. Larger productivity gains were found to be realised from increasing physical interaction of highly skilled people compared to lower skilled people. Abel et al. (2012) also noted that other agglomeration benefits positively impacted on productivity; particularly, thicker and denser labour markets yielded significant productivity benefits by improving the efficiency of the labour exchange.³³

The benefits of thicker and denser labour markets (Moretti 2012, Bleakley & Lin 2012) logically suggest there will be concentrations of knowledge-intensive workers within cities or parts of cities. There is considerable evidence to support this (Moriset 2003, Bade et al. 2004, Searle & De Valence 2005, Britton & Legare 2005, Echeverri-Carroll et al. 2007, Hu 2010, Johnson 2010, Rawnsley & Szafraniec 2010, Rawnsley & Spiller 2010, SGS 2012a,

³³ Thicker and denser labour markets are where there are more job opportunities and more workers within a given area, which provides for improved (job) searching and a resulting greater level of matching (Bleakley and Lin 2012).

Kelly & Mares 2013, Lee & Rodriguez 2013, Kelly & Donegan 2014, Lee 2014).³⁴ In the US Echeverri-Carroll et al. (2007), using data from the 2000 Census of Population, found ICT workers were not homogeneously dispersed across metropolitan areas with 20 of the 100 largest metropolitan areas in the United States having 33 per cent of the ICT workers. A key conclusion was that cities with larger concentrations of IT workers enjoyed productivity-enhancing effects. Moriset (2003) similarly found concentrations of ICT workers in Lyon, France, concluding that concentration of ICT workers in larger cities was due to a number of factors, often relating to scale. These included larger firms needing access to larger labour markets, smaller firms needing access to wider commercial opportunities, and the availability of higher standards of data security and ICT infrastructure. Larger cities were also found to have greater knowledge spillover and networking opportunities through access to greater depths of local intellectual wealth, including access to city universities, graduate schools and research laboratories.

Studies in Australia support the conclusion that knowledge-intensive workers (and certain groups of knowledge-intensive workers) were concentrated in cities, and in particular, in more urban areas of cities (Forrest 1996, Spiller 2004, Rawnsley & Spiller 2010, Johnson 2010, Hu 2010, SGS 2012a, ABS 2013d, ANZSOG 2013, Kelly & Mares 2013, Kelly & Donegan 2014). The spatial distribution pattern of knowledge-intensive workers is not straightforward. The distribution has changed over time with the increasing levels of education, knowledge intensification of employment and the modernisation of the Australian economy (Mitchell & Carlson 2003, Lewis 2004, Bunker 2009, Dodson et al. 2010, ABS 2011a, ABS 2013d). The ABS 2011 Census (ABS 2011a) data on education levels of working age Australians demonstrated a clear urban-regional divide (see also ABS 2013d).³⁵ The highest rates for tertiary qualifications³⁶ were found in and around the capital cities, particularly in and around the inner cities.³⁷ In Western Australia, the regions with the highest rates of attainment of non-school qualifications were all in the greater capital city of Perth.³⁸

Davies (2011) noted that in Melbourne, jobs filled by workers with Bachelor's degree or higher are more likely to be in the suburbs due to the overall mass number of jobs in the

³⁴ Further it has been found that in cities where there are large concentrations of ICT workers or university or college workers, all workers tend to have higher wages (Moriset 2004, Moretti 2012, and Lee 2014).

³⁵ Within Australia's major cities there is little difference between the number of people with university degrees and the number of people with vocational qualifications. However outside Australia's major large cities, there were more than twice the number of vocational qualifications compared to degrees and diplomas.

³⁶ Tertiary qualifications being post year 12 and includes certificate level III and IV, diplomas and advanced diplomas, and university level qualifications.

³⁷ The lowest tertiary qualification rates were in the Northern Territory - Outback and Queensland - Outback where only about one in three people had a tertiary qualification. Notably resource regional areas of Mackay, Hunter Valley (excluding Newcastle), and Western Australia - Outback regions lead the way in engineering and related technology qualifications.

³⁸ These regions and their rates of attainment of non-school qualifications were Perth - Inner (64.6 per cent), Perth - North West (52.0) and Perth - South West (51.3 per cent) (ABS 2013d).

suburbs. Only 28 per cent of total jobs in Melbourne Davies (2011) found were within 5km of the CBD, though in terms of density of employment it was accepted that the inner city had the higher density of graduate jobs. The dispersed knowledge-jobs, Davies (2011) identified, were typically located in human service industries, in suburban hospitals, universities, schools, and local government administration, although they were also increasingly in manufacturing and warehousing. Knowledge workers, for example, are strongly represented in industries, such as health services and education, which are both dispersed and concentrated.

The dispersed distribution of graduates however belies the spatial concentration of higher value, higher intensity knowledge workers and industry within the CBD and inner city of Australian cities. In Australia, CBDs are identified as centres of higher employment density and higher productivity (BITRE 2010, Rawnsley & Spiller 2010, Trubka 2010, Davies 2011, SGS 2012a, Kelly & Mares 2013, Kelly & Donegan 2014). Suburban jobs are generally dispersed; servicing a dispersed suburban population, while more densely concentrated inner city knowledge workers and firms are likely to be specialist servicing other firms (Spiller 2003, Davies 2011, Kelly & Mares 2013). The centrally focused CBD location, with its higher employment density and accessibility, effectively provides scale and intensity. The centrality of the CBD provides accessibility and reach across an entire metropolitan area to a thicker and larger labour market for specialist skills. The scale and intensity of the CBD resulted in inner city knowledge-intensive workers having higher levels of productivity (Rawnsley & Spiller 2010, Trubka 2010, SGS 2012a, Kelly & Mares 2013, Kelly & Donegan 2014). This, in turn, leads to knowledge-intensive inner city workers receiving a wage premium. The higher labour productivity also attracts knowledge service firms seeking to locate in the central and inner city. Effectively there is an economic difference in the value of services distinction between specialist firm servicing and population servicing.

The spatial intensity of knowledge employment in the inner core contrasts with the absence of knowledge-intensive jobs in the outer suburban areas of Australian cities (Spiller 2005, Davies 2011, SGS 2012a, Kelly & Mares 2013, Kelly & Donegan 2014). Other research confirms the lack of higher value employment and the economic vulnerability of outer suburban areas across all major Australian cities (Dodson and Sipe 2008, Baum & Mitchell 2009, BITRE 2010, Kelly & Mares 2013, Kelly & Donegan 2014).³⁹ Baum and Mitchell (2009) identified Australian suburbs vulnerable to increases in unemployment, and these were found to include many existing outer older suburban areas as well as newer suburbs. These newer suburbs also tended to be on the periphery of metropolitan areas with poor

³⁹ This research is consistent with USA trends which are seeing increased suburbanisation of poverty in cities with dispersed employment (Raphael and Stoll 2010) and more employment vulnerability in dispersed employment (Kneebone 2013).

connectivity. Research on mortgage and petrol price sensitivity by Dodson and Sipe (2008) established that the typically car-dependent residents of outer suburbs were poorly served by public transport and relatively isolated from employment and urban services. This resulted in increased levels of vulnerability to both high vehicle operating costs and mortgage debt. The Bradley Review (Bradley et al. 2008) into higher education also found outer suburban Australians under-represented within the university education system⁴⁰. The lack of connectivity and disadvantage in outer suburban areas means that outer suburban inhabitants are less able and likely to be engaged in the knowledge economy. Concentrations of urban disadvantage, following the proposition of Morone and Taylor (2004) that isolated urban areas can be vulnerable to negative knowledge spillover, have the potential to lead to a spiralling reinforcement of disadvantage.

The Sydney metropolitan area provides a compelling demonstration of the density and scale (in terms of the numbers) of knowledge workers employed in the central city. The ANZSOG Institute for Governance examined the spatial distribution of workers in the main private sector knowledge-intensive industries⁴¹ in the Sydney metropolitan area and found they were heavily concentrated in central Sydney (ANZSOG 2013) – see **Figure 4**. While not necessarily indicative of all knowledge economic activity, it does provide an indication as to spatial focus of market based private investment in the knowledge economy. The number of knowledge workers in the City of Sydney, while less than 50 per cent, was considerably higher than any other council area in 2001 and more so in 2011. North Sydney was a distant second; however, when combined, the City of Sydney and North Sydney had more jobs in knowledge-intensive industries in 2011 than the total for all other 41 council areas in the Sydney region combined.

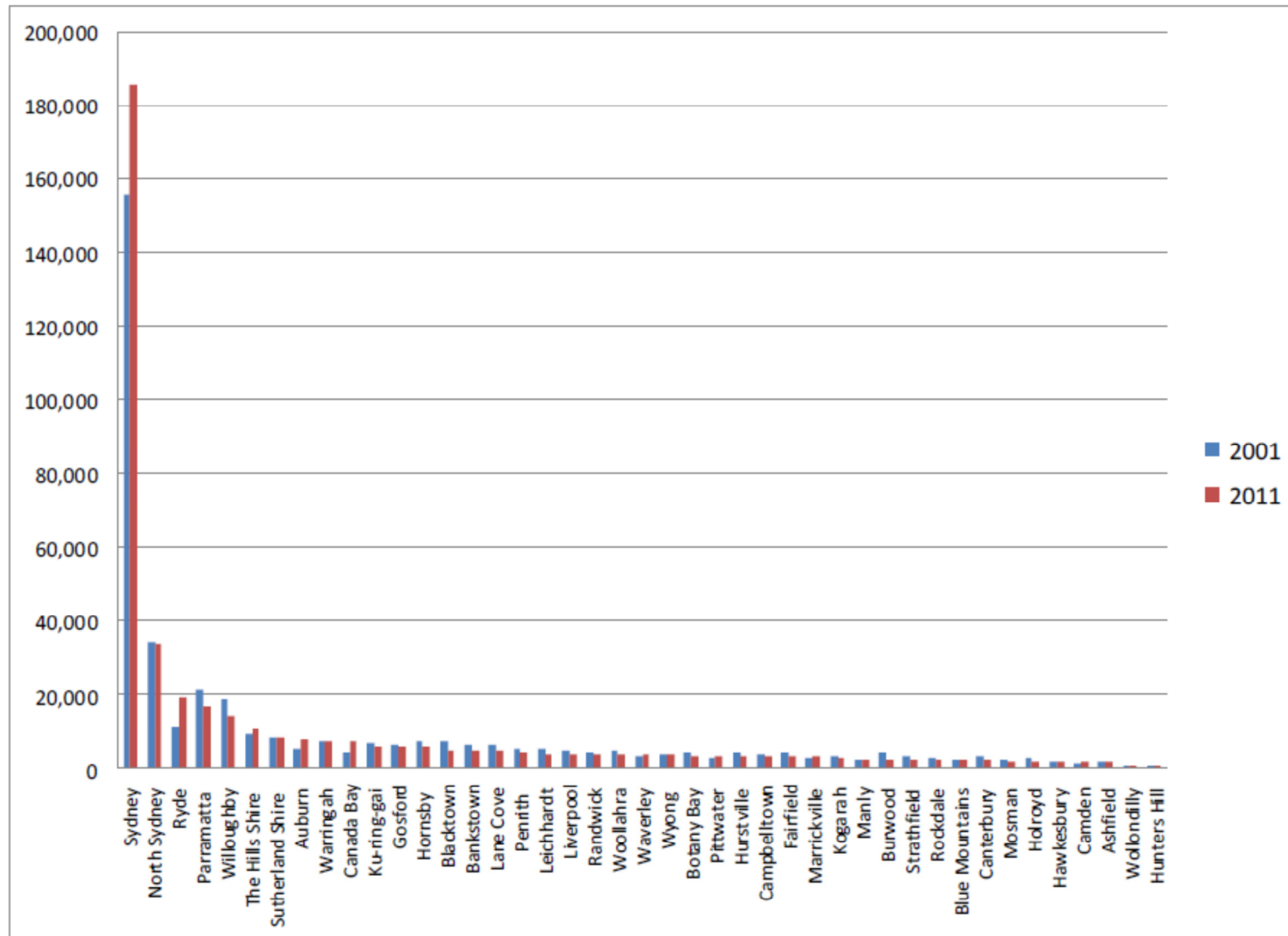
⁴⁰ Other disadvantaged groups included Indigenous people, people with low socio-economic status, and those from regional and remote areas.

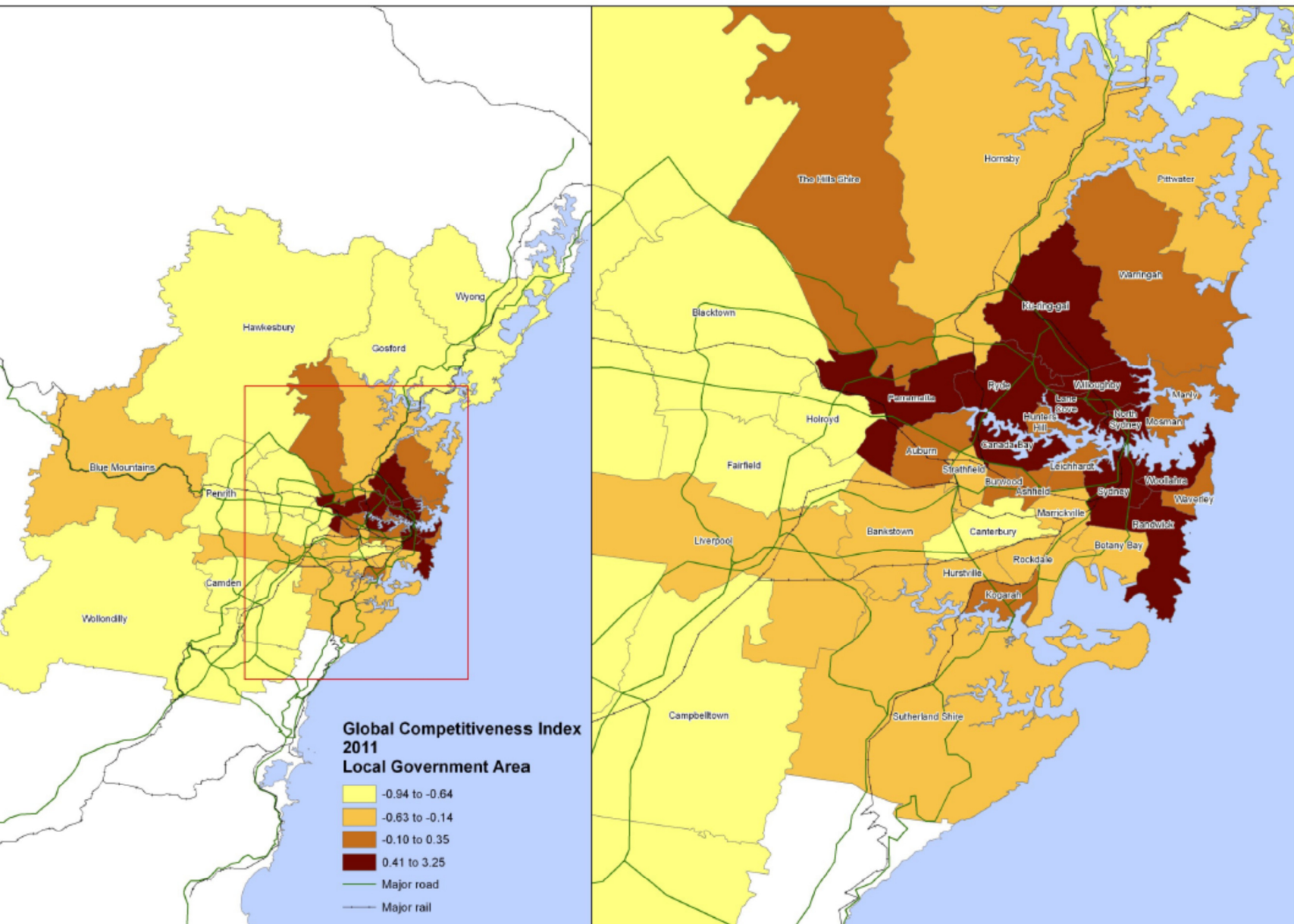
⁴¹ Using the Australian and New Zealand Standard Industrial Classification (ANZSIC), the following divisions were chosen to denote knowledge-intensive industries:

- Information Media and Telecommunications;
- Financial and Insurance Services;
- Rental, Hiring and Real Estate Services; and
- Professional, Scientific and Technical Services.

Notably, health and education divisions are excluded, which biases the ANZSOG Report towards private sector and non-institutionalised knowledge workers (i.e. largely excluding university or hospital knowledge workers).

Figure 4 Number of workers in knowledge intensive industries in Sydney 2001-2011 with Global Competitiveness Index 2011 Local Government Area





This is consistent with research on Sydney by Hu (2010), SGS (2012a) Kelly & Mares (2013) and Kelly & Donegan (2014).

Johnson (2010) similarly established the particular different spatial characteristics of knowledge workers within the Melbourne metropolitan area. In the Melbourne study, Johnson (2010) analysed⁴² workers in five subsets in the industries of:

1. Telecommunications, IT and media
2. Finance and banking
3. R&D and Higher Education
4. Design related industries
5. Cultural industries

Johnson (2010) established that there were distinctive clustered patterns in the relationships between jobs and place of residence for knowledge workers for the Melbourne metropolitan area. Combined these clusters accounted for around 34 per cent of all jobs in the metropolitan area but for over two thirds of all knowledge economy jobs. The two thirds of all knowledge economy jobs were clustered in only around 2 per cent of the total land area of the Melbourne Statistical Region. Within these clusters, there were variances according to location and subsectors of the workforce. IT/media and finance tended to group in inner city clusters. R&D/higher education and cultural industries were more self-contained.

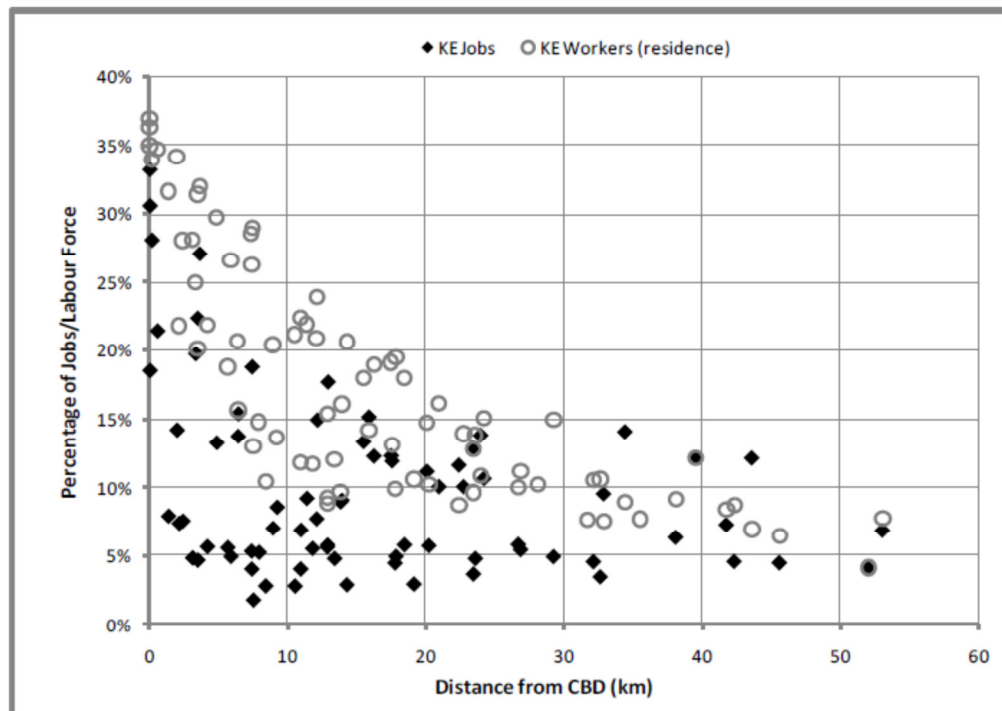
Johnson (2010) also found that Melbourne knowledge workers tended to live in and around the central city (as did Kelly & Mares 2013 and Kelly & Donegan 2014). The central city clustering of residential locations (Johnson 2010) was greater than the central city clustering of knowledge economy jobs (see **Figure 5**). Preference for knowledge workers to live in and around the central city was seen as an attractor for inner city knowledge-intensive jobs (Johnson 2010). Although it could be argued that the agglomeration benefits accrued to *both* inner city jobs and inner city residents through the increased social *and* workplace face-to-face interactions, create knowledge spillover and innovations (as per Knudsen et al. 2007) . Britton and Legare (2005), and Moriset (2003) also found that particular tacit knowledge-intensive industries, such as creative industries were networking rich (both in *AND* out of work hours). These creative industries tended to be clustered in inner areas that supported

⁴² The definition of knowledge worker used in this analysis was industry based, similar to Hu (2010), rather than occupational as used by Florida (2002), Lorenzen and Andersen (2009) or Boschma and Fritsch (2009). Using employee's industry provided the capacity to explore the spatial distribution of particular industry subsets. Using the two different approaches generated somewhat different data for Victoria with Johnson (2010) finding overall only a 4.5 per cent variation in the total number of knowledge workers between the two methods.

physical social networking. Johnson (2010) similarly found that design, cultural and R&D/higher education workers were more likely to live and work in the same statistical local area (SLA). If they did not live in the same SLA, they commuted some distance in to work (i.e. not from adjacent SLAs). This could reflect low income levels of some cultural industry and other creative workers contrasted with high inner city real estate costs (Hall 2010). It can be argued that knowledge capital accumulation and tacit knowledge spillover is not necessarily tied to work activities or working hours, but occurs during cultural, recreational and other private social activities. This face-to-face interaction of social, professional and work activities and time logically would be expected to create a preference among knowledge-intensive and creative workers for more walkable, mixed use inner city areas (that notably predated the car oriented single use type suburbs).

Johnson (2010), while recognising that knowledge economy clustering was spatially linked to high amenity (including housing, transport and services), questioned the lack of self-containment in and around outlying knowledge clusters. Within the Victorian Government's Activity Centres policy in 2010, Johnston (2010) identified six higher order Central Activities Districts (CADs). Johnson (2010) found that there was a dis-connect between the distribution of high-income, high skilled, knowledge economy jobs and workers and where the CADs were located.

Figure 5 Proximity to CBD and knowledge economy place of residence and work for Melbourne



Source: Johnson 2010

Consistent with the research findings of Johnson (2010), Langworthy (2008), using an O*NET analysis of the Melbourne metropolitan labour market, identified that knowledge intensification was not only uneven between industries, occupations and genders but between regions⁴³. Langworthy (2008) found that the skill intensity in the Melbourne metropolitan area, the Melbourne Statistical Division (SD), had grown over the period 1991-2006, consistent with national trends. However, skill intensity had declined for peri-urban Outer Eastern Melbourne residents. This was despite both the Melbourne SD and Outer Eastern Melbourne (Shire of Yarra Range, Cities of Knox and Maroondah) having experienced similar jobs growth during the period. Disaggregating the data down there was declining knowledge intensity, and, consistent with Esposto and Abbott (2011), men fared worse than women, and part-timers fared worse than full-timers. In Outer Eastern Melbourne, only in the higher skilled occupations was there any growth in knowledge intensity. This was, however, weaker than the overall growth in knowledge intensity of employment in the Melbourne SD. Particular local peri-urban areas also fared worse than others. The semi-rural Shire of Yarra Range was the weakest and City of Knox the strongest. Langworthy (2008) concluded that there was a shift in regional resident job creation from high and medium skilled occupations to lower skilled occupations. Men, in particular, were increasingly being employed in occupations with lower skill intensity.

There are some exceptions to the spatial urban concentration of knowledge intensive workers. The advent of Internet technology in the USA saw an increase in telecommuting amongst some knowledge-intensive workers. A comparison of the 1995 and 2001 USA's National Household Travel Surveys (NHTS) found an increase in telecommuting (US Department of Transportation 2008). The 2001 NHTS established that 10.4 million workers telecommuted at least occasionally (at minimum, once in the previous two months) instead of travelling to their normal workplace. The most likely telecommuters were found to be workers in technical, professional and sales/service fields of employment (and increasingly older workers with more than double the number of older workers being 65 and over). The groups increasing in telecommuting numbers from 1995 to 2001 also included persons in high income households, suburban residents, workers with longer distance commuters, and males (with the percentage of female telecommuters declining). The increased telecommuting was attributed to the advent of electronic communication and increased acceptance of its use for professional occupations (US Department of Transportation 2008).⁴⁴

⁴³ The O*Net considers the knowledge intensification of occupations over time - see also Sheehan and Esposto 2001, Esposto 2010, Esposto and Abbott 2011.

⁴⁴ Longer commutes were also associated with higher income male workers, which is consistent with the often higher residential amenity away from some inner city areas in the USA (Frey 2014). This is not necessarily

Surveys specifically on telecommuting amongst knowledge workers do not indicate high levels of telecommuting activity (generally lower than 10 per cent of the workforce on any day). An Australian survey of 157 companies (including 98 of the 1998 Business Review Weekly 'Top 100' companies) and a European study on home-based telework, found the proportion of telecommuters being far below predictions, typically below 10 per cent (Lindorff 2000, Baker, Avery and Crawford 2006). Nationally the 2011 ABS Census (2011a) indicated 5 per cent of all employees worked from home (somewhat lower than the 2006 census at 5.5 per cent). In 2011, white collar and more knowledge-intensive occupations (Managers 11 per cent, Professional 5.9 per cent, and Clerical and Administrative occupations 7 per cent) had much higher levels of working from home than blue collar and retail occupations at 1 per cent to 2.5 per cent. Johnson (2010) found in Melbourne that Design and Cultural industries workers were 10 times more likely to work from home than other workers. However telecommuting or working from home does not always mean spatial dispersement. This same category of workers was also found to be more likely to work and live within the same local area, which often means inner city. Overall employee interest in telecommuting has been noted as being higher than actual telecommuting. Many of the problems with telecommuting have been found to be related to social isolation (Baker, Avery and Crawford 2007, Marshall et al. 2007, Mulki et al. 2008, Fay and Kline 2011). Another means of telecommuting that shows possibly more promise, in terms of social isolation, is telecommuting from community or workplace based smart work hubs (Buksh & Mouat 2015, Finch, Devereux, James & Nott 2015). Smart work hubs, in Australia, have operated from, or are being proposed for outer suburban or metropolitan hinterland sub-centres to minimise commuting. There is however, little to suggest that smart work hubs can be scaled to compensate for the agglomeration draw of CBDs or major centres and their role is likely to be complementary in terms providing workers flexibility.

The conclusion from the literature review into the spatial distribution of human capital within cities is that an increase in the employment and residential density of knowledge-intensive workers delivers economic benefits. Within a metropolitan city area it is logical to assume, (with cities not being a consistent density) that increasing the density of human capital within the denser parts of cities with high levels of connectivity will lead to higher productivity. This appears linked to increasing the efficiency of knowledge spillover and labour market exchange. Importantly, as knowledge-intensive services, advantaged by agglomeration, become increasingly important to the Australian economy, there is likely to be even stronger demand for inner city knowledge-intensive economic opportunities and spaces. This

comparable to Australian cities with their higher amenity inner city and middle suburban areas (Forster 2006, Dodson 2008, O'Connor & Rapson 2003, Kulish, Richards & Gillitzer 2011, Kelly & Mares 2013, Kelly & Donegan 2014).

suggests an increased centrality in terms of the urban structure for knowledge-intensive cities. An increased centrality or concentration, in turn, raises issues of equity of access and urban efficiency arising from increased congestion. Rawnsley & Spiller (2010) have, for example, argued that it should not only be the inner city and CBDs where these opportunities should be developed, contending that there should be focus on developing the highly productive CBD type environments in other parts of metropolitan areas. These issues will be explored in Chapter 8.

Chapter 5 – Knowledge intensification of ICT

5.1 Knowledge intensification of modern ICT, the Internet and the link to the knowledge economy

This chapter examines the interrelationship between the spatial characteristics of knowledge economic activity and ICT. The modern knowledge economy has been variously described as the 'new economy', 'high tech economy' and the 'digital economy' (Hacker, 2006, OECD 2007, AIIA 2014). The modern knowledge economy is extrinsically linked to (on-going) advancements in ICT (Castells 2005, OECD 2007, Sosa 2015, Oomens & Munisteri 2015, Tomer & J Kane 2015, Yigitcanlar 2015). The importance of ICT to the modern economy is linked to the data intensification of both ICT technology and infrastructure. It is somewhat trite to state that ICT technology and devices have rapidly intensified their information capacity in recent decades.⁴⁵ Intensification can be seen with increased data capacity (memory and processing) of ICT technology (devices, networks) and the resulting development of ICT infrastructure to process the data intensification. The impact of this intensification of ICT is higher economic output (OECD 2007, AIIA 2014, Sosa 2015, Oomens & Munisteri 2015). Sosa (2015) and Oomens and Munisteri (2015), for example, found that improved broadband⁴⁶ technologies and speed positively impacted on economic activity and that this had been consistent over time.

The impact of modern ICT can also be considered in the context of the wider impact that technologies have on urban form. Kim, Claus, Rank and Xiao's (2009) work on analysing the impact of a wide range of available technologies and their unit costs on urban form over the 20th century provides an explanation of how technology, including ICT, is driving and will continue to drive change in urban form. They found that in the period 1900-1950, the available technologies (rail, water sanitation, elevators and other building technologies) led to an increase in the growth and density of cities. For the period 1950 - 1980 (mainly driven by cars and freeway construction technologies) urban population increased by 72 per cent but land use increased by 146 per cent, and urban density dropped by 70 per cent. The period 1980 - 2000 saw an increase in available ICT technologies. The dominance of these technologies allowed for a significant reduction in the lowering of urban density. This occurred, Kim et al. (2009) contended, because the lower costs of the available technologies

⁴⁵ See ICT 'laws' of increasing ICT capacity: Moore's Law (transistor speed), Butter's Law of Phototonics (data through fibre optics), and Kryder's Law (on hard disk capacity) (see also Schaller 1997, Tuomi 2002, Walter 2005, Shiltsev 2011).

⁴⁶ A broadband connection is a channel over which digital data services such as Internet and digital TV can be delivered (Oomens & Munisteri 2015).

provided the benefits of agglomeration and proximity to drive urban form back towards density. The geography of the Internet and its incorporation into knowledge economic activity though has not strongly influenced spatial planning (Banister & Hickman 2006, Kim, Claus, Rank & Xiao 2009, Alizadeh, Shearer & Sipe 2015). Alizadeh et al. (2015), in respect to Australia, have noted that there is a dearth of evidence-based research on the implications of telecommunications infrastructure on urban and regional Australia.

At the turn of the millennium there was a debate over the impact of the Internet and the knowledge economy on 'distance.' A new school of thought emerged that proposed that modern economies would be transformed spatially by the technological transformational powers of ICT, particularly the Internet (Brulhart and Sbergami 2009). The emergence of the Internet and the knowledge economy was even being touted by some as the "end of geography" with the future requirement of cities questioned (see S. Graham 1996 for the early debate). This school considered that there would be an end of distance with the removal or the lessening of the spatial characteristics for new knowledge based economic activity. At a global level, the future 21st century global economy activity was expected to level out and disperse around the world. Cairncross (1997) argued that radical improvements in the cost and efficacy of long-distance communication and transportation would see the world become characterised by the free movement of goods, people, and ideas.

The potential effect of the Internet and ICT to disperse urban activity was rejected by a number of writers (see Warf 2001, Page & Phillips 2003, Morgan 2004, Gorman, Schintler, Kulkarni, and Stough 2004, Bannister & Hickman 2006). As Gorman et al. (2004) contended this was because the new telecommunications and IT compressed time (see also Rosa 2013) and space; it therefore reduced, but did not eliminate the effects of distance and location. A common misconception had arisen that the Internet and IT were virtual entities residing in cyberspace, which they were not (Leamer 2006). A more nuanced view of the impact of the Internet subsequently developed. Banister and Hickman (2006) asserted that the complex set of interdependencies in the transport, ICT and urban planning field were not well understood, foreseeing not dispersment but urban concentration at the international level with 'technopoles' of growth around airports and public transport with urban de-concentration and dispersal also occurring at the same time. Similarly Devriendt et al. (2008) contended that there was a nuanced spatial reality that co-existed. While there was a greater trend towards city-to-city digital city networking and interrelationships between key cities creating digital hubs, there was also a spatially free context. Devriendt et al. (2008) referred to the different contexts as 'cyberplaces' - the Internet physical fabric and 'cyberspace' - the virtual, immaterial world where distance did not matter.

Morgan (2004) contended that the 'geography is dead' thesis was grossly over-estimated because it conflated spatial reach with social depth. The error was to assume that, as information diffused across borders and through organisations, understanding did as well. Paradiso (2003), considering the research on the geography of the Internet and ICT infrastructure, also found strong arguments for the contention that while the Internet allowed for more localised freedom, it was not removed from the advantages of proximity and agglomeration, or the traditional economic, social and political realities⁴⁷.

The levelling out of economic activity argument also failed to consider the spatial concentration of ICT infrastructure and human capital. Benefiting from ICT is intrinsically linked to human capital and physical access to ICT technologies and infrastructure. As Stiglitz (2006) argued:

Countries that want to participate in the new world of high-tech globalisation need new technologies, computers, and other equipment in order to connect with the rest of the world. Individuals who want to compete in this global economy have to have the skills and resources to do so..... (even) within countries, too, the gap between the rich and the poor is increasing—and, with it, the gap between those who can effectively compete globally and those who can't.

The differing levels of Internet access was largely the result of the broader economic, social, infrastructure and cultural inequalities, creating a 'digital divide' within many countries and cities (Moss and Townsend 2000, Warf 2001, Paradiso 2003, Gorman et al. 2003, Kellerman 2004, Rutherford et al. 2004, Stiglitz 2006, Oomens & Munisteri 2015, Tomer & Kane 2015), including within Australia (Willis and Tranter 2002, Department of Broadband, Communications and the Digital Economy 2009, ABS 2009, and Tucker 2010).

The evidence on the clustered and urban spatial characteristics of ICT is confirmed by examining a range of studies into Internet and ICT economic and social activity. Studies worldwide of ICT and high technology industries demonstrate strong tendencies to cluster or agglomerate with like industries (Saxenian 1994, Giovannetti, Neuhoff & Spagnolo 2005, Strange et al. 2006, Woodcock & Adhikari 2011, Moretti 2012). For example, the importance of physical proximity to fellow ICT industry players was found in early studies of the computer industry in Silicon Valley (Saxenian 1994) and also with international and Italian peering activity (peering being network cooperation of Internet Service Providers)

⁴⁷ A consideration of goods trade data research does not see the death of distance as a factor in the world economy with distance continuing to be relevant in international trade (Leamer and Levinsohn 1995, Leamer and Storper 2001, Carrère and Schiff 2005, Disdier and Head 2008, Berthelon and Freund 2008, Boulhol, de Serres and Molnar 2008, Marks 2009).

(international peering – Woodcock & Adhikari (2011) and Italian peering - Giovannetti, Neuhoff & Spagnolo 2005). Essentially, physical proximity was found to be beneficial by Saxenian (1994) for informal, cooperative social relations playing a crucial role in enforcing knowledge exchange while Giovannetti, Neuhoff and Spagnolo (2005) found physical proximity reduced costs of monitoring and punishing deviant behaviour within an industry where cooperation was essential. Woodcock and Adhikari (2011) found in looking at 142,210 Internet carrier interconnection agreements that language, geographically proximal national neighbours and frequent commercial trading partners were factors in peering partnerships. In and around Washington DC, despite continued growth, suburbanisation ICT based activities were concentrated in the central city and the major suburbs (Maeng & Nedovic-Budic 2010). This was because ICT firms were locating where there was better accessibility, better ICT infrastructure, and higher urban density.

Similarly, new multi-media industries demonstrate high levels of clustering in urban environments (Moriset 2003, Britton & Legare 2005, Searle & De Valence 2005, Johnson 2010). In an examination of Sydney's multi-media firms, Searle and De Valence (2005) found firms concentrated around the central city. This was partially associated with an emerging inner city multimedia cluster. A third of firms were found to be reliant on multimedia services of other inner city firms with frequent input and output linkages between firms in associated industries. Importantly, where other firms acted independently of these linkages they benefited from agglomeration advantages of inner Sydney's high levels of Internet infrastructure and its transport accessibility for the wider metropolitan area talent pool. These factors, in part, provided the environment for emergence of a new industry.

Research by Gorman and Malecki (2000) and Gorman et al. (2003) on Internet traffic showed that in the USA the Internet backbone network traffic disproportionately agglomerated in the largest metropolitan areas. The result was a spatial hierarchy in the USA that saw the coasts being more connected to each other than they were to the interior of the country. The coasts were the core of activity and the interior was at the periphery of activity (Gorman & Malecki 2000, Tomer & Kane J 2015). Gorman and Kulkarni (2004) have asserted that while information networks allowed direct global connections at speeds and volumes not possible before between distant places, geography and distance were still important factors. This was particularly with the location of super connected infrastructure nodes in major urban areas with important economic, business and security roles.

The spatial mapping of economic and social ICT telecommunication activity, including mobile and smart phone, also indicates strong spatial effects (Gonzalez, Hidalgo & Barabasi

2008, Ratti, Sobolevsky, Calabreses, Andris, Reades, Martino, Claxton & Strogatz 2010, Scellato, Mascolo, Musolesi & Latora 2012, Frank, Mitchell, Dodds & Danforth 2013). Telecommunication and social media have been found to be used by people to remain in contact with other people who were spatially close to them (more so than to people who were at a greater distance such as in other cities or regions). This was not to say that ICT was not connecting people at distance but that digital communication activity was subject to 'distance-decay'. 'Distance decay' is the effect of distance on cultural or spatial interactions, in that interaction between two locales declines as the distance between them increases (Fellman, Getis, & Getis 2005). That is, the further the distance, the lower the levels of communication. Distance decay with ICT has been identified with a range of telecommunication technologies including landline telephones and Internet smart phone social media. Ratti et al. (2010) examined millions of landline calls within the UK and calculated the call time ratio for regions (defined as the percentage of time a region talked to itself) and found that telephone communications were intertwined with geographical location. Communication patterns demonstrated the relevance of regional administrative boundaries which reflected regional containment patterns and distance decay.⁴⁸ Scellato et al. (2010), examining four online social networks (OSNs), also found that there was a vast portion of users with short-distance links and that clusters of friends were often geographically close. However, there were differences depending on the focus of the OSN – those OSNs focused on geographic dimension of social interaction (BrightKite and FourSquare) had high nodal locality, while information and news sharing had lower nodal locality and geographic clustering values.

Distance decay is also likely to be the result of the limited nature of people's physical mobility, which was found to be, despite modern ICT and Internet social networking, reasonably consistent and predictable between work and home (Gonzalez et al. 2008, Frank et al. 2013). Gonzalez et al. (2008) considered human mobility from European mobile phone calls using the location of mobile phone towers⁴⁹. A high degree of temporal and spatial regularity was found, and despite a diversity of individual travel histories, people followed simple reproducible patterns, mainly between home and work. People devoted most of their time to just a few locations with the remaining time (with diminishing regularity) to a wide diversity of other locations (from 5 to 50). Frank et al. (2013), using global positioning system (GPS) geo-location characteristics of 37 million tweets of 180,000 individuals who used Twitter in the USA, was able to determine the patterns of individuals' mobility (their *radius of gyration*). Frank et al. (2013) found that most Twitter activity in the USA was in urban areas. However they also found that individuals with higher mobility tended to appear in areas of larger population density. Messages authored by small radius individuals tended

⁴⁸ The average number of calls to outside regions for all regions was only 37 per cent. Scotland was the region least connected to the other parts of the UK (only 23.3 per cent of calls were to outside regions).

⁴⁹ Taken from a sample of 6 million calls made by a random selection of 100,000 people over a six-month period.

to appear in less densely populated areas. This was so even when factoring out likely tourist tweets. Distinctive networking patterns in the knowledge economy were also identified by Eagle, Macy and Claxton (2010) in their UK analysis of the origin of mobile phone use (calls and texts) cross referenced against a UK government index of multiple deprivations.

Eagle et al. (2010) identified a clear link between more diverse and wider ties, and social and economic opportunities. The causal direction of this relationship (whether greater networked ties lead to social and economic wealth and well-being, or whether social and economic wealth leads to greater ties) was not well established. However it is clear that social network diversity is a strong signature for economic development. The analysis of various telecommunication and social networking patterns indicates strong spatial influences in knowledge-intensive cities. Tomer and Kane J (2015), examining broadband adoption in the USA, arising from the US Census Bureau survey questions from 2013 and 2014, found that while there was a high level of broadband adoption (75.1 per cent) it was spatially, socially, demographically and economically uneven. In terms of spatial distribution, 'tech centres' and larger metropolitan areas had much higher adoption rates (up to 88.2 per cent) than country areas⁵⁰ and smaller, less economically successful cities (with rates as low as 56.2 per cent). The link between wider, inter urban movement and higher social media and ICT activity, is consistent with the knowledge economy literature that identified the trend toward city to city networking (Devriendt et al. 2008) and 'technopole' cities of knowledge workers (Banister & Hickman 2006).

5.2 The urban intensification of the physical infrastructure of the Internet

It is widely accepted that the critical infrastructure of the modern knowledge economy includes information networks, like the Internet and fibre optic telecommunications (Gorman et al. 2003, Gorman, Schintler, Kulkarni, & Stough, 2004, Castells 2005, Ling, Z 2010, Tucker 2010, NBN 2013, AIIA 2014, Finch et al. 2015, SAS 2015). Modern knowledge-intensive cities are therefore not just dense physical agglomerations of buildings, transport networks and the key centres of economic, social and culture life. They have become the dominant centres for telecommunications and the nerve centres of the electronic networks that radiate from them (Graham, S 1996, Graham, S & Marvin 2001).

To understand spatial characteristics of ICT and the Internet it is necessary to consider the physical nature of ICT. Irwin (2008, p.1) succinctly stated that underpinning ICT and

⁵⁰ With lower levels of wealth and higher aged demographic.

computing is a “*collection of hardware components*” that consists of physical “*interconnections of different types of the same core elements: processors, memory, disks, I/O devices, and network links*”. The essential physical elements of the Internet are the physical fibre optic cables and other hardware such as data centres, servers, bridges and hubs, routers, personal computers, all of which have a physical location and structure (Gorman & Kulkarni 2004). The physical elements of the Internet that this thesis will focus on are fibre optic networks, data centres, and Internet exchanges.

The world’s Internet can be defined as a network of networks, consisting of many thousands of Internet service providers or carrier networks, interconnected with one another in a sparse mesh or grid (Woodcock & Adhikari 2011). These networks are in the physical form of long haul underground fibre optic cables which enter cities and (most often) surface at co-location facilities, being the network access points for a metropolitan area network or Internet exchange (Gorman & Kulkarni 2004). These operational networks then choose from a variety of protocols and technologies to set up an operational network to connect their key assets. There are a wide variety of protocols and networks that utilise the leased lines of physical fibre networks meaning that the often-confusing part is that the USA Internet infrastructure is a collection of interconnected private lines and networks. In one sense, the Internet is similar to other forms of communication and transport in that a physical network supports it. With the Internet, it is a network of fibre and cables that link a mass of computers.

The Internet network infrastructure has similarities with other networks in that all networks share a common construct of nodes connected by links (Gorman & Kulkarni 2004). The key Internet fibre infrastructure is known as the Internet backbone with the highest grade of the backbone known as Tier 1. The Internet bandwidth website (2012) has noted there is debate on what constitutes a Tier 1 Internet Backbone. Internet Bandwidth (2012) contends, on its website, that *Tier 1 Internet Backbones* are generally understood to be “*a collection of optical fibre, high-speed routers, laser transmitters and receivers and sophisticated switches that keep the Internet voice, and video and data bloodstream coursing across the globe*”. Peering is where data is transferred by exchange i.e. for free, as distinct from where interconnecting is through transit agreements which are commercial contracts (Woodcock & Adhikari 2011). However, this movement of data across the globe has a distance-cost relationship. Gibbard (2004) has noted that Internet transit costs vary around the world with traffic in the so called ‘Internet core’ regions being relatively cheap, with greater expenses being in areas with lesser telecommunication connectivity and infrastructure. That is, moving data across the Internet is significantly cheaper when it does not have to be carried across long distances (Gibbard 2004).

To further understand the spatial reality of the Internet and its physical network of supporting ICT infrastructure it is worth reviewing the network theory research on Internet activity agglomeration. Using network theory analysis, Gorman and Kulkarni (2004) found that the US Internet network at the turn of the century could not be categorised as a random chaotic network but instead could be characterised by strong spatial bias with significant clustering at the local level, with local clustering forming “small worlds” (Gorman & Kulkarni 2004). According to Schintler et al. (2005), such ‘small worlds’ in complex networks such as the Internet have been found to tend towards a heavy tailed connectivity distribution (with an inverse relationship between the number of nodes and the number of connecting links). This is in contrast to a random distribution (with an exponentially declining probability to highly connected nodes).

In the case of incremental growth in a complex network, new nodes tend to be more likely to connect with existing well-linked nodes. Consequently, hubs tend to reinforce themselves. Such networks are often coined ‘scale-free networks’. The extent of the spatial concentration that occurs with Internet activity can be gauged by estimate – that in 2004 the average performance of the Internet would be cut in half if just 1 per cent of the most highly connected routers were incapacitated (Gorman et al. 2004). Further, this analysis of the vulnerability of the USA Internet revealed the important role of distance (there was a reoccurring importance of 300 miles as a threshold distance) in the structural properties of the Internet as a small world and scale free network. As Gorman et al. (2003) stated, it would appear that in the case of vulnerability, distance has avenged the premature calls of its demise as proposed by Cairncross (1999).

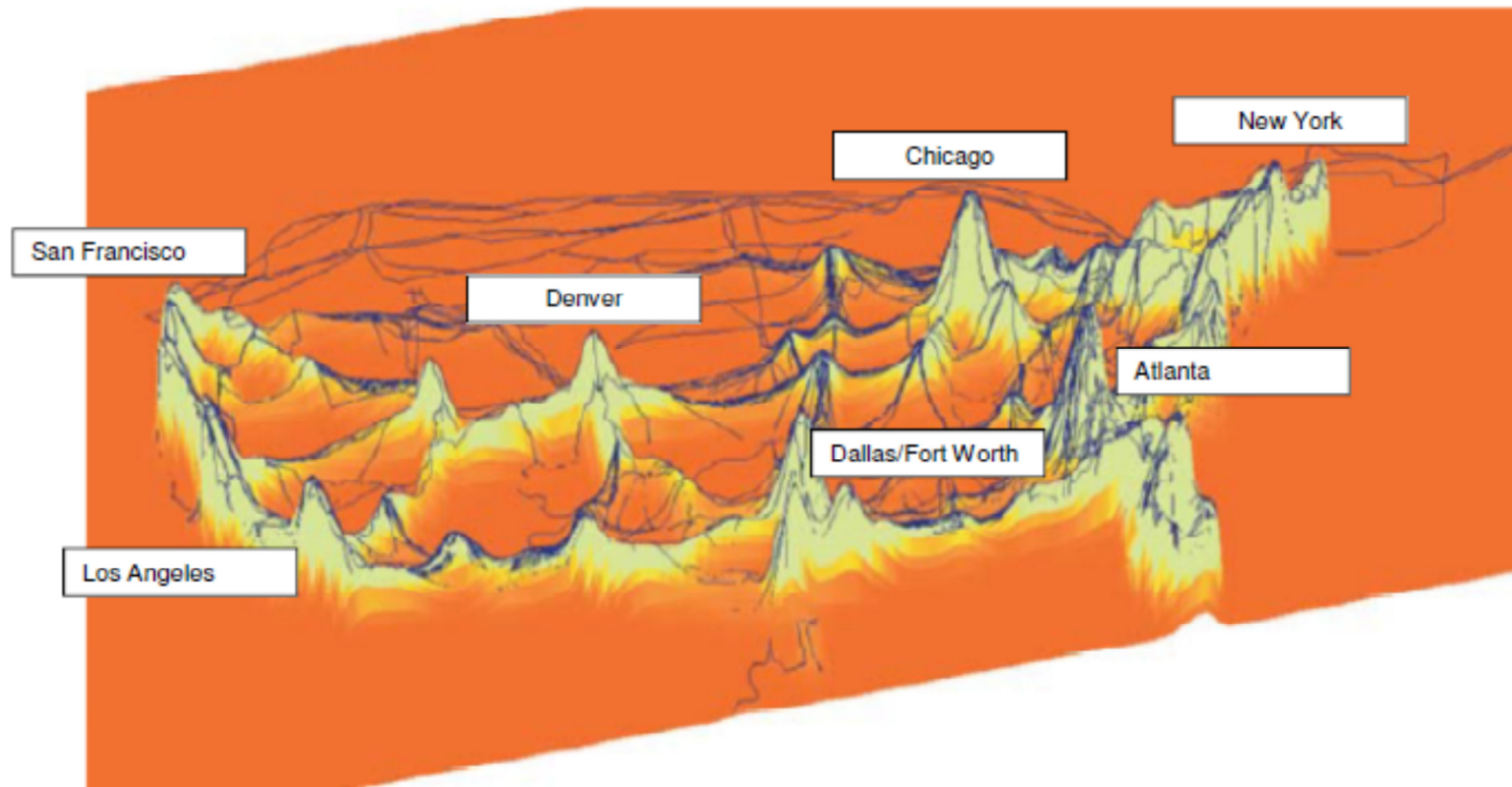
Schintler et al.’s (2005) research found major cities such as Chicago, San Francisco and Atlanta to have the highest global connectivity and the key hubs to other parts of the USA. Washington DC was also prominent early in the urban hierarchy of backbone connections, being a key location for the start of the Internet’s evolution. Washington DC however decreased in prominence as scale became more important. This saw cities such as New York, with their large market size, begin to dominate the bandwidth and roll out Internet infrastructure. **Figure 6**, which maps the Internet backbone network by bandwidth density demonstrates the connectivity of urban areas in the United States, with most of the major points of connection being near or within major population areas (Schintler et al. 2005).

Notably the Internet backbone network hubs identified in **Figure 6** line up with airport hubs that have increased airport passenger enplanements over a number of decades, as

identified in **Figure 7**. Both figures clearly demonstrated the long-term historic trend of increased importance of major inland cities, such as Chicago and Atlanta and to a lesser degree Dallas/Fort Worth and Denver, as key Internet hubs. More recent USA airport activity data confirms the continued relationship between airport activity and knowledge economic activity. Fuellhart, Ooms, Derudder and O'Connor (2016) found that in the period 2003-2013 there were distinct regional patterns in airport activity, tied, in particular, to tourism activity and urban megalopolis⁵¹. The lowest performing regions were clustered in the rust belt states and rural areas. It can be concluded that information or knowledge in the modern economy has increasingly been moving through major urban hubs, by the Internet but also by human transfer. This supports a conclusion that codified and tacit knowledge transfers are important and complementary in the modern knowledge economy.

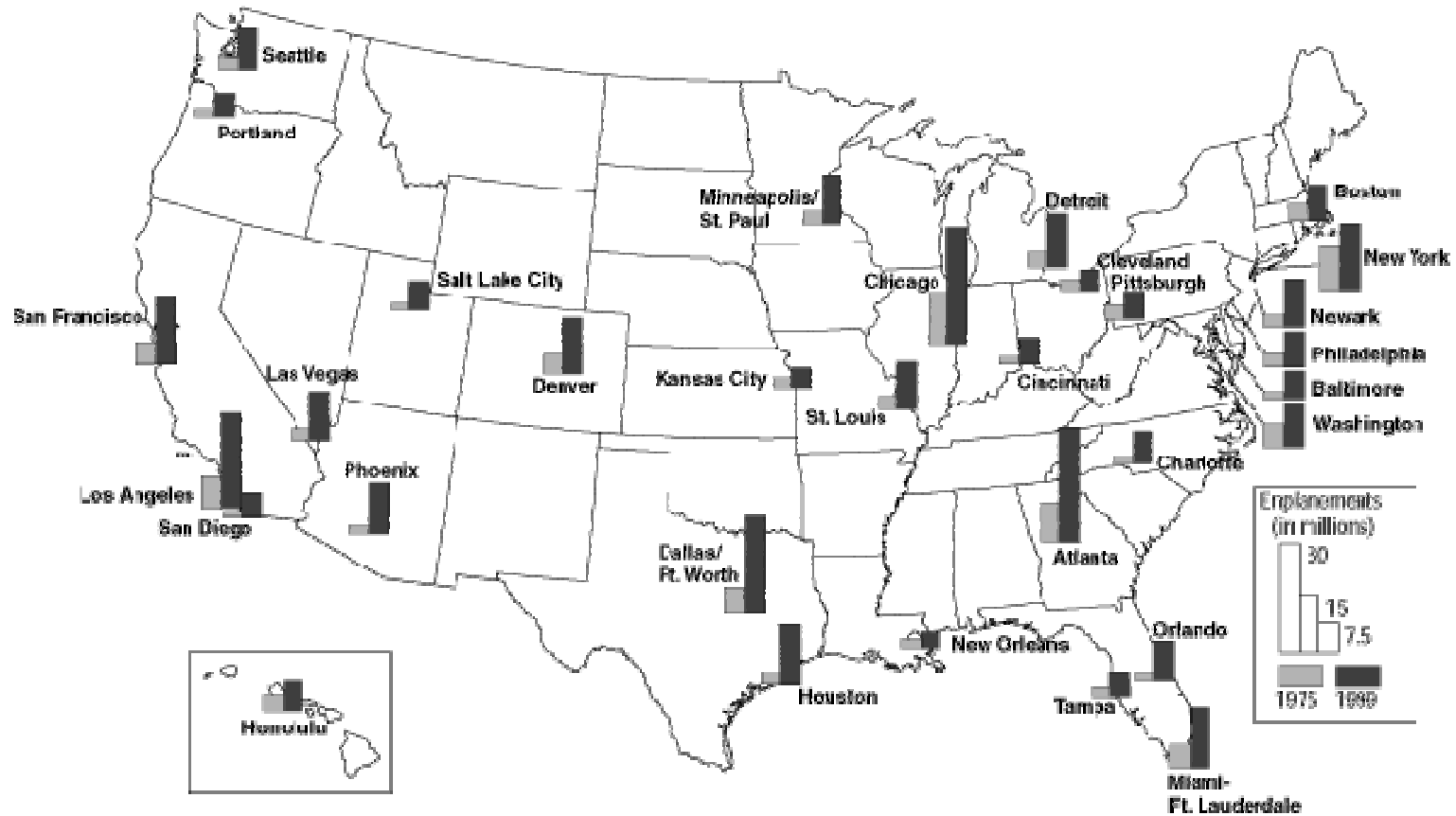
⁵¹ There are some complexities to the Fuellhart et al. (2016) research as it includes a diversity of services, including low cost carriers and subsidised regional travel.

Figure 6 The backbone density by bandwidth density for the United States



Source: Schintler et al. (2005)

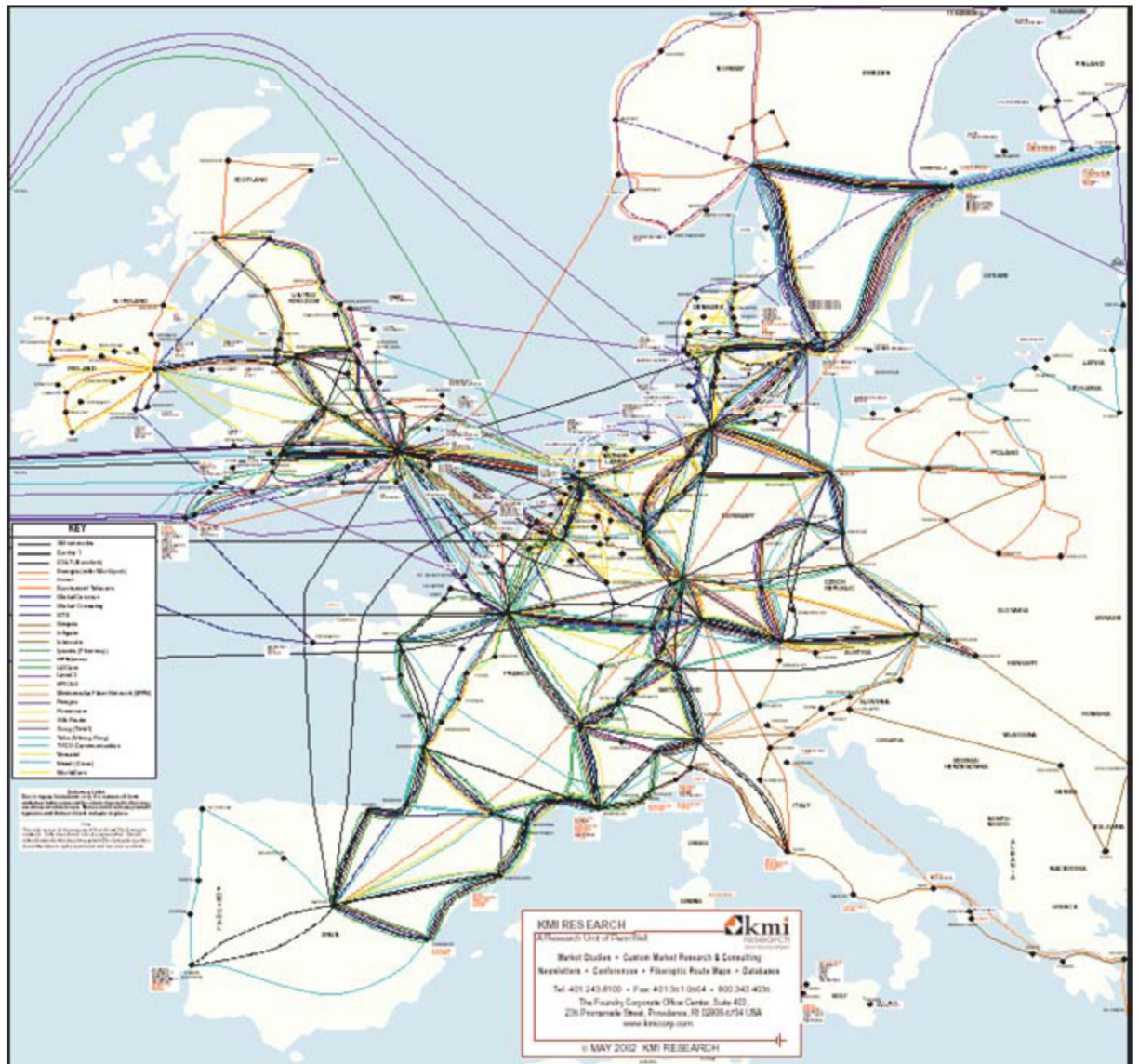
Figure 7 Enplanements at large USA air traffic hubs 1975 and 1999



Source and Note: This data includes hubs that were classified as large hubs in either 1975 or 1999 or in both years. A large hub is a geographic area that enplanes 1 per cent or more of nationally enplaned passengers. A hub may include more than one airport. Source: Civil Aeronautics Board (1976), U.S. Department of Transportation (2001)
https://2bts.rita.dot.gov/publications/transportation_statistics_annual_report/2000/chapter4/enplanements_at_major_us_airports_map.html

An analysis of the European fibre optic telecommunication networks operating in more than one country similarly found that key hubs dominated, with the most connected cities being Hamburg and London (Rutherford et al. 2004). Hamburg's prominence was due to its role as a hub or gateway. Similarly, Prague and Copenhagen also acted as a gateway. By country, the United Kingdom was at the top, followed by France and Germany. These three nations had an overall number of connections that was much higher than every other country in Europe. By the number of connections per capita, the relatively small countries, Luxembourg and Denmark, were at the top of the list, either because of their relevant geographical position or because of their higher diffusion of telecommunication technologies. Similarly, some smaller cities were at an advantage because of their role as a traditional node (see also Moriset 2003 with Lyon).

Figure 8 Pan European fibre optic network routes planned or in place



Source: Rutherford et al. 2004⁵²

⁵² Figure 8 shows the map of 'Pan European Fiberoptic Network Routes Planned Or In Place' from the telecommunications consultancy KMI Research. This displays the extent of the infrastructures of 27 alternative (i.e. generally non-incumbent) pan-European telecommunications companies as of the 3rd quarter of 2001, and the cities interconnected by each network.

The overlaying of newer infrastructure over existing infrastructure is well established. Gorman et al. (2003) and Moriset (2005) have established that the physical infrastructure of the Internet in the USA and France respectively was the physical fibre networks that was typically laid over rights-of-way established by physical transportation networks – roads, railroads, waterways, pipelines, or sewers. Fibre was then laid connecting several cities and then either leased to provide connectivity to other networks or operated by the constructing network. In his study of Internet new economy firms in France's second largest city Lyon, Moriset (2005) found that, as the optic fibre had followed existing infrastructure, such as major transport, nodes such as Lyon were among the first to be serviced with higher grade Internet infrastructure. Therefore, modern ICT, such as the Internet, is not removed from previous layers of communication technologies and their spatial characteristics.

The overlaying of newer infrastructure over the old is also demonstrated in Australia with the evolution of the telegraph to the Internet (ACCA 2006, Tucker 2010, BITRE 2014a). The telegraph was the first binary electronic digital communication ICT, which Wolf (2000) has noted, was part of a broader digital or binary communication pathway that had been evolving for centuries.⁵³ In Australia, the evolution from the telegraph has followed a reasonably linear pathway, in terms of ICT technology and infrastructure as well as organisational history. The postal service and the telegraph (inclusive of telegraph exchanges) all began within the domain of the colonial and then Commonwealth Post Master General. Voice communication infrastructure and services then evolved with telephone exchanges being key ICT infrastructure centres. Organisationally, the Post Master General evolved into Telecom, and then into Telstra. Telstra's Internet exchanges and points of presences (POPs⁵⁴) evolved out of telegraph and telephone exchanges with additional Internet exchanges having now being developed by Telstra telephony competitors and newer Internet Service Providers (ACCA 2006, Tucker 2010, and BITRE 2014a). The Australian Internet infrastructure therefore can be described as having been built or overlaid on the spatial 'bones' of previous communication technologies.

The reason for the spatial concentration of ICT infrastructure, it would appear, is because ICT infrastructure and ICT technologies continue to support the evolution of face-to-face knowledge and management economic activity centred on cities of scale. This conclusion is supported by a consideration of technology diffusion. Access to newer ICT technologies has

⁵³ The telegraph relies on the Morse code which contains three basic elements (the dot, the dash, and the silence or lack of current between pulses) and is essentially binary with the dash being a pulse three times as long as the dot (Wolf 2000).

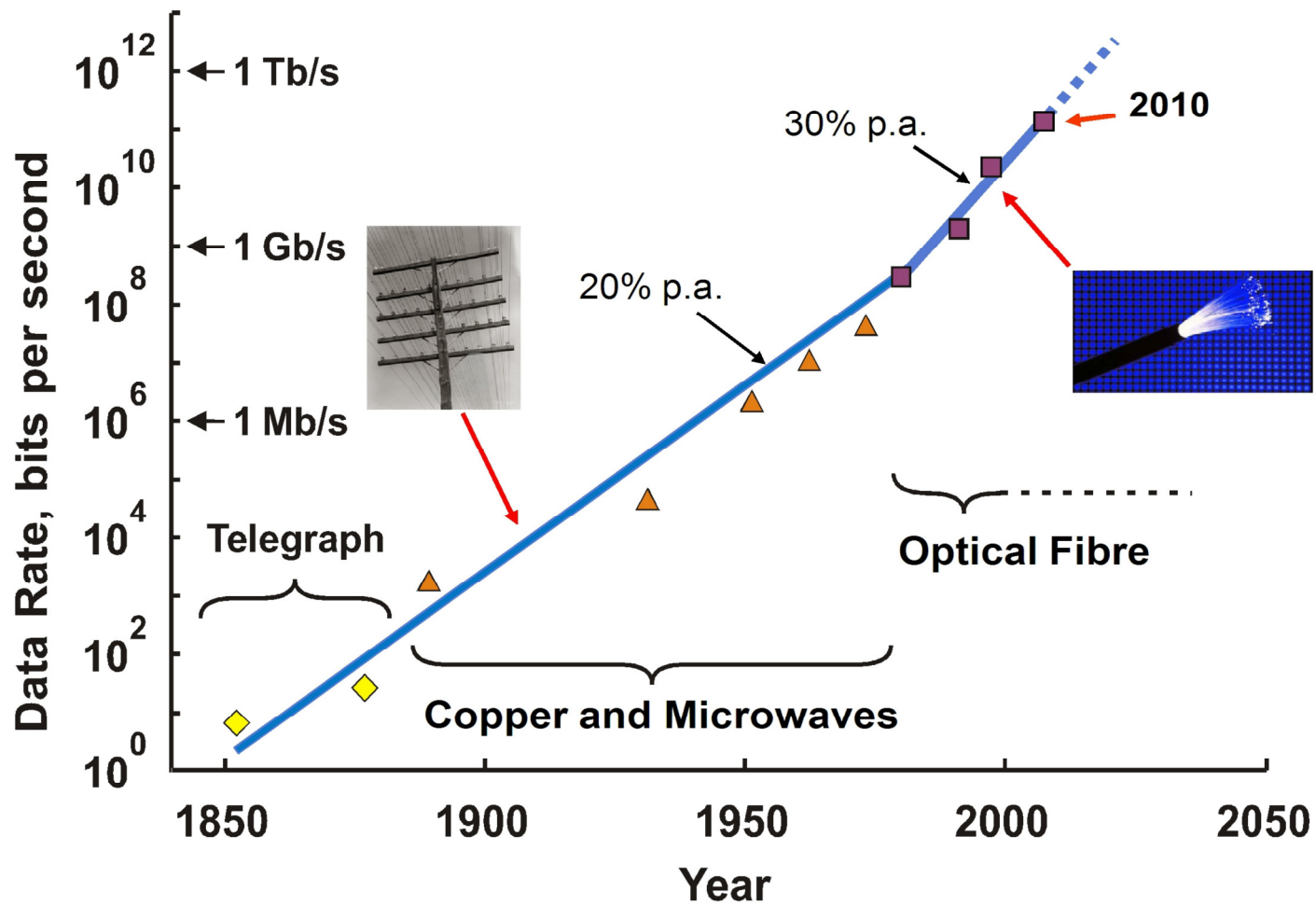
⁵⁴ A POP is a local physical access network node for data exchange for the Internet. POPs houses servers, [routers](#), [ATM](#) switches and digital/analog call aggregation systems. A POP may either be part of a telecommunication providers' facility that the [Internet service provider](#) (ISP) rents or a location separate from the telecommunications provider. ISPs typically have multiple POPs, sometimes numbering in the thousands (ACMA 2007).

followed a hierarchical diffusion pattern: starting first in large cities, where the largest markets are found, and then progressively to smaller places (Malecki 1999, Gorman et al. 2003). This has meant a first starter advantage being reinforced in major cities with regional areas often not receiving benefits from ICT because they intrinsically lag in their access to ICT. Regional Australia is an example of this ICT access lag (ACCA 2006, IEAust 2010a, BITRE 2012, AIIA 2014). The economics of rolling out fixed network infrastructure to Australia's regional areas has been strongly influenced by the distances involved. This has meant regional Australia's infrastructure costs have been more expensive compared to other national networks and this has hindered the regional ICT infrastructure roll out (ACMA 2007, IEAust 2010a, BITRE 2012a, AIIA 2014).

5.2.1 Data intensification and data centres

To fully understand the spatial characteristics of the ICT infrastructure, it is necessary to consider the impacts of the explosion in Internet and digital data. The progress made in science and information technology and the resulting complexity of economic and social change have led to a fundamental change in modern society's need for data (JISC 2004, Kishore 2007, AIIA 2014, Sandvine 2015). Increases in data capacity (in terms of data rates in bits per second) of ICT devices and infrastructure reflect an intensification of (codified) knowledge. This can be seen by the historical growth in data rate capacity of typical links in the Australian backhaul telecommunication network (see **Figure 9**) (Tucker 2010). From the early days of the telegraph through to the 1970s, the growth in the data rate grew at around 20 per cent per annum. With the advent of the Internet and increasing capacity of ICT infrastructure, the data rate on backhaul has grown to 30 per cent per annum (Tucker 2010). The decades from the 1970s was also when the Australian economy started knowledge intensifying (Productivity Commission 1998, Lewis 2004) and this was particularly so in the labour market (Esposito 2010, Esposito and Abbott 2011).

Figure 9 Historical evolution of backhaul capacity



Source: (Tucker 2010)

The shift to fibre optic technology with the NBN is likely to see continued increases in access data rates, with rates in telecommunication systems having grown exponentially (Tucker 2010, Finch et al. 2015).

Three areas that demonstrate the on-going need for increased data capacity management in the modern society and knowledge economy are social networking/media, real time entertainment (downloading video and audio streams) and scientific research (JISC 2004, Kishore 2007, AIIA 2014, Sandvine 2015). Social networking/media and real time entertainment use has and continues to increase at rapid rates (Kishore 2007, Sandvine 2015). This is being driven by digitisation of a wide range of media, increased broadband access and digital media tools (smart televisions, digital cameras and phones) (Sandvine 2015). The volume of data generated in research and by scientific instruments has also increased dramatically with the Internet of Things⁵⁵ driving rapid increases in machine-to-machine data (JISC 2004, Ortiz, Hussein, Soochang Park, Han & Crespi 2014). Data demand is only likely to increase with the relationship between the Internet of Things and social networks driving increased connectivity of people to their surrounding computer enabled public and private environments. This human-to-device interaction is effectively providing for continuous and ubiquitous data demand (Ortiz et al. 2014).

5.2.2 Spatial distribution of data centres

A key demonstration of the intensification of ICT knowledge is the growth in the number, size and capacity of data centres. Data centres are facilities that house physical server hardware for the storage, management, and dissemination of data and information and can be considered as massive warehouse scale computers (Barroso & Holzle 2009). Data centres are the result of the increasing need for data storage and the need for this data to be constantly accessible. The key role played by data centres in the Internet age (and hence the modern knowledge economy) is to effectively house and make codified knowledge highly accessible. Data centres also host data (text and video) that provides for virtual tacit knowledge exchange and connectivity through email exchange and video conferencing. Data centres are now a key part of the Internet's infrastructure.

⁵⁵ The Internet of Things is the growing network of everyday objects – from industrial machines to consumer goods – that can share information and complete tasks and consists of three main components:

1. The things (or assets) themselves.
2. The communication networks connecting them.
3. The computing systems that make use of the data flowing to and from our things (SAS 2015).

Data centres enable the increased intensification of knowledge and, through data storage, increase accessibility of knowledge. Cisco (2010a) estimated that data centre traffic (including internal and external onto the Internet) had exceeded a zettabyte⁵⁶, greater than the Internet itself with global data centre traffic continuing to grow strongly (Cisco 2014).⁵⁷ The data demand growth has resulted in large consolidated data centres becoming more and more central in Internet communications across a wide variety of commercial, consumer, and university settings (Ranganathan & Jouppi 2005, and Benson, Anand, Aditya & Ming 2010) Business and consumer demand for data is continuing at consistently strong levels in Australia (ABS 2015b).

The central role that data centres play in the on-going intensification and development of the Internet, and therefore the knowledge economy, means an understanding of spatial location factors for data centres is important. However there is little to no academic research on the spatial planning or location of data centres, though a review of the industry advice is provided in **Appendix 2 Spatial characteristics of data centres**. The underlying key spatial context for the location of data centres relates to the working efficiency of the Internet. Internet networks increasingly require access to distributed data centres within major population centres to minimise latency and network transit costs to users (Greenberg, Hamilton, Maltz & Patel 2009). As data centres require high levels of Internet connectivity, they require immediate physical access to high grade Internet networks connections. This means high capacity local fibre optic connections (often private network 'dark fibre'⁵⁸) to key POP Internet exchanges onto to other networks and to backhaul Internet fibre optic medium and long distance networks, again high capacity private dark fibre networks. Third party collocation data management specialist or data centre operators offer complementary specialist telecommunication services through Internet network dark fibre services.

Data centres are about storage of data, codified data. In this sense, the storage of codified knowledge should be less spatially clustered than relationship-based tacit knowledge focused elements of the knowledge economy. However, the reality is not so clear cut, though relatively dynamic. Therefore, whether or not data centres reflect not only the technological intensification but also spatial intensification is worthy of research and analysis. The spatial characteristics of data centres in Perth will be considered in Chapter 6.4.5.

⁵⁶ A zettabyte according to www.datacenterknowledge.com is an almost unimaginably large amount of data, equivalent to 1 million petabytes, 1 trillion terabytes and 1 quadrillion gigabytes.

⁵⁷ Cisco (2014) have predicted global data centre IP traffic will continue to grow by nearly triple (2.8-fold) over the next 5 years with overall data centre IP traffic will grow at a compound annual growth rate (CAGR) of 23 percent from 2013 to 2018

⁵⁸ Dark fibre is purpose built dedicated fibre optic, which, with fibre optic using light to transfer data, is not in constant use and therefore is sometimes 'dark'.

5.3 Spatial characteristics of Internet technology infrastructure in Australia

In terms of the Internet infrastructure, Australian residential, government and business consumers have relied on, with the roll-out of the NBN on-going, a range of dial up and broadband access backhaul technologies, typically broadband copper based digital subscriber line (ADSL, ADSL +), with other technologies being hybrid fibre coaxial, wireless, satellite and optical fibre services (ACCA 2007, Tucker 2010, ABS 2013a, NBN 2013, AIIA 2014, BITRE 2014a, Finch et al. 2015)⁵⁹. The year 2006 was the last year that dial up services were the majority of Internet connections (ABS 2015b). As at 31 December 2014, almost all (99 per cent) of Internet connections were broadband, though with fibre (3 per cent) and cable (8 per cent) being still only 11 per cent of connections. The difficulty Australia has had with provision of high speed Internet has meant Australia's broadband speeds continue to lag its international peers (akamai 2015).

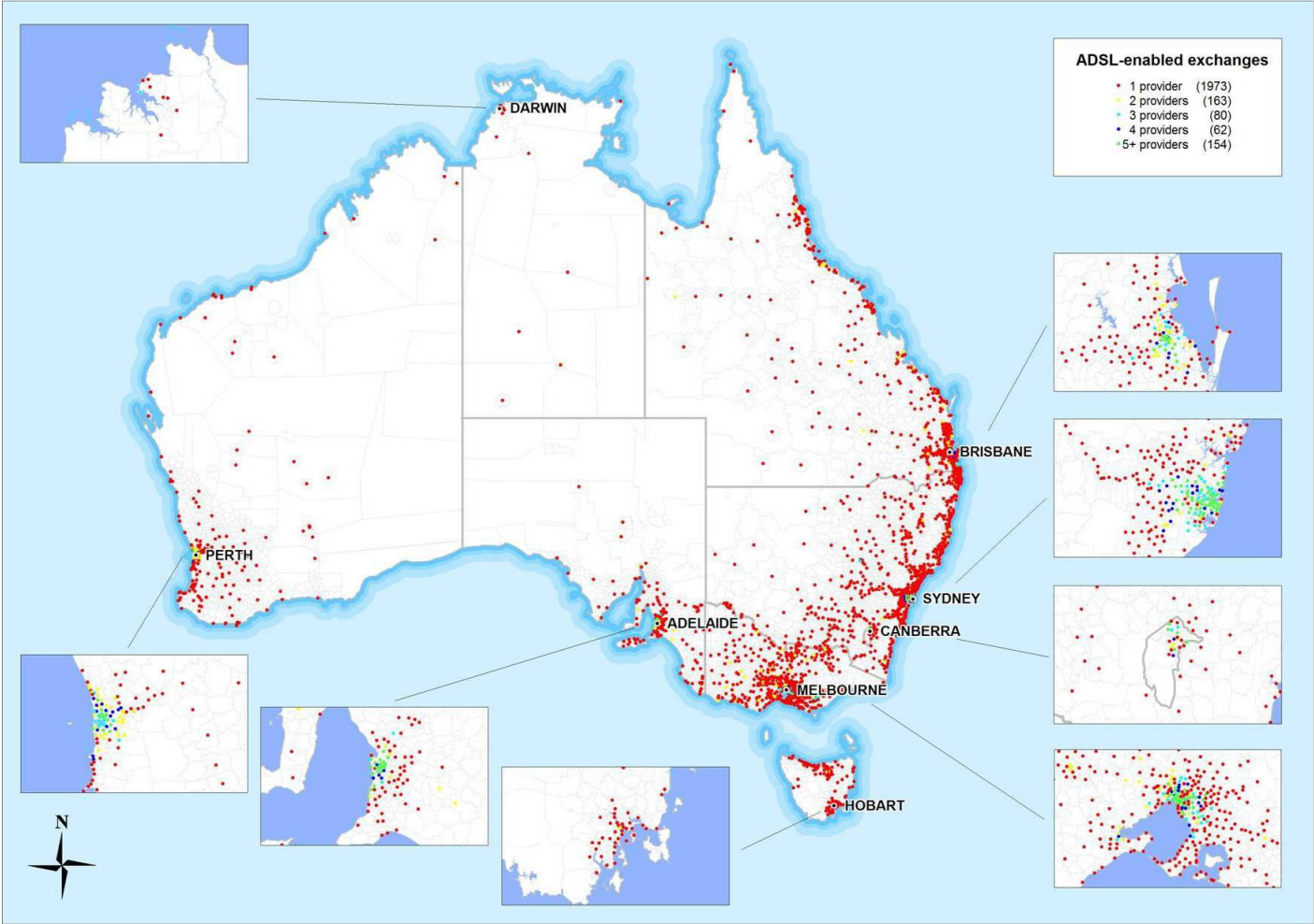
According to ACCA (2007), the basic explanation of Internet technology for Australian customers is as follows: DSL, hybrid fibre coaxial, wireless, satellite and optical fibre services technologies provide the customer connection to the local telephone exchange Internet POP. The local access network includes the connection between each subscriber and a POP, generally at local telephone exchanges. The network is linked from the node or POP to a major network node. The major network node then aggregates and interconnects traffic from a number of exchanges or switching points. The major network nodes are commonly referred to as an Internet Exchange point⁶⁰. These key POPs are specific Internet Exchanges (as distinct from telephone exchanges which house lesser POPs) and collocation centres. 19 ISPs have invested in their own DSLAM infrastructure to enable DSL services, with most of these ISPs providing ADSL2+ services to their customers. At 31 January 2007, there were 2,432 exchanges providing ADSL service coverage to 91 per cent of the Australian population.⁶¹ ADSL exchange infrastructure competition was predominantly

⁵⁹ The backhaul Internet is the medium and long distance optical fibre and microwave transmission networks that connect local exchanges, main exchanges and mobile and fixed wireless towers between all population centres in Australia: effectively the inter regional Internet backbone in Australia. Backhaul networks carry voice and data transmissions. Telstra and Optus operate substantial backhaul transmission networks. Other providers, including Nextgen, PIPE Networks, Powertel, Silk Telecom and Soul operate backhaul networks in metropolitan and regional areas across Australia. While three or more operators serve some routes, the majority of routes are served by Telstra alone (ACCA 2006). The original NBN plan was to extend the fibre optic backhaul as well as extending the localised fibre optic networks to provide cabling for up to 93 per cent of Australian homes, schools and businesses. Remaining premises were to be connected via a combination of high-speed fixed wireless and satellite technologies (NBN 2011, Finch et al. 2015).

⁶⁰ An Internet Exchange point (IX or IXP) is defined by the Border Gateway Protocol (2011) website as a physical infrastructure that allows different Internet Service Providers (ISPs) to exchange Internet traffic between their networks (autonomous systems) by means of mutual peering agreements, which allow traffic to be exchanged without cost (see also Gibbard 2004). The primary purpose of an IXP is described as allowing networks to interconnect directly, via the exchange, rather than through one or more third party networks. While advantages of the direct interconnection are numerous, the primary reasons are cost, latency, and bandwidth. Traffic passing through an exchange (often referred to as peering) is typically not billed by any party, whereas traffic to an ISP's upstream provider is (Border Gateway Protocol 2015).

based in the capital cities of Adelaide, Brisbane, Canberra, Melbourne, Perth and Sydney. **Figure 10** demonstrates the major city bias of ADSL infrastructure (see also ABS 2010b).

Figure 10 Availability of ADSL services in Australia (includes ADSL and ADSL2+ services), 31 January 2007



Source: ACMA 2007, http://archive.acma.gov.au/webwr/assets/main/lib310120/2007_adsl_enabled_exchanges.pdf

Australia's Internet infrastructure, based on OECD comparisons, trails other developed economies on a range of key telecommunications indicators (DBCDE 2009, Tucker 2010, AIIA 2014, akamai 2015). The introduction of the NBN to deliver superfast broadband infrastructure was seen by the Australian Federal Government as the way to address the problems with Australia's telecommunications sector (DBCDE 2009, Finch et al. 2015). In positioning the NBN as a key nation building infrastructure, the then Rudd Federal Government contended that telecommunications services and in particular higher speed broadband services were essential to the future efficiency and productivity of Australia's economy and a critical input to the operation of an equitable society (DBCDE 2009, Tucker 2010). The roll out of fibre optic infrastructure to 2014 has continued to be slow (ABS 2015b).

While Internet infrastructure has lagged, Australian business and consumer adoption has been strong. From 1989 onwards, Australia made rapid progress in the adoption of the Internet growing almost as fast it did in the fastest adopting countries, such as the USA and Scandinavia (Clarke 2004). For example, by 1997-8, Internet access among larger businesses was high. Of those businesses employing 100 or more persons, 87 per cent had access to the Internet (ABS 2009).⁶² By 2008, according to the ABS (2009), 78 per cent of Australian broadband subscribers use DSL services, which use an existing copper pair to the customer's premises to provide a broadband service.

The availability and quality of broadband Internet infrastructure technologies for Australian residential and business consumers is dependent upon their proximity to the broadband Internet infrastructure (ACCA 2007, NBN 2013). While most exchanges are served by only one infrastructure provider, the exchange locations with five or more infrastructure providers are in the higher density urban areas. Generally speaking, fixed networks consist of multiple local access networks, linked together by a transmission backhaul network. Local access networks are also known as the 'local loop' and represent the 'last mile' of a fixed network.

The spatial location of Australian Internet infrastructure has been driven by demand and even with the upgrading of Australia's fibre optic infrastructure with the NBN it remains to

⁶² By 2009 the proportion of Australian businesses with Internet access had grown to 90.5 per cent (with saturation levels of 98 per cent - 99 per cent for medium and larger businesses - 20 employees plus, and 87.7 per cent for small size businesses) (ABS 2009 and 2010b). In terms of web presence, the proportion of Australian businesses in 2009 was 41.5 per cent compared to only 6 per cent in 1997-1998. In 2009, the Internet presence for large businesses (200 employees plus) was 95.1 per cent while 70 per cent for medium to large businesses (20 - 199 employees) and reasonably significant even for small businesses (0-4 employees) at 31.2 per cent (ABS 2010b). While business use of the Internet was mainly email in 1998 (92 per cent of businesses with the Internet used email) other uses of the Internet grew somewhat slower (ABS 2009 and 2010b).

be seen whether the more wide spread supply of fibre optic infrastructure impacts greatly on the spatial location of economic activity within Australia. The slow and progressive upgrading of Internet infrastructure in Australia effectively means that the higher capacity infrastructure is particularly urban focused. This has reinforced already established urban patterns of economic development.

The NBN has been seen as a means of supporting regional economic development (Finch et al. 2015). However, while the NBN fibre optic roll-out will provide opportunities for regional and lower density areas, it will also mean increasing competition for economic activities (BITRE 2014a). This competition will be across an increasing range of industries and will come from Australia's larger, denser urban areas as well as from overseas. However the increased digital competition does not explain the full extent of the increased competition. The reality is that the knowledge economy is broader than the digital on-line economy and relies heavily on agglomerative benefits arising from larger, denser urban areas with greater levels of tacit knowledge exchange, larger skilled workforces and access to a broader range of services. The effect on regional Australia of the rapid ICT and transport improvements during the course of the 20th century has been loss of jobs and relative population decline, particularly in the less urbanised areas (BITRE 2014a). While the broad urban and regional roll-out of the NBN may drive increased economic activity in Australia, it is likely to do so more within the larger and denser urban areas.

Chapter 6 – Part C Research into Perth and the secondary- questions on knowledge intensification

6.1 Characteristics of knowledge-intensive cities

Before considering Perth and its knowledge intensification, it is worth summarising the key characteristics of knowledge-intensive cities. Modern knowledge-intensive economies and cities are characterised by paradoxes and complexity (Castells 2005, Rooney 2005, Foster 2006, Burger, Goei, van der Laan and Huisman 2010, Howells, Ramlogan and Cheng 2012). Following the literature review on the knowledge-intensive economy and the intensification of knowledge, it is concluded that the knowledge economy is characterised by a series of paradoxes, including that it is:

- Dynamic (being in constant evolution), competitive and future orientated, but influenced heavily by past economic and social patterns and infrastructure,

- Dependent on both tacit and codified knowledge,
- ICT enabled yet also dependent on face-to-face relationships,
- Ingrained in a diversity of urban industries both 'high tech' and 'low tech',
- Organisationally dispersed, complex and resistant to being organised, but urbanised and both spatially and temporally concentrated (i.e. activity times and location of activity is driven by human physical and social needs and wants), and
- Both localised in urban areas and globalised.

Knowledge-intensive cities operating in the modern knowledge-intensive economy have somewhat clearer characteristics and it can be concluded that they are characterised by:

- Scale, delivered (preferably by both) size and or density,
- First starter advantage (though secondary to scale) particularly with infrastructure and economic linkages,
- A strong focus on a high profile central, dense and walkable urban core delivering face-to-face economic exchange (i.e. high levels of centrality for knowledge economic activity),
- Higher levels of human knowledge capital, including higher levels of education, but also cultural, language and scientific openness,
- High levels of connectivity externally (regional and international) and internally (between metropolitan catchments and centres) delivered by quality transport and communications infrastructure (which results in high speed information and knowledge flows, including with routine commercial, advanced scientific knowledge or cultural fashion trends), and
- Being politically and economically liberal (or open) with a strong commercial or trading orientation (i.e. pro-trade and supportive of different political, cultural and religious views and beliefs, as seen historically with major trading ports).

The above characteristics of the modern knowledge economy and knowledge-intensive cities inform the thesis research and the addressing of the thesis secondary questions.

6.2 Secondary question 1: Is knowledge economic activity intensifying in Perth, both in terms of an increase in knowledge-intensive industries and their spatial distribution? ⁶³

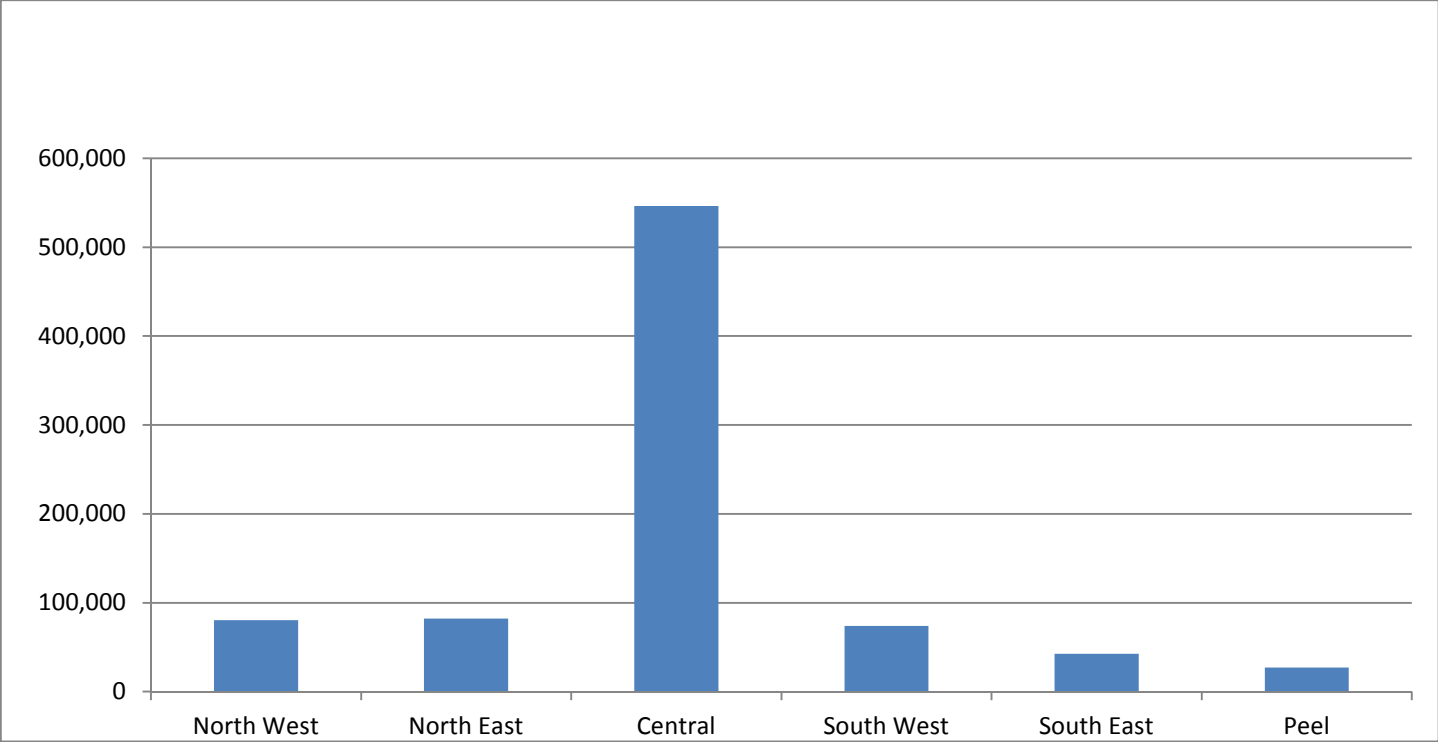
Perth's employment is concentrated in the inner and middle suburbs (see **Figure 11**), while population and population growth is concentrated in the outer suburbs. (BITRE 2013, WAPC 2015). From 2001 to 2011, while Perth's outer regions added the most jobs, inner-city Perth also had substantial job growth (BITRE 2013). Despite this job growth,

⁶³ The research for this section of knowledge economy intensification uses secondary sources.

Perth's outer suburbs have had an on-going shortfall in employment compared to population growth (WAPC 2015). The contrast between the inner and outer suburbs is highlighted by the outer regions of the Perth metropolitan area having had 50 per cent of employed residents, but only 30 per cent of jobs, while the inner regions accounted for 15 per cent of the population but 36 per cent of the employment (BITRE 2010, Major Cities Unit 2010). The Central sub region⁶⁴, compared to Perth and Peel metropolitan area, has the largest population (782,974 people in 2014 or 42.6 per cent) and employment concentration (64 per cent of all jobs) (WAPC 2015). The CBD and the immediate surrounds account for 19 per cent of all metropolitan jobs (WAPC 2015).

⁶⁴ The Central sub-region covers 19 local government areas (Stirling, Bayswater, Bassendean, Cambridge, Vincent, Nedlands, Subiaco, Perth, Cottesloe, Claremont, Peppermint Grove, Mosman Park, Fremantle, East Fremantle, Melville, Canning, South Perth, Victoria Park and Belmont).

Figure 11 **Employment for Perth and Peel by sub-regions 2011**



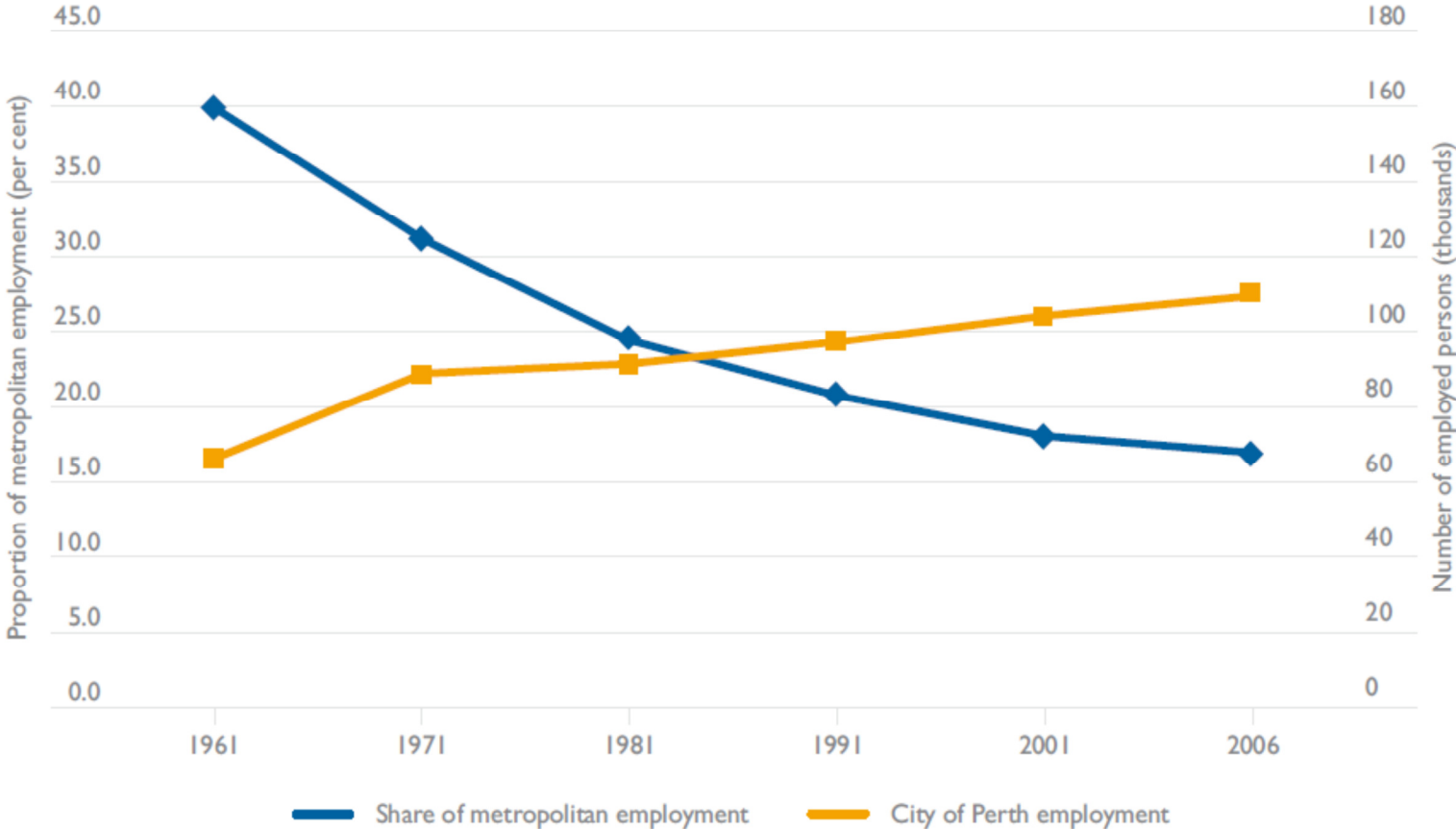
Source: ABS Census 2011

Population growth in Perth since the 1960s has been dispersing towards the outer suburbs, although in recent years, population growth has also been occurring in the inner suburbs (Houghton 1981, BITRE 2010, BITRE 2013). Similarly, employment has been dispersing, starting in the 1960s to the middle suburbs and then, from the 1990s, to the outer suburbs. Houghton (1981) found that from the mid 1960s to the mid 1970s, the proportion of white-collar jobs located within the Perth Central Area (CBD and surrounds) actually declined from 51 per cent in 1966 to 39 per cent in 1976. Outside the Central Area, the new white-collar jobs were well dispersed, but with a tendency towards concentration in middle-distance suburbs. Some of this dispersement at this time was concentrated in medical and educational institutions in inner to middle ring suburban Nedlands. White-collar dispersement to the middle suburbs of Osborne Park and Belmont followed the relocation of industrial production processes. The other concentration of employment was in industrial Welshpool. Houghton (1981, p. 108) also noted at this time the continued importance of the CBD with a “boom in office redevelopment” largely associated with minerals and resources. In the CBD and surrounds, the only occupational categories that recorded significant growth in the period from 1971 to 1976 were Professional and Technical, and Clerical and Service occupations, while there was a net decline of more than 5,000 jobs in Retailing, Wholesaling, Transport, Communications, and Production Processes and Labouring.

From the 1970s, the Perth CBD, while growing in absolute numbers, continued to decline in terms of the proportion of metropolitan employment (See **Figure 12**)(BITRE 2010, BITRE 2013).⁶⁵ Perth’s major job concentration remained in the CBD (19 per cent of the total jobs in 2011), with other major concentrations in the industrial areas of Kewdale-Welshpool, Malaga, Osborne Park and Canning Vale, which combined, accounted for 17 per cent of employment (BITRE 2010). The centrality of employment distribution around the CBD is particularly notable, with 51 per cent of jobs within 10km of the CBD and 64 per cent within 15km (Davis 2016). This is greater than with other major Australian cities.

⁶⁵ In terms of absolute numbers of persons employed in the CBD there was a decline in the early 1990s but since then steadily increased (Department of Planning et al. 2009, see also BITRE 2010). Perth’s CBD and inner suburban population densities are also notably lower than other major Australian cities (Davis 2016).

Figure 12 **Employed persons in the City of Perth 1961-2006** (Source: BITRE 2010)

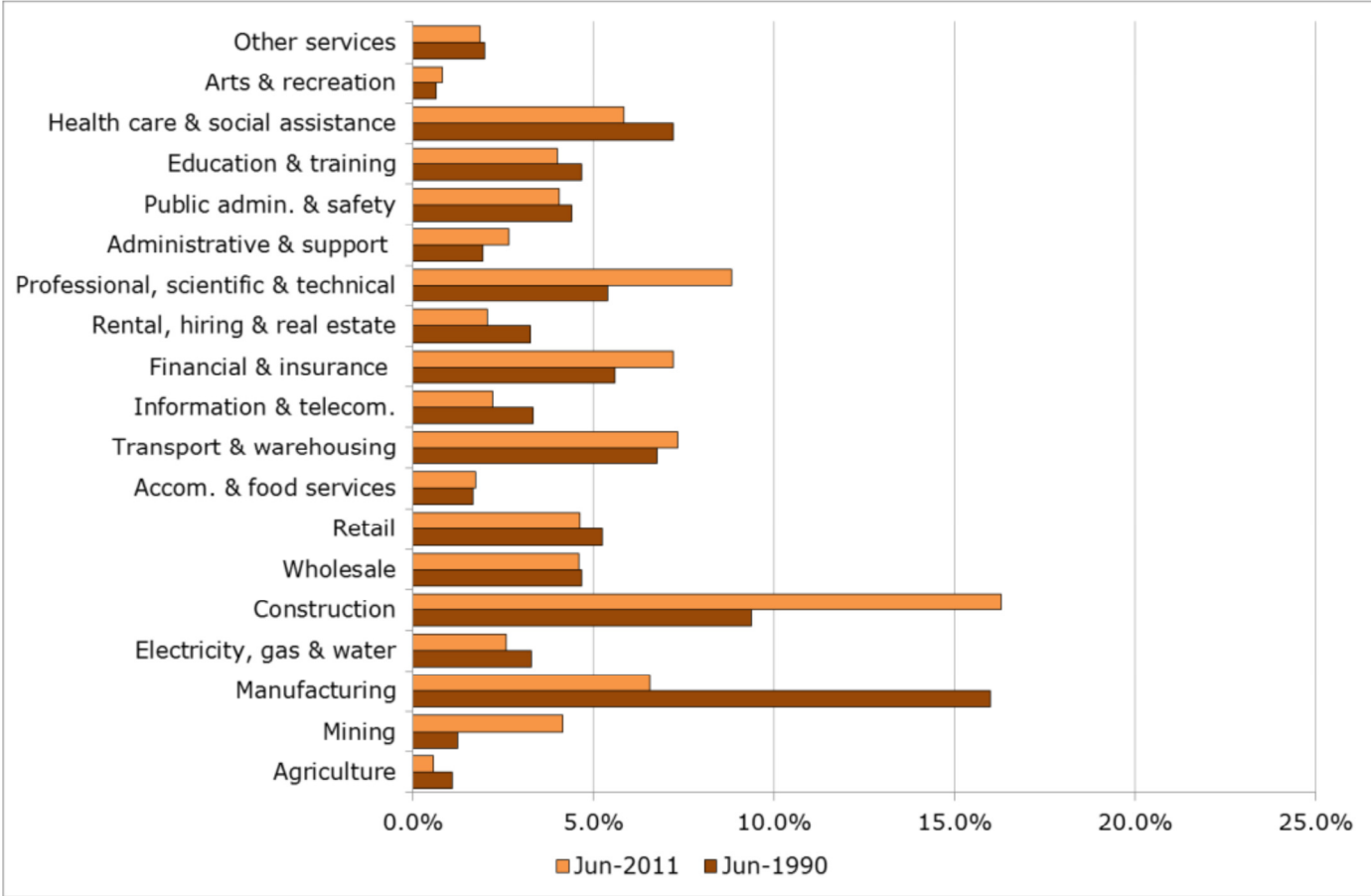


Source: WAPC 2003c, except for 2006 data which was derived by BITRE from ABS Census of Population and Housing data.

From 2001–2006, employment in outer suburbs grew at 3.7 per cent per annum, much higher than the Perth average of 2.3 per cent. From 2001–2006, Perth CBD added 11,000 jobs, although its share of jobs remained steady. This record of employment dispersal since the early 1960s, despite the retention of a strong inner and middle core, does not provide the entire picture. An examination of employment type is required. Western Australian workers are less likely to hold Bachelor degrees or higher qualifications than workers nationally (Department of Employment 2015), although the demand for skilled and professional labour has been increasing (DTWD 2014). An examination of the spatial distribution of Perth's employment, using education and occupation profiles, demonstrates the relatively higher concentration of high-skilled 'knowledge workers' in professional and intermediate clerical occupations and industries who work in the Perth CBD and immediate surrounds compared to suburban areas (DEEWR 2006, ABS 2008c, BITRE 2013).

Perth's professional workforce is heavily focused on servicing the commodities and mining sector, with estimates of 40 per cent of people in the professional, scientific and technical services industry engaged in some mining-related or support activities (ABS 2008a, DTWD 2014). In this sense Perth, and in particular the CBD, acts as the knowledge economy centre for the Western Australian mining and resources sector. The Perth CBD, and overall Western Australian economy, rises and falls with the state of the mining and resources sector. The origins of this can be traced back to the 1970s when the Perth CBD, as identified by Houghton (1981), experienced the early stages of a minerals and resources-led knowledge intensification with an increase in knowledge-intensive professional and other white-collar service-based employment, while experiencing a loss of more labour-intensive industries. Further, an examination of economic activity in the last decade strongly supports an increased intensification of knowledge economy activity within central Perth. There has been considerable GDP growth in metropolitan Perth in this period. This is particularly so for professional, property, financial and insurance services (SGS 2011, Department of Planning 2009) (see **Figure 13 – Perth Industry Structure**). What is notable about this growth is the strength of knowledge intensive industries that are known to be advantaged by agglomeration. The financial and insurance services industry has become a larger part of the Perth economy than manufacturing, which has continued to decline post mining boom (SGS 2011, Department of Employment 2015). The other growth industry sector in the 2000s was mining, particularly construction, however SGS (2011) noted caution with construction figures due to the potential inflation effect of the large fly-in-fly-out workforces leaving Perth for work in regional mining and resources construction projects during this period.

Figure 13 Perth Industry Structure



Source: SGS Economics and Planning 2011 - as measured by industry gross value-added share of total industry value added (excluding ownership of dwellings).

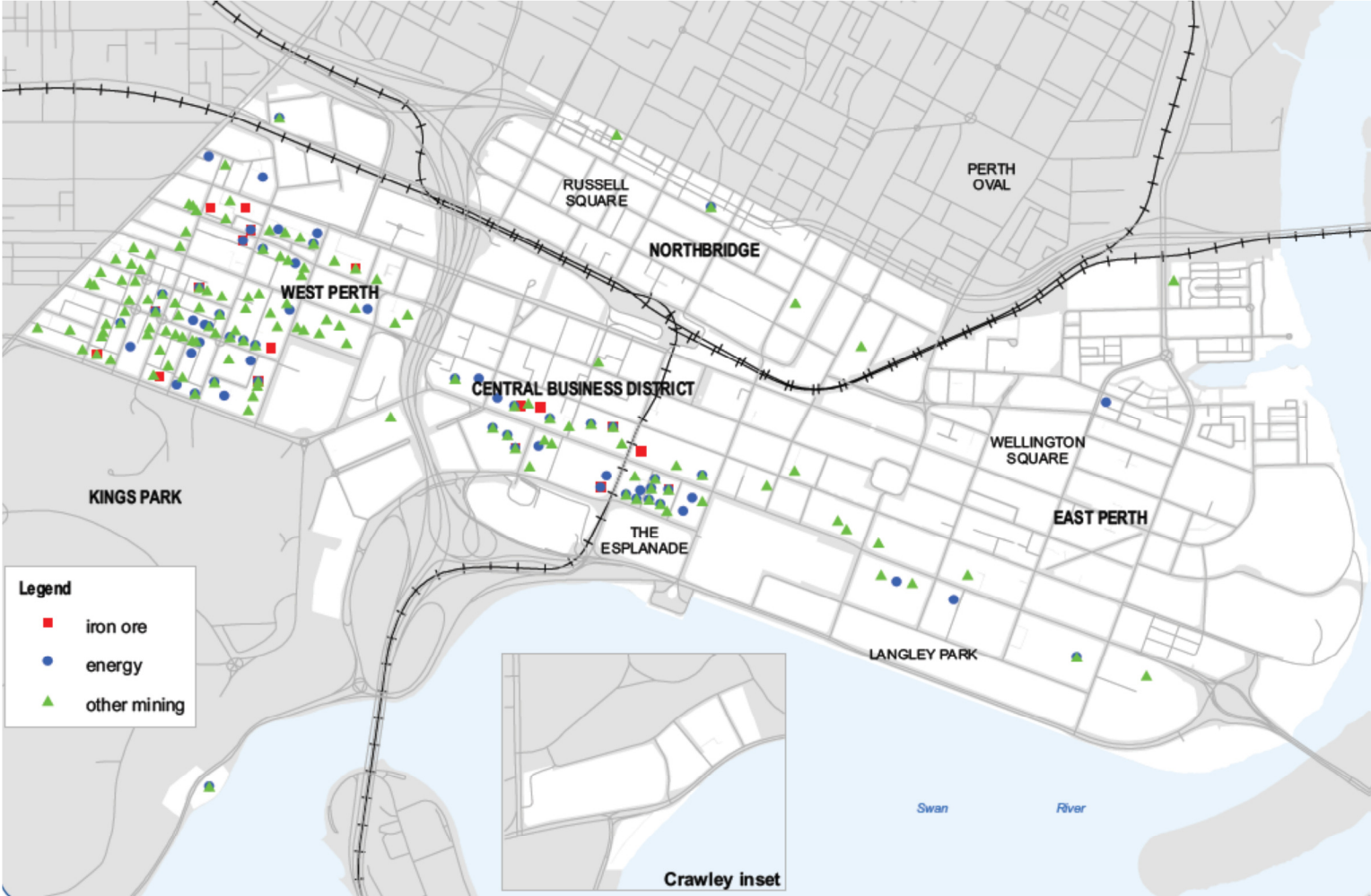
The growth in knowledge services was particularly strong in the CBD in the last mining boom, and drove a huge demand for commercial office space (Department of Planning et al. 2009, Property Council 2012). Employment levels in the commercial office areas surrounding the CBD, such as West Perth, Northbridge and East Perth, also increased considerably. The Perth CBD and surrounding areas also saw a major increase in knowledge-intensive creative industries and professionals. For a resource-focused city, not surprisingly, engineering and computing services had the most CBD establishments and employees within the creative and professional industries (Department of Planning 2009). Increased employment was identifiable within engineering services, and from a lower base, computing communication services and Internet related businesses. Computing and information services were not notably clustered within any particular part of the CBD; however, at the Perth metropolitan scale, they were notably clustered in and around the CBD (Department of Planning 2009). Within the CBD and surrounding areas, the industries that were clustered included mining and resources (**see Figure 14**), medical, legal, and the fashion industry (Department of Planning et al. 2009). This is consistent with the findings of Martinez-Fernandez (2010), who found mining technology service companies predominantly located in business centres and inner city locations, with specific clustering in cities, including Perth, Brisbane and Sydney (see also Kelly & Mares 2013).

From 2014 there was a significant decline in commodity prices resulting in the Western Australian mining boom going into a significant reversal. This impacted the overall Western Australian economy (Nahan 2015). With the significant mining and resources sector decline, the CBD office vacancy rose significantly to 19.2 per cent (Property Council 2016). The vacancy levels have also been impacted by the increased supply of office stock driven by earlier mining boom driven shortages. The Western Australian knowledge intense economy is significantly tied to the mining and resources sector, which suggests there will be a comparative decline in the knowledge intensity of the Western Australian and Perth economy. Perth effectively lacks a diverse knowledge intense industry base. As Kneebone (2013) has noted, with the spatial impacts of Great Recession decline and recovery with various industries in the USA, there are complexities as to impacts with any recession. The Great Recession in the USA saw decline across all industries and employment segments, particularly those segments in outer suburban areas that were consumption credit dependent. Diverse knowledge intense industries and knowledge employees in denser urban areas were less impacted and more resilient. Similarly an examination of the 2015 and 2016 unemployment rates across Perth metropolitan's regions indicate that outer suburban areas have significantly higher unemployment rates than the inner city, with the inner city employment rates

bouncing back strongly (Department of Employment 2016)⁶⁶. This suggests that knowledge intense workers that predominate the inner city areas are more flexible and or mobile. This is likely to be due to both age and knowledge intensity (which are interrelated) of the inner city workforce.

⁶⁶ Unemployment rates for Greater Perth increased from 5.7 per cent to 5.9 per cent over the year 2015 - 2016. The Mandurah region, as the worse performing outer suburban areas, increased from 8.2 per cent to 11.1 per cent. Inner Perth's unemployment was slightly higher than the metropolitan average in 2015 at 5.8 per cent but significantly lower at 2.2 per cent in 2016.

Figure 14 Mining and resource establishments in central Perth



(Source: Department of Planning, WAPC and City of Perth 2009)

This clustering suggests the mining and resources industry benefits strongly from localised agglomeration, which in turn, suggests a high reliance on local knowledge spillover and tacit knowledge exchange. Localised agglomeration relies on beneficial results of physical proximity and networking connections (Jacobs 1963). For the Perth CBD, this localised proximity and networking is likely between mining and resources corporate headquarters and other knowledge-intensive activities such as business services associated with financial centres and state government executive and administration⁶⁷. Martinez-Fernandez's (2010) analysis found that knowledge intensive services have played a significant role in transforming the mining industry in Australia, with the mining companies' innovation relying upon the constant and continuous tacit and codified interaction between mining and resources companies with the MTS/MTSE companies. The transformation of the Australian MTS/MTSE sector from the turn of the last century, as tracked by Martinez-Fernandez (2010) and Tedesco and Haseltine (2010), has coincided with the resource-led rebirth of the Perth CBD, as identified by the Department of Planning et al. (2009). The collaborative interaction and networking was identified as being critical not only within CBDs, but also on mine sites (Martinez-Fernandez 2010). This strongly suggests a need for head office locations with high-quality ICT infrastructure to enable real-time ICT links between mine sites and city head offices as being critical in maximising the body of tacit and codified knowledge. Similarly, Martinez-Fernandez (2010) also suggested that the locating of mining and resource companies in CBDs (with their ICT infrastructure advantage) indicated the importance of internationalisation for competitive processes in the mining and resources sector.

Another notable change within the CBD since 1990 was the increase in small business establishments, particularly since 2001 (Department of Planning et al. 2009). The CBD and inner-city business areas were developing into multi-purpose mixed-use hubs of commercial, economic and social activity, with an increased number of drinking and dining establishments (Department of Planning 2009). This is consistent with an increased agglomeration role for the CBD, being the location for higher amenity (attracting knowledge intense labour and businesses) and for tacit knowledge spillover activity for the resources and other industries. At the peak of the last mining boom, the suburban area office precincts (i.e. outside the CBD and the inner city areas of West Perth, Northbridge and East Perth) were generally notably smaller in floor-space, with much higher vacancies and lower rents (Property Council 2012). To a degree, the exceptions to this were Subiaco and Herdsman, on the periphery of the inner city.

⁶⁷ Access to state government decision making is a historic key factor with all Australian state capitals (Robinson 1961).

The increased focus of the knowledge economic activity in and around the CBD raises the question as to the future growth of knowledge-intensive industries in Perth. It is contended in this thesis that Perth is characterised by being a knowledge economy monocentric city within a consumption-based, dispersed or weak polycentric sprawling metropolitan area in a monocentric state. Trubka (2009), in one of the first analyses of agglomeration in Australian cities, found that outside the Perth CBD agglomeration, benefits were low and there was little relationship to urban density. It was contemplated that this may be because the SLAs of Perth may not have industries that are most impacted by agglomeration economies. Trubka (2009) proposed that automobile-dependent cities take on a somewhat polycentric economic formation where most of the high-quality employment resides in the CBD. The surrounding centres, because of poor planning for economic development and the tendency to sprawl, means the benefits of densification may be lost. Arguably, the metropolitan planning strategies and policies for Perth, focusing on a dispersed number of retail focused metropolitan regional centres, are flawed. The corporate shopping centres in outer Melbourne, according to Goodman (2005, p22–24), by their nature both economically and culturally, provided the blandest representation of a monoculture and add very little to the ‘sense of place’. Suburban shopping centres in Perth, following the standardised corporate model, are little different.

6.3 Secondary -question 2: Is human knowledge capital intensifying in Perth, both in terms of the labour market knowledge capacity and in terms of the spatial distribution?

6.3.1 Methodology

The research in this section relies on ABS Census data from six census periods from 1986 to 2011. For consideration of the knowledge intensification of Perth’s metropolitan labour market, the labour force within *Greater Perth* was used (for the 2011 Census Table *P37 Selected Labour Force, Education and Migration characteristics by sex*).⁶⁸ For previous censuses, the broader Perth-Peel metropolitan labour market was used to ensure consistency with the 2011 Census.

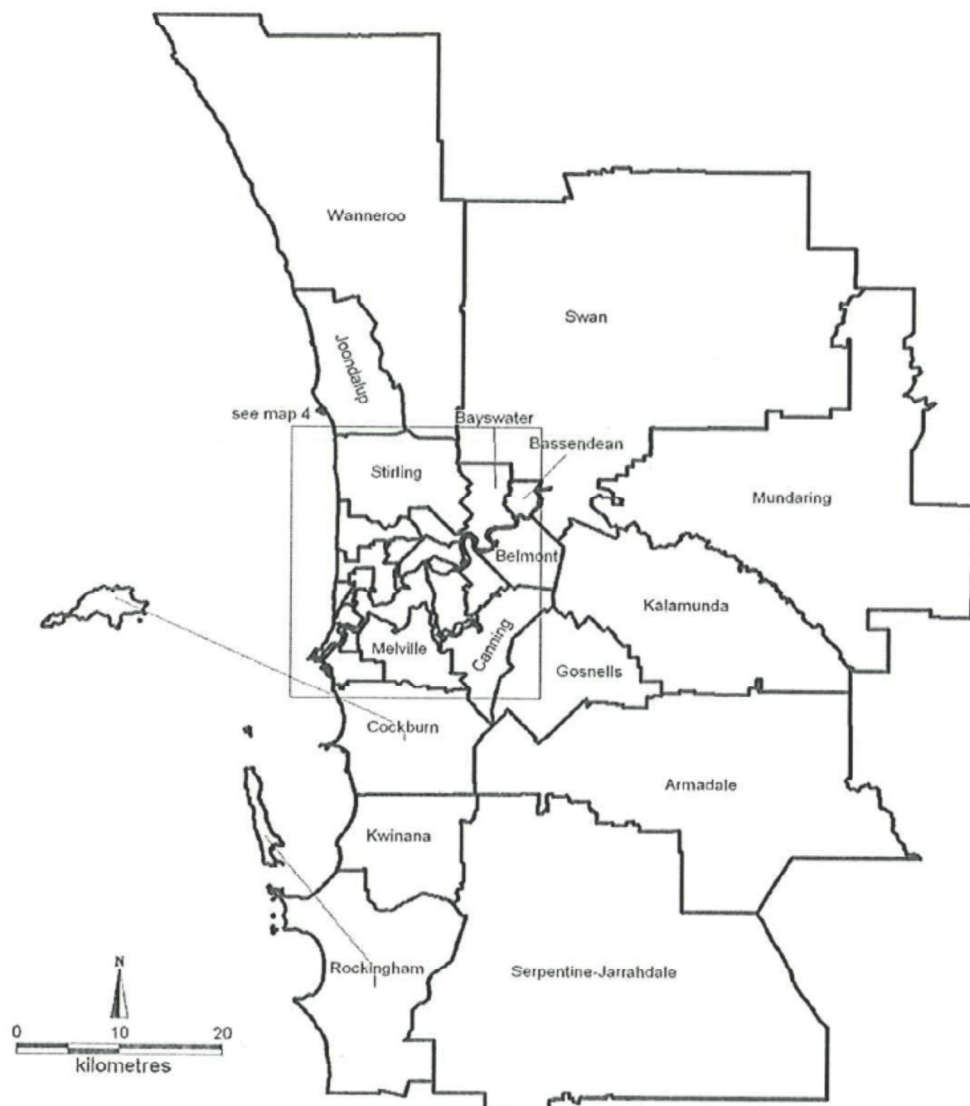
The research on the spatial distribution of education attainment used the census reports for ‘Bachelor degree and higher by residences for Perth metropolitan LGAs’⁶⁹ in the ‘Basic Community Profile’ and the ‘Non-school qualification: Level of Education’ (the highest completed non-school qualification) by LGA. Using LGA is useful, as LGAs are

⁶⁸See definition of Greater Capital City Statistical Areas (ABS 2011a). This includes the Peel region. The broader Perth and Peel metropolitan area is used for the Greater Perth local labour market, because Australia’s capital cities contain urban areas and surrounding areas of non-urban land where the population demonstrates, through commuting patterns, strong linkages to their capital city.

⁶⁹ An explanation of the various definitions of the Perth metropolitan area are provided by the Metropolitan Local Government Review (2011).

relatively numerous in the Perth-Peel region (31) and are readily identifiable as being inner, middle or outer suburban LGAs⁷⁰ (see **Figure 15**)

Figure 15 Maps of Local Government Areas (LGAs) of the Perth metropolitan area



⁷⁰ However one limitation on using LGAs is that LGAs in Perth vary in population size (in 2011 Census the City of Stirling had a population of 155,758 whereas the western suburbs LGAs generally have lower populations than other LGAs (ranging around 10,000 -20,000) in particular the Shire of Peppermint Grove having 1,528 residents).

Inset – Inner Councils

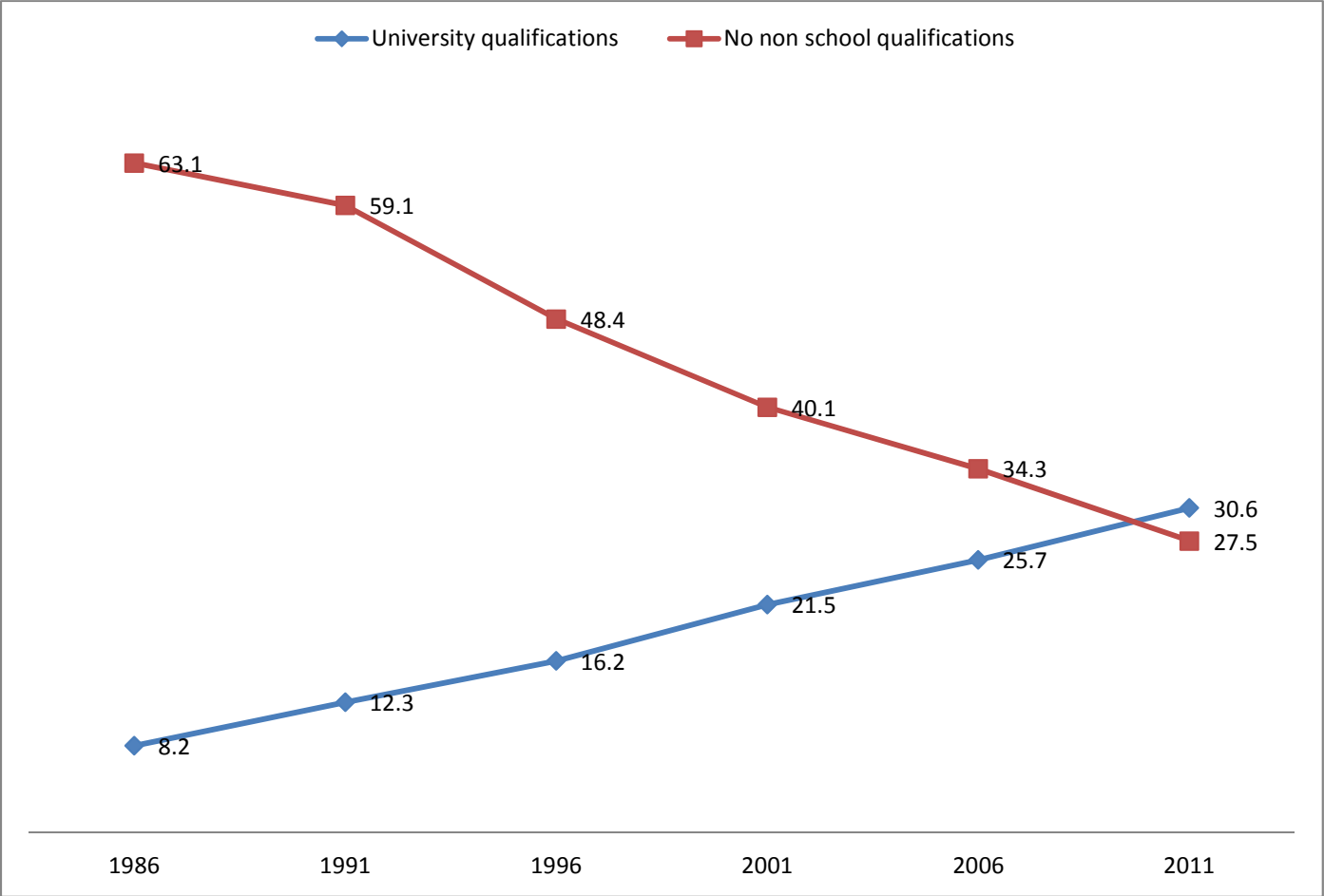


Source: Metropolitan Local Government Review Tribunal (2011)

6.3.2 Human knowledge capital intensification research

In terms of capacity, human knowledge in the metropolitan Perth labour market has been intensifying consistently at least since the 1980s and this can be seen by contrasting the two ends of the labour market: university qualified members of the workforce and those without post-school qualifications. An examination of ABS Census data from 1986 to 2011 for the *Greater Perth* labour force finds a major transformation in the knowledge intensity of the metropolitan Perth labour market. In 2011, only 27.5 per cent of the total labour force for the Perth–Mandurah labour force had no non-school qualifications. This was down from 63.1 per cent in 1987. In contrast, the labour force participants with university qualifications rose from 8.2 per cent in 1986 to 30.6 per cent in 2011 (see **Figure 16**).

Figure 16 Knowledge intensification of Perth – per centage of labour force with university qualification versus no non-school qualifications



Source ABS Census 1986, 1991, 1996, 2001, 2006, 2011

At some point around 2010, it could be argued, Perth became a 'knowledge-intensive economy' at least in terms of its labour market. This is because it was in 2010 that the Perth metropolitan labour market first had more university-qualified workers than 'no non-school qualified' workers. **Figure 16** also demonstrates that knowledge intensification is happening at both the low and high knowledge end of the Perth labour market. Future demand for labour in Western Australia is projected to be increasingly knowledge and post-secondary and tertiary education driven with a significant decline (minus 24 per cent) in jobs with no post-school qualifications (DTWD 2014). Projecting the knowledge intensification of Perth's labour market, based on the trend rate from 1986 to 2011 of a 4.5 per cent increase (per five-year census period) in university-qualified workers, Perth would have 50 per cent of its labour market sometime after 2030. However looking at a national comparison for the 2011 Census, the percentage of the Greater Perth metropolitan labour market participants with university qualifications (at 30.6 per cent and similar to Greater Brisbane at 31 per cent and Greater Adelaide at 29.9 per cent) was notably lower compared to the larger metropolitan labour markets of Greater Sydney (39 per cent) and Greater Melbourne (37.6 per cent). In Australia, with the exception of the national capital Canberra (46.3 per cent), the larger the metropolitan area, the higher the percentage of university qualified people in the labour market. The state capital metropolitan areas also have significantly higher numbers of university qualified people in the labour market compared to the Australia's regional cities⁷¹.

In Perth, educational attainment is closely related to the level of access to jobs. The proportion of people with no post-school qualifications is comparatively low in areas with ready access to jobs (BITRE 2010, Major Cities Unit 2010). The Census data demonstrates the spatial separation of education and wealth by inner and outer suburbs (ABS 2006, 2008c, 2011a). People with university qualifications have traditionally been concentrated in the western suburbs of Perth, with some areas having more than 50 per cent of the labour force being university qualified (ABS 1996a, 2001, 2006, 2011a). These areas also had high proportions of high-income households and dwellings that had earlier access to broadband Internet. Outlying suburbs to the north and south of Perth city had lower proportions of the labour force with university qualifications (ABS 1986 and 2006).

In terms of the residential spatial distribution of knowledge-intensive workers, while the high socio-economic western suburban councils have always had high levels of knowledge-intensive workers, there has been a broader knowledge intensification occurring within the inner ring (and to a lesser degree the middle) suburbs. This is reinforcing the role of the CBD as the knowledge economy centre of Perth. For the LGAs

⁷¹ Similarly in the USA there is a notable disparity of percentages of college graduates in the labour force between larger metropolitan areas and smaller metropolitan areas (i.e. with populations of less than 500,000 people) (Moretti 2012, ppp94-95).

of Subiaco and Vincent, the turnaround in population decline to growth occurred in the early-1980s, when the decline in manufacturing and industrial activity began to be replaced with service sector employment (State Planning Commission 1988). Subiaco and Vincent have the highest urban densities in Perth (2,700 person per km²) with a corresponding change to relatively higher representation of professional and managerial workers (ABS 2006, 2011a).

In terms of knowledge intensification, represented by educational attainment from 1991 onwards, this has been most noticeable in the inner, western and middle ring LGAs (see **Figure 17**).

Figure 17 Level of increase in education attainment 1991-2011 Bachelor degree and higher by residences for Perth metropolitan LGAs
 (red lines denote outer metropolitan councils, black lines denote middle ring suburbs and blue denotes central and western suburb councils)(ABS Census
 2011 2006, 2001, 1996)

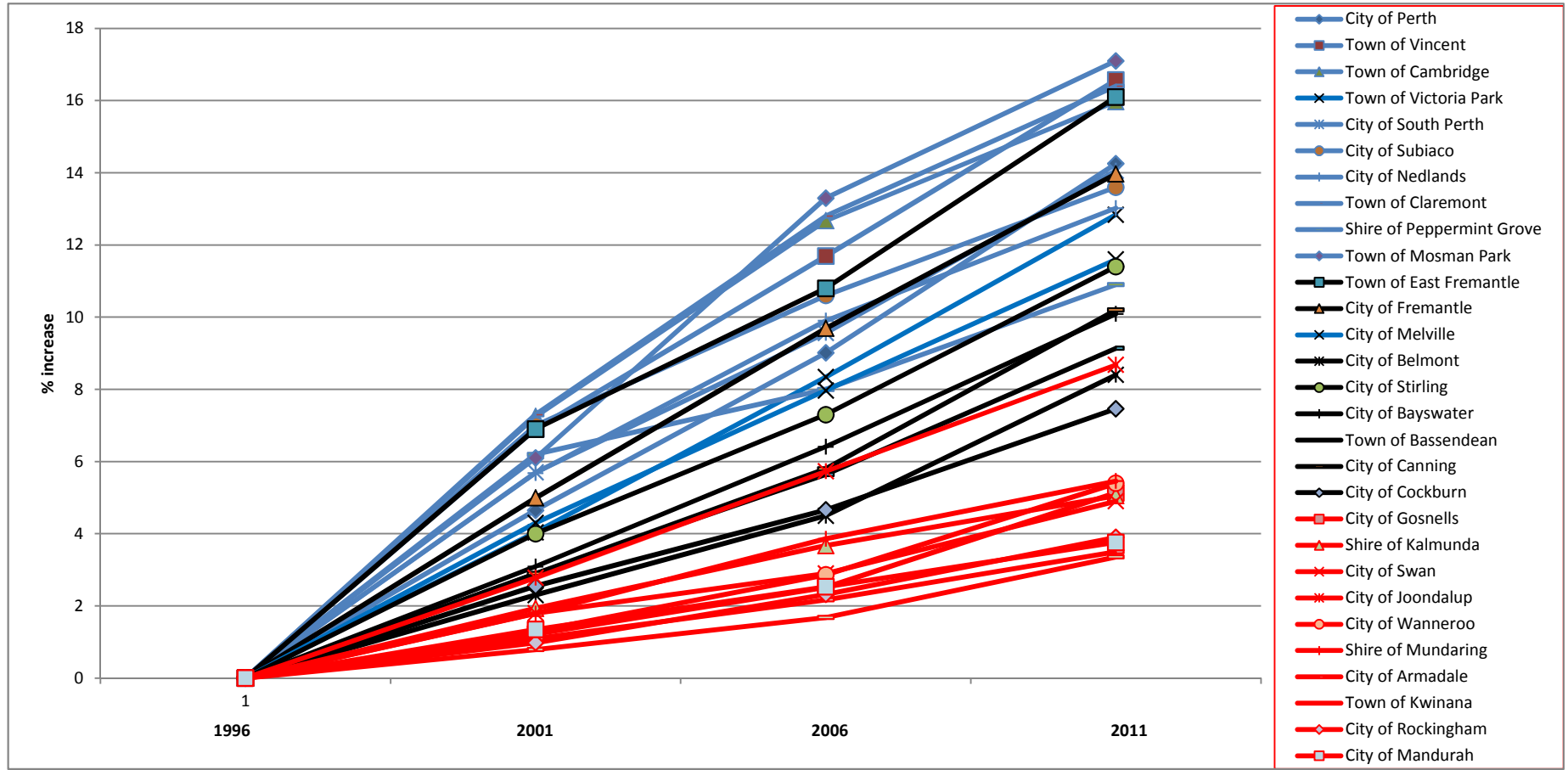
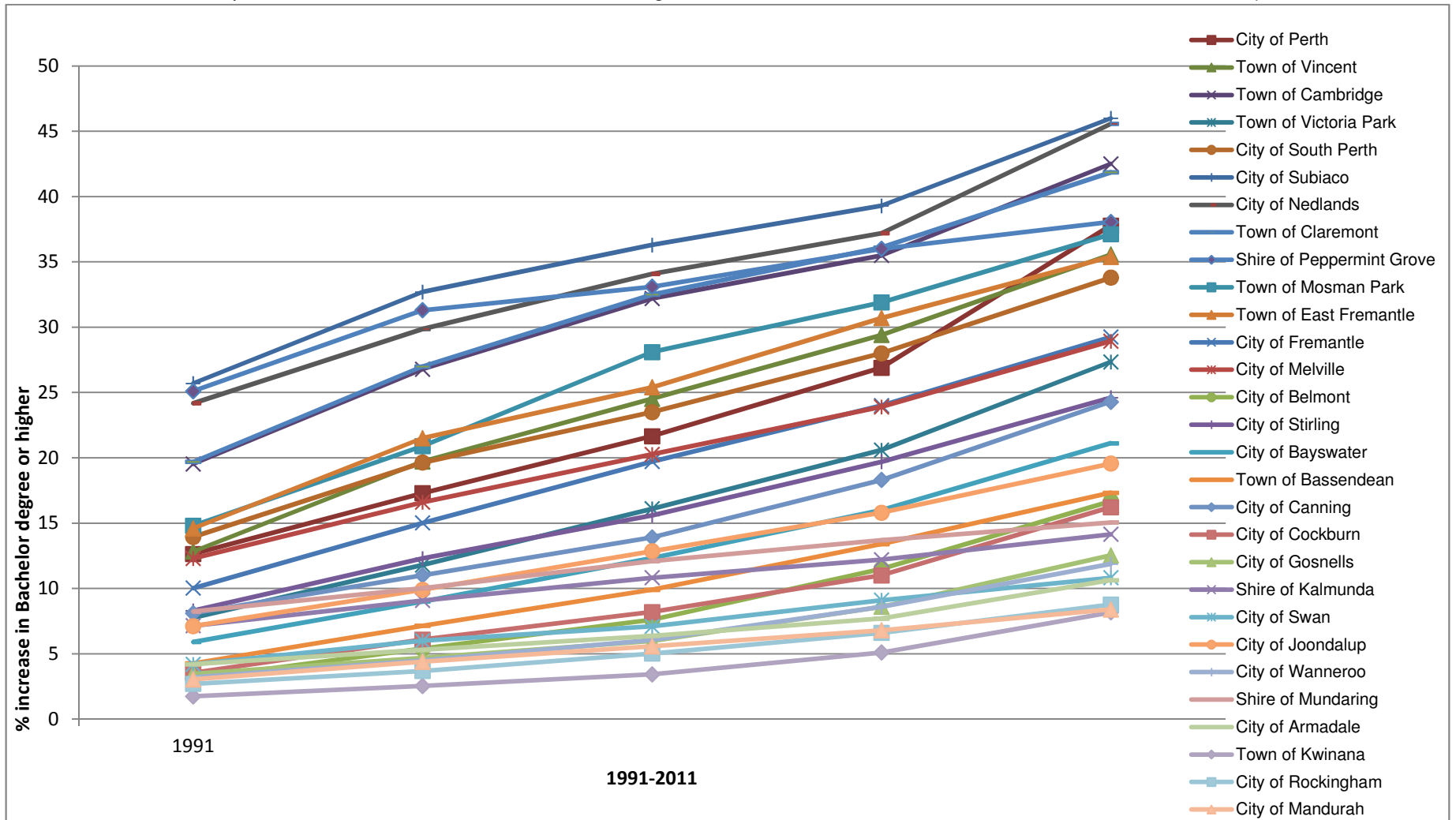


Figure 18 Education attainment 1991-2011 Bachelor degree and higher by residences for Perth metropolitan LGAs (red lines denote outer metropolitan councils, black lines denote middle ring suburbs and blue denotes central and western suburb councils)



Figures 16 and 17 demonstrate that the growth in tertiary education attainment was occurring in the inner and central council areas with the least growth being in the outer council areas. Knowledge intensification, in terms of the residential location of human capital, is occurring in the council areas around the Perth CBD. The councils with the highest growth have been the Towns of Vincent, East Fremantle, Claremont and Cambridge, and the Shire of Mosman Park. All of the outer suburban councils saw lower rises in Bachelor and higher education attainment, with the only exception being the City of Joondalup which out-performed two of the 11 middle ring councils. Notably, even outer suburban councils such as the Shires of Mundaring (growth of 5.46 per cent) and Kalamunda (5.05 per cent), which had relatively high levels of professional qualifications in 1991 (similar or higher than the middle ring councils such as the cities of Belmont, Canning, Stirling and Bayswater and the Town of Bassendean), saw little growth compared to the middle-ring suburbs (with growth ranging from 8.4 per cent to 11.4 per cent). Knowledge-intensive human capital, from the mid 1990s onwards, has increasingly spatially concentrated in those suburbs closest to and most connected to the Perth CBD.

6.4 Secondary question 3: Is ICT knowledge intensification occurring in Perth, both in terms of the spatial distribution of infrastructure and ICT enable businesses?

The spatial distribution of ICT infrastructure in Western Australia and in Perth is notably uneven. The Institution of Engineers Australia (IE Aust) (2010b) WA Infrastructure Report Card on ICT identified the Internet infrastructure characteristics of Western Australia. The existing dominant infrastructure, the public switched telephone network, while of a good standard for telephony, has major limitations in providing data services with significant broadband blackspots in metropolitan Perth and very limited availability in non-metropolitan areas. Effectively, Western Australia's extremely large land mass and relatively low population outside the Perth metropolitan area has strongly influenced the development of the state's ICT infrastructure. Since 2007, IE Aust (2010b) found there had been a decline in telecommunication quality due to increased congestion. The IE Aust Report (2010b, p.180) further highlights the urban nodal nature of broadband backhaul infrastructure in Australia, with backhaul providing the connection of "telecommunication aggregation points to major nodes in capital cities or regional centres" and providing "high capacity links between capital cities, or from regional centres to capital cities".⁷²

⁷² Backhaul refers to the long distance optical fibre and microwave transmission networks that connect local exchanges, main Internet exchanges or main Points of Presence (POPs) and ultimately end users.

Telstra and Optus (in the pre-NBN period) operated a substantial backhaul transmission network in WA with a range of other providers, including Nextgen, PIPE Networks, Powertel, Silk Telecom and Soul (IE Aust 2010). While some routes are served by three or more operators, the majority are served by Telstra alone (ACMA 2007). There are four interstate backhaul fibre cables connecting WA to the rest of Australia – two owned by Telstra, and one each by Optus and NextGen (Leighton Contractors) following the interstate rail (IE Aust 2010, Govt of WA 2008). All of these backhauls terminate in Perth, with only the NextGen cable having an access point outside Perth (in Kalgoorlie). Within Perth metropolitan area, the CBD dominates, with a number of companies offering fibre backhaul capacity in a competitive environment (Govt of WA 2008). Within the Perth CBD, a number of companies offer fibre backhaul capacity, and competition is strong. Some companies – Silk (Bright), Amcom and Telstra – have fibre rings or tails into key urban areas and thus competition exists in these areas (Govt of WA 2008). Some of the outer metropolitan areas rely on the less-effective microwave backhaul due to affordability issues, with areas on major infrastructure corridors (along transport and energy corridors) being serviced by fibre (IE Aust 2010, Govt of WA 2008). Regional WA backhaul is dominated by the Telstra monopoly with cost constraints limiting investment (IE Aust 2010).

In terms of Internet exchange points (being the key physical infrastructure for the exchange by autonomous networks of Internet activity), there are three in WA, which converge in Perth CBD. Perth's Internet exchanges include the cooperative WA Internet Exchange (WAIX) in the QV1 Building at the corner of St Georges Terrace and Milligan Street, operated by the Western Australian Internet Association, and two Internet exchanges operated by Telstra Inc. Backhaul transmission networks Nextgen, PIPE, Silk, Soul and Optus connect into the WAIX. The Telstra Internet exchanges are in Wellington Street 600 metres from the WAIX and Pier Street, 1km further east (Telstra Wholesale 2011).

The CBD location of the Internet exchanges in Perth demonstrates that little has changed in the location of ICT exchanges over the last 150 years starting with the telegraph, the first electric digital communication technology. The first telegraph service in WA opened in 1869 between Perth and Fremantle (Ward 1991). The General Post Office took over telegraph services from private operators in 1871 with the telegraph service relocating to General Post Office on St Georges Terrace between 1887 and 1890 (Ward 1991). A new General Post Office (and telegraph exchange) was opened at Forrest Place in 1923. Therefore, over the last 140 years, the key ICT exchange centres for WA have remained within a 1km radius of the CBD. This supports the contention that, despite the leaps in ICT technology, spatially modern ICT has been developed on the spatial 'bones' of older ICT technology.

The spatial clustering of the Internet exchanges has meant that the private fibre optic network radiated in and around the Perth CBD. While this would have been led by CBD demand, it has also reinforced the CBD as the primary centre for ICT and Internet- related business. An examination in the next section on the spatial distribution of ICT infrastructure in Perth will demonstrate that the location of ICT infrastructure is heavily influenced both by present day agglomerated economic activity and past economic and technological infrastructure patterns.

6.4.1 Methodology

An examination of the spatial distribution of WAIX participants provides a means of gauging the extent of clustering of any Internet-dependent businesses in Perth. The methodology used to map the spatial location of the WAIX participants is as follows.

Lists of WAIX participants (and links to their websites) were obtained from the Western Australian Internet Association (Inc) (WAIA) website in November 2010 and again in November 2012 (see **Appendix 3 List of WAIX Participants 2010 and 2012**). Addresses of head offices were obtained from company websites. In some cases, the participants were part of larger corporate or government organisations and the participant listed was a particular entity that operated Internet exchange dependent ICT infrastructure (i.e. data centre). The industry code of WAIX participants in 2010 and 2012 was determined using the ABS's Australian and New Zealand Standard Industrial Classification (ABS 2013i) and from an examination of services offered on the company or organisation websites (see **Appendix 3**). For the purpose of this exercise of spatial mapping of participants, where known, the participants' stated corporate offices were mapped. In the absence of the street address, at least the suburb was noted. Participants' spatial locations were mapped by using street addresses with Google Earth's search facility. With a number of overseas-based participants, particularly USA university participants, the exact street addresses were not provided and hence the centre of the university, as determined by Google Earth, was used. This, however, was of minute impact considering the international distances considered.

6.4.2 Spatial distribution of WA Internet Exchange participants

An examination of the spatial location and spatial proximity of participants in the WAIX, operated by the WAIA, demonstrates the spatial clustering of new Internet-based companies. The WAIA is an incorporated organisation formed in 1995 to represent the Internet community in Western Australia (WAIA 2010). WAIA's formation, as noted on its

website, was due to the “pending regulation and uncertainty” at the time of its formation meaning “that collaboration between different businesses in the Internet industry was a necessity” (WAIA 2010). The WAIA started in 1997 as an industry association for Internet-based companies and organisations to allow members the ability to inter-connect using an independent Internet exchange facility (WAIA 2011). The Internet exchange facility allows members to multi-laterally peer their networks at a considerably reduced rate (WAIA 2010).

In 2010 and 2012, the industry codes of the participants were overwhelmingly in the digital economy, Internet, and computing industry codes. In both years, the largest industry code was ‘5910 Internet Service Providers and Web Search Portals’, while the number of participants and the variability of other industry codes increased from 2010 to 2012.⁷³ An obvious conclusion is that the overwhelming majority of WAIX participants were Internet-dependent companies. The WAIA started in 1997 as an industry association for Internet based companies and organisations to allow members the ability to inter-connect using an independent Internet exchange facility (WAIA 2011).⁷⁴

6.4.3 Analysis of spatial location of WAIX participants

As **Figure 19** and **Figure 20** demonstrated, Perth WAIX participants were strongly clustered both in 2010 and in 2012.

⁷³ In both years, ‘5922 Electronic Information Storage Services’, ‘5801 Wired Telecommunications Network Operations’, ‘5802 Other Telecommunication Network Operations’, ‘7000 Computer System Design and Related Services’, and ‘5921 Data Processing, Web Hosting and Electronic Storage Services’ were among the top seven industry codes. Outside the top seven industry codes, the small number of participants (5 in 2010 and 8 in 2012) was spread evenly across a number of variable industry codes, with no more than one participant per code.

⁷⁴ WAIA’s formation was due to the “pending regulation and uncertainty” at the time of its formation meaning “that collaboration between different businesses in the Internet industry was a necessity” (WAIA 2010). The Internet exchange facility allows members to multi-laterally peer their networks at a considerably reduced rate (WAIA 2010). The WAIA operates under a Code of Conduct, which provides for a degree of industry self-regulation (WAIA 2010).

Figure 19 Distance from the WAIX of Perth WAIX participants 2010 and 2012

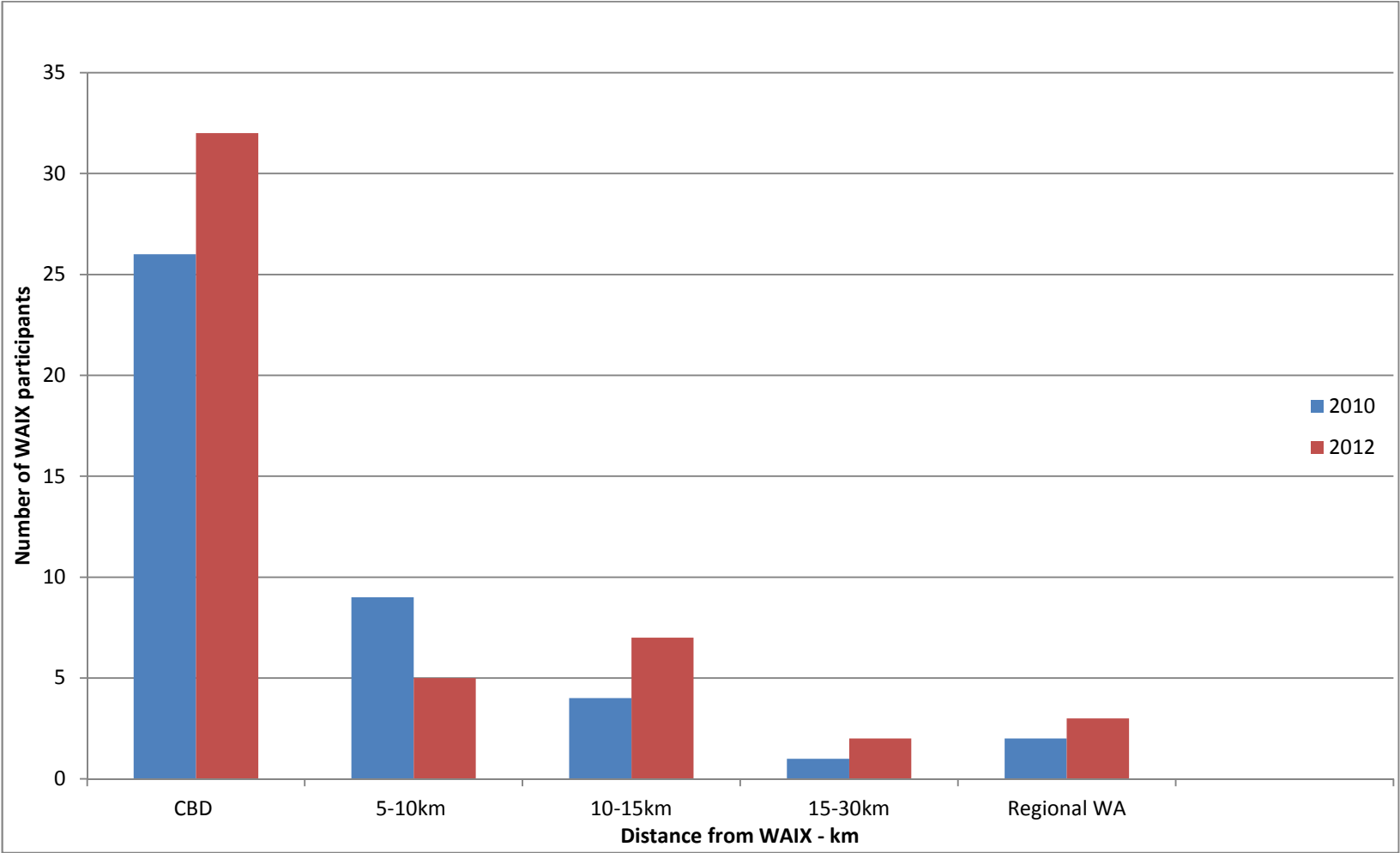
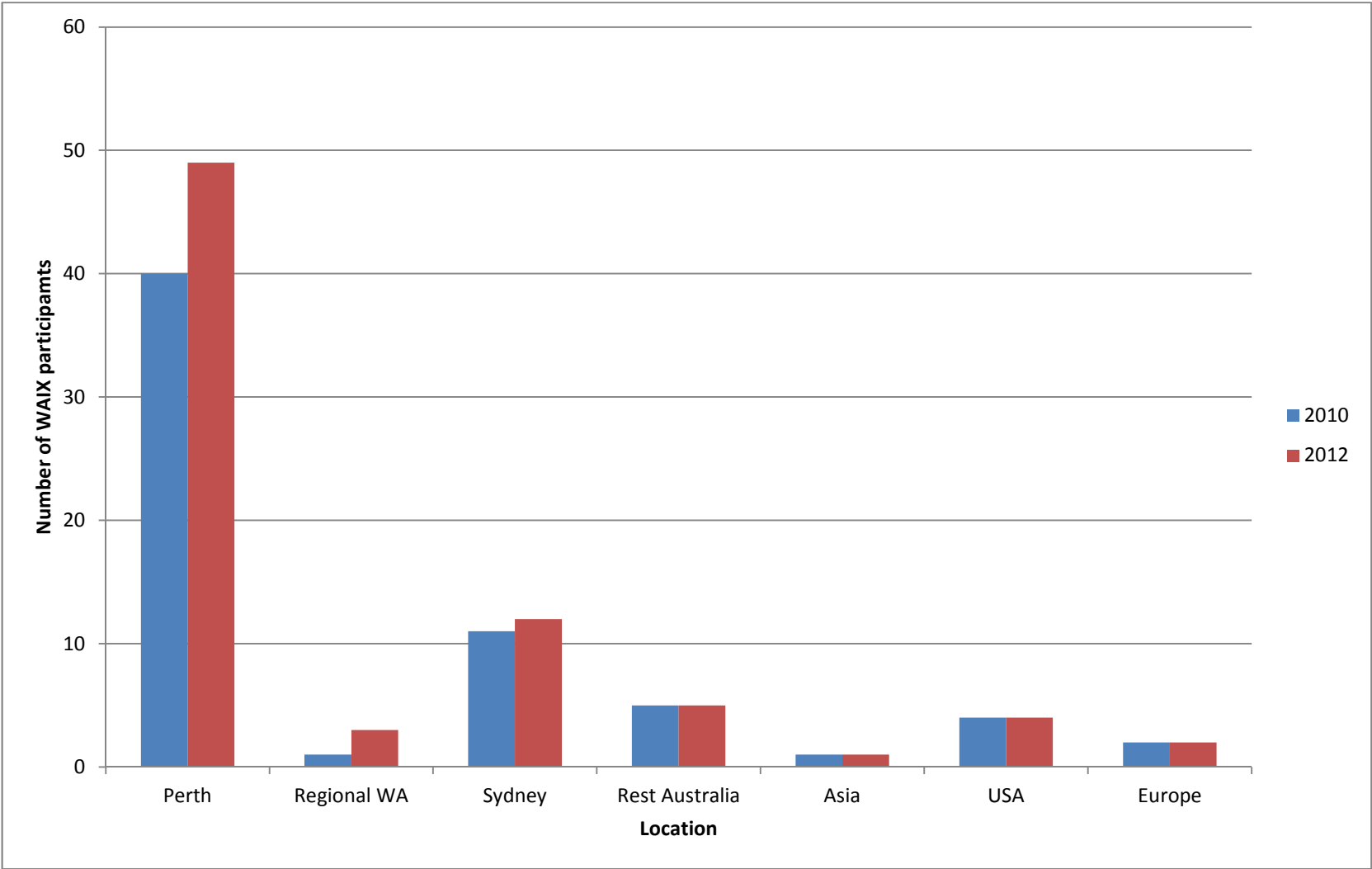


Figure 20 Distance from the WAIX of all WAIX Participants 2010 and 2012



Various nodes or clusters are apparent in **Figure 19**: a dominant Perth CBD and an inner city cluster (26 participants in 2010 and 32 in 2012); a middle ring 5–10km (9 participants in 2010 and 5 in 2012); another group spread beyond the middle suburban highway ring roads (4 in 2010 and 7 in 2012); and a small number of outer suburbs participants 15–30km (1 in 2010 and 2 in 2012). There were only two regional WA participants (one each in Bunbury and Kalgoorlie in 2010 and two in Bunbury in 2012 and one in Kalgoorlie). This was, as per **Figure 20**, exceeded by large clusters in Sydney (11 participants in 2010 and 12 in 2012) and smaller numbers across the other state capitals (5 in 2010 and 6 in 2012).

Internationally, there are four participants in the USA (exceeding regional WA) despite the distance, one in Asia with offices in Singapore and Hong Kong), two in Europe, one in the UK (Bath) and one in Sweden. Notably, all the international locations, except for Sweden, are the UK or ex-British colonies with English as the language of commerce.

The WAIX Perth 2010 and 2012 participants as shown in **Figure 19** were heavily clustered in and around the CBD. The cluster groups reduce in size the further away a member is from the Perth Internet exchange. This is consistent with a 'small worlds' graph identified by Schintler et al. (2005) and their examination of the US complex Internet networks. The clustering found with the WAIX confirms the importance of physical proximity to fellow ICT industry players. Similar clustering was also identified in a study of Italian Internet exchange peering activity by Giovannetti, Neuhoff and Spagnolo (2005) who found that physical proximity related to managing behaviour within an industry where cooperation was essential. This indicates similarities with the WAIX and WAIA's networking peering and dispute resolving role.

Figure 20 demonstrates the concentrations of participants outside Perth; mainly in Sydney (11 in 2010/12 in 2012), other major Australian cities combined to a lesser degree (5/6) and across major cities in north-east and western USA (5). These were all higher than in regional Western Australia (2/3). This is consistent with literature that sees city-to-city digital city networking (Devriendt et al. 2008) with urban concentrations at the international level and 'technopoles' of growth (Banister and Hickman 2006) with the knowledge economy agglomerating in particular regions and in particular parts of cities, usually the city core (Spiller 2004, 2005, Burger et al. 2009). Major urban centres have the capacity to overcome distance, in part because of the nature of their density and size provides knowledge gateways. The concentration of WAIX participants outside Perth being greatest in Sydney is also consistent with the notion of Sydney being Australia's global city, as argued in the *Sydney City of Cities* Report (Gleeson et al. 2004). In this sense Perth, as demonstrated by the WAIX participants at least, relates more to Sydney than any other Australian city, including closer cities such as Adelaide and Melbourne. The greater number of WAIX participation businesses and organisations in Sydney and the USA, rather than in regional

WA or other Australian capitals, supports Johansson and Quigley's (2004) arguments on the combining of network theory and agglomeration – that is, larger agglomerations have the greater networks and higher levels of connectivity.

The 2012 participants' spatial distribution was little changed from 2010. The CBD and inner city locations remained at 65 per cent of all Perth participants. There was a noticeable decrease in participants in the 5–10 km range and a small increase in 10–15km range. Notably, one new participant who was not CBD centric was the data centre AMC DC located in Munster, 22.5km south of the CBD. As is noted later, when the distribution of data centres in Perth is considered, there does seem to be a notable dispersement trend with newer and larger data centres that is not evident with other Perth-based WAIX participants.

6.4.4 Discussion of the spatial distribution of WAIX participants

The spatial distribution of the Perth-based participants in the WAIX is the result of a layering of economic, social and historical factors. As previously stated, an examination of ICT infrastructure in Perth supports the argument that the location of ICT infrastructure is heavily influenced both by present agglomerated economic activity and past economic and technological infrastructure patterns. This is highlighted by the advancement of digital telecommunication technology, but with the exchanges for the telegraph, the telephone and Internet remaining within the CBD in a 1–2km radius over 150 years. The spatial context of technology is intrinsically linked to access to communication technologies and broader present and historical economic, social, infrastructure and cultural inequalities of the 'digital divide' that exist in many countries, not just Australia (Gorman & Malecki 2000, Moss & Townsend 2000, Warf, 2001, Willis & Tranter, 2002, Gorman et al. 2003, Moriset 2003, Paradiso, 2003, Gorman & Kulkarni 2004, Kellerman 2004, Rutherford et al. 2004, Department of Broadband, Communications & the Digital Economy 2009, ABS 2008c, Tucker 2010, Tomer & Kane J 2015). This digital divide is spatially represented by a concentration and intensification of activity in and around city cores and the WAIX participants' distribution is particularly consistent with a wide variety of literature on the spatial location of ICT within post industrialised countries.

Kane (2010) identified five key proximity factors that drive the spatial concentration and intensification of ICT activity toward cities:

1. Physical proximity of Internet infrastructure
2. Knowledge content proximity

3. Technical network client support proximity
4. Labour market access and liveability proximity
5. Need for trust and business security proximity

The simple establishment of a new technology infrastructure such as the NBN will not necessarily remove these pre-existing layers of influence. Internet technology has been shown not to be removed from the advantages of proximity, economic agglomeration or from the traditional economic, social and political inequities. As the majority of Perth WAIX participants were office-based operations clustered in around the main office locations in the CBD and surrounds, it could be concluded that the key location decisions were based on a combination of Internet infrastructure and agglomeration benefits relating to knowledge spillover, accessibility to skilled labour markets, and access to other service providers and importantly to customers.

One potential weakness with this conclusion is that, with the exclusive and dominant role that ICT infrastructure has in the Perth CBD, it is arguable that the clustering is not surprising. To fully determine whether the clustering is due to a combination of ICT infrastructure and the benefits of agglomeration, further research would be required once the NBN has had time to have an impact on the location of WAIX participants. The extent to which the roll-out of NBN fibre optic across Perth and Western Australia's regional cities and towns in the next decade may or may not overturn the layers of spatial concentration of WAIX participants in around the Perth CBD can only be speculated at this time. It may be that the location of the Internet exchanges remain in the Perth CBD and this ensures a CBD-centric spatial distribution of firms dependent on the Internet. As noted in the next section of this thesis, there does seem to be, with the distribution of data centres in Perth, a notable dispersement trend for newer and larger data centres that is not evident with Perth CBD based businesses who are WAIX participants. A revisiting of the spatial location of WAIX participants in a decade from now would probably be required to address this question fully.

6.4.5 Spatial distribution of 'open' data centres in Perth

The extent of clustering of Internet activity in Perth can also be determined by consideration of the spatial location of data centres in the Perth metropolitan area. The remoteness of Perth means that activity requiring access to large data volumes quickly will be impacted by latency, which will limit Perth's desirability as a place to locate large volumes of data required readily elsewhere. In this sense, data centres in Perth would be expected to focus on local client needs or provide relay services to companies with Perth-based demand. As data travels at the speed of light, latency or lag can be noticeable and relevant. Seconds –

or even milliseconds – can make a significant difference, with quality of delay-sensitive traffic, the end user experience with cloud-based services, or the ability to trade fairly or quickly (Bernier 2010). As a location for data centres, Perth does offer some advantages. Spectrum Data (2012) promotes its Perth data centre Perth location as being a:

very safe and secure location for data storage as it is isolated from potential “hot spots”, pollution and larger population areas, but is connected by regular daily flight services to many international cities.

6.4.6 Methodology

Data centres can be categorised as business or consumer data centres (Cisco 2010a). Business data centres are dedicated to organisational needs and handle traffic for business needs that may adhere to stronger security guidelines. Consumer data centres cater to a wider audience and handle traffic for mass consumer and broader small business markets. A similar but alternative categorisation of data centres is to see them as enterprise (internal data) centres or external data centres. External data centre services can either be colocation (self-managed or through a third party) or fully externally managed data centres. Colocation is where an organisation locates their servers and storage off site at a data centre managed by the organisation itself or by a third party data management specialist. Colocation with a third party specialist data manager sees the third party lease rack space from a data centre to place its own servers (racks of servers) within the data centre and lease the servers to organisations. A fully managed service is where an organisation’s data is located at externally owned and managed data centres. Secondary data centres also provide data security through providing redundant infrastructure services by operating virtual back-up data systems (with secondary centres being separately located).

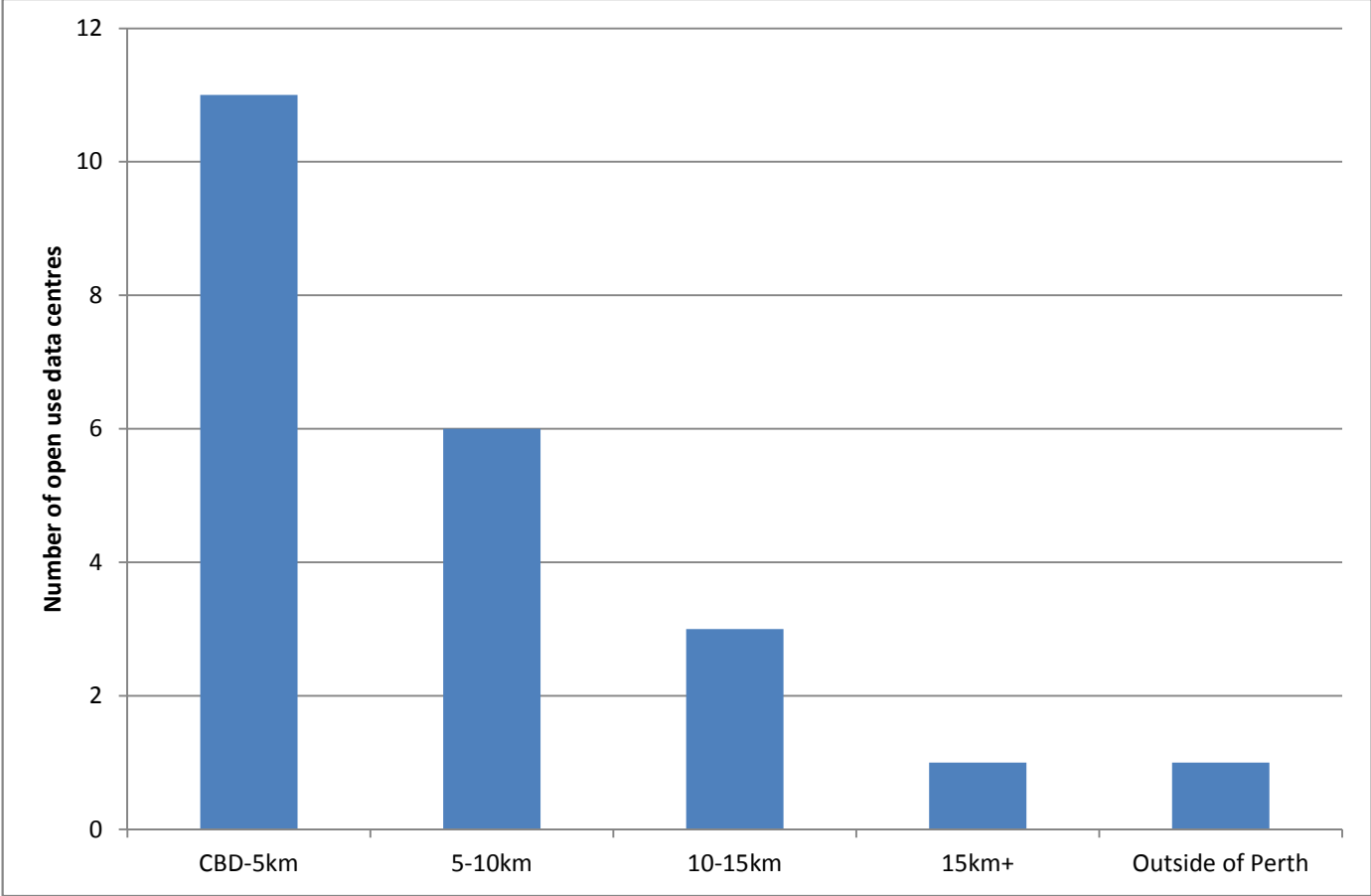
Using a Google Internet search for non-enterprise data centres located in Perth offering services to commercial or government sectors as colocation or managed services (distinct from enterprise internally managed data centres), during the period of February 2012 to May 2012, 22 data centres were identified. These data centres are referred to as ‘open use’ in that they are open for services to external parties. Companies offering colocation services at data centres owned by other companies were excluded to avoid double ups. All sites locations were identified within a reasonable distance of actual location (generally within 2km) as all suburb names were able to be identified and, in some cases, street locations. For security reasons, a number of data centres do not identify their street locations; however most of these companies identify their general location (i.e. within 2km of the Perth General Post Office (GPO). IsecT (2004 and 2011) notably advised that data centre physical signage

should be discreet as it is not good practice to broadcast precise locations. The extent to which organisations follow this advice obviously makes the study of the spatial location of data centres somewhat difficult. However a number of addresses were located through Google searches of the data centre's name or owner. Some searches provided the websites of contracting firms (e.g. construction industry firms) that provided information on the data centres as examples of their work or capability – and included the data centre's physical address. **Appendix 4** lists the open data centres in Perth, inclusive of their company name and, where known, their specific location.

6.4.7 Results and analysis on open data centres in Perth

There were 22 open use data centres identified that offered services to commercial or government sectors as colocation or managed services. The identified open use data centres were banded into groups based on their distance from the CBD GPO and this is graphed at **Figure 21**. A majority (52 per cent) of data centres (11) were identified as being in the CBD or immediate surrounds (within 5km) including Subiaco, East and West Perth. Of the 10 outside the CBD, there was a relationship proximity to the CBD: the further from the CBD, the fewer number of data centres. Six centres were located in light industrial or business parks in the middle ring suburbs of Bentley Technology Park (3) (6km south of the CBD), Osborne Park (8km north–west of the CBD), Shenton Park (6km west of CBD) and Belmont (6.5km east of CBD). Three were clustered at Malaga (including the new Fujitsu and NDC data centres), 12km north of the CBD. Notably, there were clusters at Bentley Technology Park and Malaga, with these areas containing significant fibre optic and/or electricity infrastructure (NextDC 2011, Fujitsu 2012). A further solitary newer data centre opened in 2011 in the outer suburb of Success. This AMC Data Centre was located 23km south of Perth at the Australian Marine Complex. In regional WA, ISA Technologies, in addition to a data centre in Bentley Technology Park, had another in Bunbury, 155km south of Perth.

Figure 21 **Open use data centres – distance from the Perth GPO - 2012**



While the majority of data centres were clustered around the CBD, the newer, larger stand-alone, purpose-built data centres were located away from the CBD in Shenton Park, Malaga and Bentley Technology Park – i.e. Vocus’s William Street data centre, the 540m² PerthiX, is considerably smaller than the newer Malaga Fujitsu and NextDC data centres which have or are to have data halls and technical space of over 3,000m² (Vocus 2010, NextDC 2011, Fujitsu 2012).

The CBD centres tended to be promoted on the infrastructure and accessibility advantages of the CBD – the CBD double power grid, the CBD fibre optic ring for redundancy, being on a privately-operated fibre optic network, closeness to Internet exchanges, and location accessibility for colocation services – where clients were able to locate their servers. Telstra’s Wholesale Colocation service website noted that customers were able to “*rent space for their IT&T equipment in a secure, reliable, and cost-efficient managed environment*”, contending “*colocation is suitable for all ... customers who want to house their equipment in a secure, reliable, controlled environment without having to find or build appropriate floor space*” (Telstra 2011). A number of CBD data centres advertised the advantage of a CBD location by its closeness through dark fibre links to CBD-based Internet exchanges. Telstra (2011) noted that colocation was not sold in isolation, but was bundled with other Telstra Wholesale products meaning that customers had the “*best access to Telstra’s unparalleled networks*”. Similarly, Central Data noted that their data centre, within the QV.1 tower, was the premier corporate building in Perth, had 24x7 security, dual diesel power generators and that the QV.1 building also hosted the “*main Internet Exchange in the region*”. This, they contended, meant that QV. 1 was the “*core of the Internet within Western Australia*’ with ‘*extremely high speed connectivity with Asia and America*” (Central Data Services 2011).

The newer, larger data centres, while noting their infrastructure capability, also played up being purpose built, stand-alone larger buildings (for example Fujitsu Malaga data centre is on 10,000m² site with an 8,500m² building and a data hall of 3,200 (Fujitsu 2012) and the NextDC’s building is 8,000m² with 3,000m² of technical space (NextDC 2011). The larger scale requirements obviously do not obviate the need for energy and telecommunication infrastructure. The NEXTDC site in Malaga, located approximately 12km north of Perth’s CBD, for example, was selected, after evaluation of a number of alternative sites, because of its closeness to a major electricity substation as well as significant telecommunications and public infrastructure (NEXTDC 2011, 2014). Among the newer larger centres, ‘The Metronode’ Shenton Park data centre uniquely had a key feature relating to its connectivity (as proposed) with the developer seeking for it to be the ‘wet ending’ site for a privately-owned submarine Internet cable linking Singapore to Sydney via Perth (Leighton Holdings

2011). Singapore was noted as a critical ICT infrastructure node in Asia with existing fibre optic infrastructure links.

The location of earlier data centres within the CBD and inner city is likely to have resulted from the early ICT infrastructure bias towards the Perth CBD. This is likely to have reinforced the first starter advantage for ICT-dependent knowledge economy companies in Perth. As with the WAIX Internet exchange participants being spatially concentrated within and around the Perth CBD, there are a number of factors potentially driving a firm's locational decisions and not only related to ICT infrastructure (closeness to labour, suppliers, clients and other industry players). What is clear from the literature and what would appear to be evidenced by this spatial study is that the combination of ICT infrastructure, and central location for proximity to labour, suppliers, clients and other industry players, strongly favours the CBD and surrounds.

The research into data centres in Perth suggests that the locational factors identified in this thesis are generally followed by external data centres offering services to industry in Perth. Earlier external data centres have seemingly taken advantage of the early bias of ICT infrastructure into the Perth CBD (the Internet exchanges, location of dark fibre networks and the landing sites of tier 1 Internet networks, as well as the CBD's other advantages of double power grids, and the ease of physical access for clients and workers needing to access data and servers). Notably, a trend was identified that newer and larger centres were locating in purpose-built facilities outside of the CBD (probably because of the desire for new construction of larger, unencumbered, more affordable non-CBD construction and land costs, purpose-built sites). There could also be a growing splintering difference in demand for data centres with some users in the central CBD area having a preference for colocation and therefore physical access to data centres (i.e. preserving their opportunities to access their servers) whereas other firms (possibly larger) are possibly more comfortable having their data managed in larger, more remote data centres. The larger stand-alone purpose-built data centres could also be providing a different, more complete data centre services. Arguably, as data demands rise and data centres improve their technology and capacity (and therefore their need for space) it could also be argued that external data management will become more standardised and acceptable.

This splintering and the standardisation in demand for data centres could be consistent with Leamer and Storper's (2001) view that in the 21st Century there will be a dividing of modern knowledge production process. On one side, there are intellectual/immaterial activities that are amenable to extremely fine and highly-efficient divisions of labour, requiring the employment of a range of specialists, which will locate in denser urban centres. This will be

because of the greater specialisation and complexity requiring greater coordination, longer-term relationships, closeness and agglomerations. On the other side, the standardisation of once intellectual/immaterial activities sees these activities moving further away to cheaper production locations. The more routine functions can be outsourced and extended geographically with communication technologies. In this sense, the geography of the Internet is double edged, with tendencies towards specialisation and agglomeration with newer and more complex products and transactions. Over time, the opportunity to simplify and codify older services and products permits the dispersing of routine activities away from denser more active centres. This understanding would suggest a pathway of external data management starting as specialised complex services, where trust-demands require data centres to be located close to clients. In part, the trust could be seen to be infrastructure dependent, in that CBDs had the early starter access to the key ICT Internet infrastructure. With growing demand for external data management being paralleled with technology improvements, the extension of tier 1 and dark fibre networks, and access to larger dedicated data centre premises, the likely trend would be to greater standardisation and reduction in costs. What is being seen in Perth, with the evolving location of external data centres, would appear to be this trend in process, not its conclusion.

6.4.8 Discussion – Contrasting and comparing the spatial location of data centres and location of the Perth-based participants of the WAIX

In a number of ways, the spatial comparison of data centres and the location of participants in an Internet exchange is a comparison of very different groupings. The participants in the WAIX were relatively varied in terms of their industry profile. The locations identified, of the WAIX participants, were corporate operating offices which are the physical public face of the organisations. The open data centres considered and located for this research were the hardware and software infrastructure sites rather than corporate head offices (i.e. the role of data centres is not focussed on providing face-to-face services). There was overlap with eight (8) WAIX participants being open data centres providers. While both WAIX participants and data centres had a majority within the CBD area, the WAIX participants (at 65 per cent) were more heavily concentrated than the data centres (52 per cent). The relatively high concentration of data centres, particularly the older centres, being CBD located, is consistent with the digital divide and CBD focus of key physical Internet infrastructure.

Notably, a number of data centres (8) had different locations for their corporate offices and data centres. Datacom's head office was in Adelaide Terrace while their data centre was in Belmont. Amcom Pty Ltd had their head office at 44 St Georges Terrace, with three data centres – one within 2km of Perth CBD, one in Adelaide Terrace and the third in Osborne

Park. This differing corporate head office is, in part, due to some data centres being part of larger companies offering a range of services beside data centres. Amcom Pty Ltd, for example, provide a range of other services including communications, cloud, and managed IT services (Amcom 2012). Another reason for differing locations was because the head offices were based in other states, such as Metronode, NextDC, and Vocus.

One key similarity between data centres and WAIX participants is their business reliance on the Internet and therefore access to quality Internet infrastructure such as fibre optic cabling and Internet exchanges. This reliance on Internet infrastructure likely gives rise to the most notable similarity and that is the concentration of data centres and WAIX participants in and around the Perth CBD. The location of Internet exchanges, high-quality fibre optic cable and being the terminus of interstate and international cables provides the Perth CBD with notable advantages for Internet-dependent organisations. One notable trend, noted with the newer and larger data centres, is that they are located out of the CBD/inner ring suburbs. These data centres were increasingly purpose-built on larger land parcels of up to 10,000m² which limits location options. Their choice of locations is somewhat further limited with their reliance on wired technology (both with high-quality fibre optic Internet access and reliable electricity connections). The need for industrial and light industrial businesses to have access to quality and reliable electricity and ICT (fibre optic) is seemingly providing an opportunity for data centres to locate in or near these areas. Outside the CBD and immediate surrounds, the notable favoured locations for data centres included the Malaga light industrial area, Bentley Technology Park, Osborne Park business and light industrial area, and the Australian Marine Complex at Success. Explanations for this are that data centres are becoming larger, needing specific, purpose-built buildings and larger parcels of land, with this need overriding any agglomeration benefits of being in and around the CBD. Improvements in Internet infrastructure beyond the CBD (e.g. in Malaga) are also a probable additional explanation.

This contrasts with the continued agglomeration of WAIX participants in and around the CBD. The analysis of the spatial location of WAIX participants over the (short) survey period does not show any notable trend to decentralise out of the CBD. The conclusion – with the caveat that there is little longitudinal data – that can be reached is that the WAIX participants (similar to other knowledge based companies) have a continued reliance on the agglomeration benefits of CBDs and inner urban areas. This contrasts with the data centres being less concentrated and showing signs of decentralisation. As standardisation and growth in demand for external data management increases, newer data centres are taking advantage of Internet infrastructure improvements in some middle ring suburbs. This is seeing the location of newer, larger data centres away from the CBD. As data centres' services become more standardised, more remote and less urban centre oriented locations

become more cost effective. This is, however, unlikely to impact on the location of immaterial/intellectual knowledge economy activity which relies more on agglomerative benefits of urban density such as specialised services, tacit knowledge exchange, and access to large skilled workforces. This is consistent with the principles that codified knowledge (e.g. data managed in data centres) is more likely to be standardised and subsequently dispersed or decentralised as distinct from continued agglomeration of tacit-based knowledge (see Leamer & Storper 2001).

**Part D: City spatial planning for a knowledge-intense economy:
Understanding Australia's and Perth's urban structures through
capacity for knowledge intensification**

Part D provides an alternative knowledge intensity approach to the current metropolitan regional planning for Perth. This new approach considers knowledge intensity and agglomeration through the different scales of urban development: national, metropolitan and the urban centre.

"Every city is a living body."

- Saint Augustine, *City of God*, early 5th century

"Not for us are content, and quiet, and peace of mind

For we go seeking a city that we shall never find."

- John Masefield, UK Poet Laureate, *The Seekers*, 1917

Chapter 7 Literature Review – Spatial scales and urban structure

7.1 Spatial scales

Part D of this thesis seeks to determine an alternative appropriate urban structure for post-industrial, knowledge-intense cities. Cities can be understood as operating at and within broad economic and spatial scales, including at the international, national, regional, urban metropolitan and urban centre scales. These scales provide for differing economic agglomeration drivers (Fujita, Krugman and Venables 1999, Schmutzler 1999, Arnott 2011). To provide an understanding of Perth's urban structure, the influence of the national urban system is first considered by using a 'new economic geography' 'system of cities' approach.⁵⁶

At the national urban system, Perth can be seen not only as a peripheral city but also as a primary city for its region (being the state of Western Australia). Following consideration of Australia's national structure, Part D examines Perth's urban

⁵⁶ There are a number of theories to explain urban settlement patterns, many of which provide useful and valid means to understand spatial development (see BITRE 2014a, pp.17-33).

structure, which is used as an example of a city whose urban structure has largely been driven by car use. The Perth urban structure is then reviewed through consideration of monocentric, polycentric and dispersed city structure typologies to determine the most apt characterisation. The importance of centres within cities is addressed in light of the need to maximise agglomeration and face-to-face knowledge spillover. This gives rise to consideration of non-CBD centres as potential knowledge-intensive centres to increase knowledge-intensive agglomeration economic activity. Ultimately, an ideal knowledge-intensive urban structure is proposed, which could be applied to Perth or other post-industrial cities.

While Part D seeks to provide an understanding as to the structure of cities, it is recognised that cities are full of complexities and diversity, reflecting the infinite mass of evolving and changing internal and external market forces and activities. Our planning and theoretical understanding is somewhat challenged by the endless changing complexity and diversity of cities. A key argument of this thesis is that planning needs to be cognisant of the market forces and influences shaping our cities. Without this understanding, we are seeking to create through our metropolitan planning “cities we shall never find” (Masefield 1917). Post-industrial cities are arguably ultimately about the efficiency of knowledge agglomeration processes within the labour and business-to-business service markets. Yigitcanlar and Martinez-Fernandez (2010) have argued that knowledge economic growth happens primarily through continuous waves of innovation and knowledge production. This requires, they contended, that urban structures need to be transformed into new forms to become highly competitive. If we accept that the market reality of our post-industrial economy is becoming increasingly knowledge-intensive, what then is the appropriate urban structure to support a strong knowledge-intensive economy? Is there in fact a single appropriate urban structure for a post-industrial knowledge-intensive city?

7.2 Urban structure: System of cities – the national context

The first context for understanding urban structure is how a city fits within the system of cities within its region, be it national or international. Cities are influenced by their wider geographic and economic contexts. As previously noted, 'new economic geography' provides a framework for understanding regional, national and international agglomeration (Fujita, Krugman & Venables 1999, Krugman 1999, Schmutzler 1999, Batty 2013, BITRE 2014a). The 'new economic geography' approach emphasises the existence of large economic agglomerations at the various spatial scales. It also recognises various scales of economic activity agglomerative or centripetal forces (Arnott 2011). In particular, Fujita, Krugman and Venables (1999) identified that cities operate within a system of cities that emerges as populations increase. A key factor in economic concentration is the circular logic of concentration due to pecuniary externalities from demand in the presence of scale economies and imperfect competition (Davis, D 2002). This occurs through certain regions enjoying 'first-nature' or 'first starter' advantages over others, such as superior natural resources. These 'first-nature' advantages are reinforced as agglomerative productivities arise unrelated to the natural advantage – providing a 'second-nature' advantage (Schmutzler 1999, Batty 2013). With regional and urban agglomerations, these externalities come from the presence of scale economies and costs of trade, which leads to producers wanting to locate near their major customers. The result is some cities develop an early dominance that often persists and reinforces itself. Batty (2013) has argued that this early dominance with particular cities, that were able to grow and increase their functional role over ever-larger populations, effectively explains city scale at the macro level.

Australia's system of cities also needs to be seen in the context of how the 'tyranny of distance' or Australia's geographical remoteness has influenced Australia's economic development (Blainey 1966). This is both in terms of distance from the rest of the world but also distances within Australia. Boulhol, de Serres and Molnar (2008) found that distance was a negative influencer of global GDP per capita, with various measures of distance to markets having a statistically significant negative effect. This was particularly so for Australia's and New Zealand's lesser access to markets relative to the OECD average having contributed negatively to GDP on a per capita basis by as much as 11 per cent. The 'tyranny of distance' has had a particular impact on Perth's and Western Australia's economic and cultural development that can be traced back to the beginning of European settlement (Department of Treasury and Finance 2004). This is not surprising with Perth being the capital of the largest state in Australia. Western Australia's land mass is 2,529,875sq km (more than a third larger

than the next state, Queensland⁵⁷). Western Australia also has the second-lowest population of any mainland state and the lowest prior to the 1980s when it passed South Australia (ABS 2012b).

The impact of distance must also be seen in the context of Australia's relatively small population. McLean (2004) contended that the most striking aspect of the Australian economy is that its land mass (7,659,861sq km) is similar in size to the continental contiguous 48 states of the USA (7,663,941sq km) but with a population equal to only a single USA state, Texas or New York. This limited population has resulted in a dispersion of the population around thousands of kilometres of coastline, which has given Australia a distinctive characteristic to its economy. Offsetting this, McLean (2004) noted, was the tendency, evident since the 19th century, for Australia's scattered population to concentrate in a few large urban areas (see also Robinson 1961, Butlin 1964 and 1984, Hugo 2002, Major Cities Unit 2010, Daley 2012, BITRE 2014a). Hugo (2002) asserted that a key characteristic of the Australian pattern of population distribution was not just concentration in urban centres but a concentration in, and growing dominance of, the largest metropolitan areas (see also Daley 2012). The relatively high levels of urbanisation in Australia were established in the colonial period (Butlin 1964, 1984). Butlin (1964) noted that by 1891, two-thirds of Australia's population lived in cities and towns, and it was not until 1920 that this was matched by the USA and not until 1950 in Canada. Butlin (1964, p. 6) saw the process of early urbanisation as the central feature of Australian history, overshadowing rural economic development.

Historically, the reason for the tendency for Australia's scattered population to concentrate in a few large urban areas, McLean (2004) argued, is the economic benefit from agglomeration. The earlier levels of urbanisation in Australia, compared to many other countries, is likely to have had an indirect contribution to Australia's historical high productivity and income levels (Butlin 1964, 1984, McLean 2004, and Attard 2008). There are a number of factors that influenced the early urban agglomeration in Australia; including the European settlers having limited capacity to deal the aridity and harshness of much of the Australian interior (Butlin 1964). McLean (2004) contended that this historical lesson is relevant to Australia's economic future: if economic density and agglomeration economies matter to the efficiency of Australia's economy, then long-run growth would be enhanced if the Australian economy were highly oriented to urban development. Despite the lack of research and understanding of agglomeration in Australian urban planning, agglomeration has likely

⁵⁷ In comparison, Alaska (at 1,717,854sq km) and Texas (696,200sq km) the US's two largest states would only rank third and fifth largest respectively if they were Australian states.

been driving the dominant form of urban settlement in Australia since the 19th century. Agglomeration benefits, supported by continued advances in transport and ICT are also likely to allow regional economic development to be managed most efficiently from capital and other major cities.

The dominance of a few large urban areas in Australia is consistent with modern urban development elsewhere in the world. Bertaud (2004) has argued that larger cities worldwide have grown despite the discouragement of engineers, planners and municipal officials, who in the 1960s and 1970s believed larger cities of several million people would be unmanageable and unliveable.⁵⁸ The reason Bertaud (2004) believed large cities grew and kept growing, in spite of national policies biased against larger cities, was because of the higher productivity benefit of large cities compared to smaller cities. This higher productivity was because of the larger effective labour markets provided by bigger cities. It is generally accepted, all other things being equal, that larger labour markets are more efficient than smaller ones (Baumgardner 1988, Prud'homme & Lee 1999, Glaeser & Ellison 1999, Bettencourt, Lobo, Helbing, Kuhnert & West 2007, Moretti 2012). A large, unified labour market is arguably the *raison d'être* of large cities.

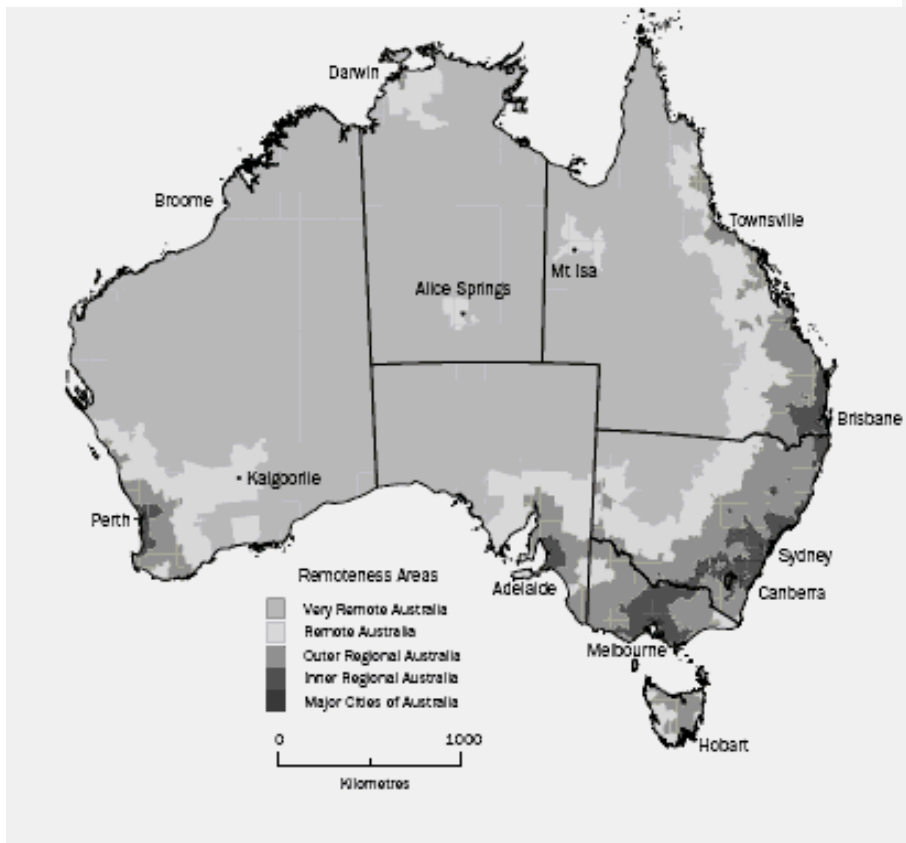
Prud'homme and Lee (1999), Moretti (2012) and Pan et al. (2012), however, each contended that it is not necessarily the size of the city alone that matters, but more so the effective labour market size. The effective labour market for any firm is determined by a combination of factors such as how close people live to their jobs, the speed or time it takes people to get to their jobs (i.e. the efficiency of a city's transport system), as well as the population size of the city. A larger effective labour market makes it easier for firms to find skills, and for workers to find desired jobs. Knowledge economy industries with diverse or specialised skills requirements, in particular, seek larger labour markets to draw upon (Moretti 2012). Daley (2012, p. 4) similarly argued that agglomeration economics is becoming increasingly influential in explaining the central role of large urban areas in Australia's economic growth. In particular, there is a consistency to agglomeration theory and the most rapidly growing areas being in or close to major capital cities (and that the larger inland regional cities also grow faster than their surrounding districts).

Since the 1970s, which marked the start in the growth of knowledge service industries and the corresponding decline in manufacturing, there has been a reinforcing of the

⁵⁸ Possibly this was due to the lack of understandings by planners and other officials of the benefits of agglomeration (and an over-focusing on disagglomeration externalities such as congestion).

growth of Australia's major cities (Hugo 2002, McManus 2005, Daley 2012, Kelly & Mares 2013, Kelly & Donegan 2014). The dominance of Australia's major cities has increased further since the turn of the century (ABS 2015a). This can be seen from the map of Australia's population distribution or lack thereof (**Figure 22**) (see also BITRE 2014a, pp 59-60). As of 2014, 15.63 million people, nearly two-thirds of Australia's population, were in the eight state and territory capital city metropolitan areas (ABS 2015a). Considerable growth has also occurred in some major regional cities such as the Gold Coast in Queensland; however, the Gold Coast is within the South East Queensland conurbation around Brisbane.⁵⁹

Figure 22 Remoteness areas and population distribution 30 June 2006



Source: (ABS 2008d)

The lack of population scale in Australia, agglomerating in only a few capital cities, has driven the primacy of Australia's state capital cities. As a nation, Australia does not have a primary city (Lanaspa, Pueyo & Sanz 2008) although its state capital cities

⁵⁹ Overall, Australia's urban population dominance meant that by 2014, 71 per cent of the population were living in the state and territory capitals and major regional cities (ABS 2015a). In 2012, it was estimated that 88.1 per cent of the population lived in these major cities and their regional hinterlands (ABS 2012b).

have had a high degree of primacy or urban dominance in their state regions since the mid 19th century (Robinson 1961, Butlin 1964, McManus 2005, Major Cities Unit 2010). This has been due to their dominance in factors such as population, rail and port infrastructure, commercial, financial, and manufacturing activity, as well as political governance (Robinson 1961, McManus 2005, Major Cities Unit 2010, BITRE 2014a). McManus (2005) and Daley (2012) have both noted that government action since the 1970s, for the decentralisation of activity away from the major cities, has been largely unsuccessful. There was little to no siphoning of activity, except where it was consistent with market forces and long-run trends (such as high real estate costs in cities such as Sydney pushing people to Queensland or the Northern NSW coast).

Notably, Perth, Adelaide and Melbourne have higher levels of primacy in respect to their states (78 per cent for Perth, 77 per cent for Adelaide and 74 per cent for Melbourne) compared to other state capitals (Sydney at 61 per cent is the next highest when combining ACT and NSW) (ABS 2013e). The reasons for the differing levels of primacy of Australian state capitals are not obvious, although the research section in Chapter 8 seeks to explain the Australian system of cities using a 'new economic geography', in particular, to explain the continued increasing primacy of Australian state capital cities.

7.3 Knowledge intensification and urban structures of cities: monocentric, polycentric and/or dispersed

The next scale to consider is the city structure. Traditionally, the monocentric city has been the model most widely used to analyse the spatial structure of cities (Glaeser & Kahn 2001, Kraus 2003, Bertaud 2004). The influential works of Alonso (1964), Muth (1969) and Mills (1972) on density gradients in metropolitan areas were based on the hypothesis of a monocentric city. The monocentric model seeks to explain prices for housing and land, preferences for quantity of housing, building height, and population density at various distances from a CBD. The general findings of the model emerge from a key insight that commuting cost differences within the city must be balanced by differences in the price of living space (Brueckner 1987). For any given piece of land, the shorter the trip to the CBD, the higher the value of the land. This is because a geometrically central location will provide trips of a shorter length to all other locations in the city. Densities, when market driven, tend to follow the price of land – hence the negative slope of the density gradient from the centre to the periphery.⁶⁰

⁶⁰ This leads to several related factors necessary to achieve spatial equilibrium in a monocentric city (Kraus 2003):

Commuting costs and congestion essentially result in decreasing returns as populations in monocentric cities increase (Berliant and Wang 2006). As a result, over time, as cities increase in size, their structure departs from the monocentric model with many trip-generating activities being spread in clusters over a wide area outside the traditional CBD. Therefore, we should expect polycentric cities to also have a negatively sloped density gradient, centred usually, but not always, on the CBD. In the polycentric city, the gradient slope should be flatter, as the accessibility advantage, based on proximity to the centre of gravity, is not as large as it is in the monocentric city.

The existence of a flatter but still negatively sloped density gradient in polycentric cities can be observed in cities that are obviously polycentric, such as Los Angeles or Atlanta (Bertaud 2004). Glaeser and Kahn (2001) believe that the dominant force explaining the rise in polycentric suburbanisation since 1900 is the automobile, but note that others emphasise different drivers of demand for modern suburbanisation, such as rising incomes that increase demand for low-density dwellings, government policies that favour suburban living, or big city socio-economic problems. Depending on the strength of these drivers, the evolution to polycentricity will be accelerated or restrained. Traditional historical CBDs with low level of amenities, high private car ownership, cheap land, flat topography, and grid street design will tend to accelerate polycentricity. Other drivers – historical CBDs with high level of amenities, rail-based public transport, radial primary road networks and difficult topography preventing communication between suburbs, will restrain polycentricity (Bertaud 2004). In this sense, the location of households comes from the interplay of commuting times, home prices, and the demand for land, non-government locational amenities, and government (Glaeser & Kahn 2001).

With decentralised activity, trips are generated over the wider metropolitan area. The spatial distribution and mobility of labour within cities is therefore critical. The efficiency of labour markets in modern complex cities means there is a need to avoid spatial fragmentation in an inefficient polycentric city. Bertaud (2004) argued that this means all the locations where jobs are offered should – at least potentially – be physically accessible from the place of residence of all households within about an

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- The price of housing is a decreasing function of distance to CBD.
 - Individuals who live farther from the CBD consume more housing. The rental value of land decreases as distance from CBD increases.
 - Structure density decreases as distance from CBD increases.
 - Population density decreases as distance from the CBD increases.

hour's travel time. Importantly, for a labour market to be efficient, workers need to have ready access not only to their current job location, but to future and prospective employment (Bertaud 2004).

Bertaud (2004, p. 6) dismissed the thinking that often idealised polycentric cities as potentially combinations of self-sufficient communities, each a cluster of employment within 'urban villages', aggregating to form a large polycentric metropolis. Bertaud (2004, pp 6–7) contended that

In such a large city, trips would be very short; ideally, everybody could even walk or bicycle to work. To my knowledge, nobody has ever observed this phenomenon in any large city.

The reason for this not occurring, according to Bertaud (2004, p. 7) was that a metropolis constituted by self-sufficient 'urban villages' would contradict the reason for the existence and continuous growth of large metropolitan areas; the increasing agglomeration returns obtained by having larger integrated labour markets. The self-contained urban village, Bertaud (2004) argued, was the ultimate way of fragmenting labour markets. Similarly, Jacobs (1961) also rejected the notion of self-contained neighbourhoods in cities when she called for recognition of the importance of the collective role neighbourhoods played in the wider city. In this sense, large competitive labour markets are efficient when they are flexible and able to meet the complexities of people living within complex network economies. As Jane Jacobs (1961, p. 132) said, in respect to jobs, entertainment and friends: "Isn't the wide choice and rich opportunity the whole point of cities?"

The key role that cities play in enabling complex and diverse social and economic life is dependent on mobility within and beyond cities.⁶¹ Burger et al. (2011) concluded that in addition to commuting, there are a number of complex economic interactions between locations within cities. These locations are functionally connected through trade, capital movements, leisure trips and shopping trips. Commuting, both in distance travelled and time taken, is a key influence on both workers' and employers' preferred location. It is generally accepted that there is a relationship between

⁶¹ Mead (1978) noted that a key function of the city was to provide for wide learning and knowledge-creating interactions. This learning and knowledge creation were able to be transferred to surrounding regions and beyond because of the superior infrastructure connectivity inherent in cities. A number of writers, including Glaeser (2005) on New York and WH Smith (1984) and Lambregt et al. (2005) on Amsterdam noted the wider connectivity role provided by major port trading cities for regions and nations. These port cities being at the front end of the receipt of global knowledge and new information resulted in them also being first in developing the latest commercial knowledge and information. This enabled mass media services not only for the port cities' consumers but for wider national and international markets. Through being a major centre of mass media, these cities were also then able to influence wider cultural values.

employer location and employee residential location preferences within cities. Workers in cities generally prefer, on average, to have a personal one-way trip commute of no more than 30 minutes (Marchetti 1994, Prud'homme & Lee 1999, Bertolini 2005, Scheurer 2010). Glaeser and Kahn (2001) found the strongest determinant of whether an industry locates in the city centre or the suburbs was access to its labour force. Using both cross-industry and industry-metropolitan statistical area (MSA) combined variation; it was found that when the workforce is predicted to live in suburban areas, the firms will also locate in suburban areas. This suggested that the primary determinant of the degree of suburbanisation was the demand of workers for suburban lifestyles. Glaeser and Kahn (2001, p. 36) concluded that although there was considerable heterogeneity across cities and industries, it was very clear that most of America's cities were fairly decentralised – typically more in Los Angeles than New York City. Across regions, the share of employment within three miles of the city centre was found to be no more than 29 per cent.

In decentralised cities, Glaeser and Kahn (2001) saw the decentralisation of employment as the result of an economic equilibrium where both firms and workers balanced the benefits of density against commuting costs. This meant the basic Alonso-Muth-Mills framework (Alonso 1964) was no longer the reality in the USA. In decentralised USA cities, commuting times barely rose with distance and this was because it was believed that increased commuting distances had been offset by the increased commuting speeds. Further, Glaeser and Kahn (2001) found that housing prices in American decentralised cities had not fallen with distance from the city. This has not been the case in Australia with increasing price values for CBD centric real estate (O'Connor and Rapson 2003, Forster 2006, Dodson 2008, Kulish, Richards and Gillitzer 2011, Kelly & Mares 2013). This was a strong indication that Australian cities still had, or had rediscovered, strong monocentric characteristics.

Bertaud (2004, p. 6) had contended that large cities are not born polycentric; they may evolve in that direction with monocentric and polycentric cities “being animals from the same species observed at a different time during their evolutionary process”. Further Bertaud (2004, p 6) made the point that:

No city is ever 100% monocentric, and it is seldom 100% polycentric (i.e. with no discernible “downtown”). Some cities are dominantly monocentric, others are dominantly polycentric and many are in between.

This makes the simplistic labelling of cities difficult. Lambregts et al. (2005, p. 32) contended that “polycentricity is, up to a certain extent, in the eye of the beholder”.

According to Burger et al. (2011), any perspective on a city needed to take into account the spatial scale (international, regional, city, and neighbourhood) at which polycentricity was studied. How territories were spatially organised and how this spatial organisation changed over time, they argued, was only possible to completely grasp when considering different spatial scales. While the monocentric city with strong population growth theoretically gives way to polycentric city-regions, the actual resultant metropolitan spatial structure often remains unclear (Burger et al. 2010).

The growth of polycentric cities was also conditional on providing a unified labour market. Bertaud (2004) argued that, in reality, a polycentric city functioned very much in the same way as a monocentric city. Jobs, wherever they were, attracted people from all over the city (Bertaud 2004, Lin, Allan, Cui and McLaughlin 2014). However, the pattern of trips was different, as in a polycentric city, each sub-centre generates trips from all over the built-up area of the city. Trips tended to show a wide dispersion of origin and destination; appearing almost random. Trips in a polycentric city tended to be longer than in a monocentric city (Bertaud 2004); however, they might be quicker or more efficient due to avoiding the congestion closer to the city centre (Glaeser & Kahn 2001, Lin, Allan, Cui and McLaughlin 2014). This is not true in all dispersed polycentric cities where urban congestion was not ameliorated and commuting distances and times were higher (Lin, Allan, Cui and McLaughlin 2014). Sydney and Perth travel data has shown distinctive and concentrated commuting patterns, consistent with a mono-centric city with the CBD and certain centres such as universities with a metropolitan catchment, whereas sub regional commuting is notably localised. This is suggestive of Perth and Sydney not being polycentric cities. This will be addressed in Chapter 11.

7.4 The evolution of urban structures in modern cities

Meijers and Burger et al. (2010) proposed, from the USA perspective, that modern urban life is now taking place in a *polycentric city-region*. The evolution from monocentric has seen an evolution of spatial area dominated by one principal centre to an area in which no centre dominates the other centres and where the emphasis is on the city-region with its wider surrounding territory. Lambgrets et al. (2005) however, questioned – with the supposed polycentric Randstad⁶² – the extent that one centre (Amsterdam) still retains the key global connectivity and economic activity. Meijer and Burger (2010, p. 1383) found a key driver for movement away from the monocentric

⁶² Randstad is a megalopolis in the Netherlands consisting of the four largest Dutch cities; Amsterdam, Rotterdam, The Hague and Utrecht.

model of cities was the fusion of formerly relatively independent and distinct cities into wider metropolitan areas. Meijers and Burger (2010, p. 1383) contended: "Nowadays, what is 'urban' increasingly spreads out over a wider region, requiring us to think of the city as a regional phenomenon."

Batten (1995) similarly argued that the global economy was nurturing an innovative class of polycentric network cities. Network cities were seen to evolve when two or more, previously independent adjacent cities, with potentially complementary functions, achieve significant economies by fast and reliable corridors of transport and communications infrastructure. The Randstad in the Netherlands and Kansai⁶³ in Japan were noted as prime examples of networked regions. Purmain (2003) noted that the spatial continuity of the built-up area made understanding agglomeration for a specific spatial area difficult. Purmain (2003) did not deny urban agglomeration, noting that, despite urban sprawl, the continuously built-up area still concentrated the major part of urban activities. This was particularly the case with jobs which concentrated in central locations more so than for residential populations. There was also a rough proportionality between the size of this core and that of the daily urban system (the extent of the commuting area). Noticeable exceptions, Purman (2003) found, were in North America where the presence of new-edge cities, located far away from an older centre, were blurring the concept of urban agglomeration or even of the daily urban commuting system.

Purman's findings were consistent with the evolution of USA cities identified by Glaeser and Kahn (2001). They contended USA cities had diverged into three different types of urban structure. The first class, were the dense information rich, knowledge capital intense and economically resurgent cities (New York, San Francisco, Boston and several others). They had a rich set of consumption activities with similarities to European cities. The increased demand for density and skilled knowledge workers with higher salaries had driven out lower human capital manufacturing industries. The second class, were the older denser cities, with lower human capital, and no opportunities for growth. These cities included Detroit, St Louis and Philadelphia. The third class, were the edge car-based cities, notably in Texas which had lower density. Glaeser and Kahn (2001) noted that these cities (prior to the GFC) were thriving. This was because, it was argued, car-based commuting was effective and desired in these cities. The effect of car-based decentralisation of employment was a reduction in commuting costs.

⁶³ Kansai is a region in southern-central region of the Honshu Island, Japan with the cities of Osaka, Kobe and Kyoto.

More recent USA labour market data (Bureau of Labor Statistics 2015) has largely upheld Glaeser et al.'s (2001) contentions surrounding the variable economic prospects of the three distinct classes of USA cities.⁶⁴ Notably, unemployment in the USA has been much higher in less knowledge-intense occupations regardless of city type (Bureau of Labor Statistics 2014, Table 29)⁶⁵. Consistent with this, Raphael and Stoll (2010), Moretti (2012) and Florida and Mellander (2013) all found that, in the GFC, unemployment was higher with population and consumption⁶⁶ focused jobs in the outer edge of cities compared to knowledge jobs in inner cities.

A polycentric structure assumes the existence of a number of self-evident centres within a metropolitan area. Many large metropolises develop from a core central city to a number of peripheral sub-centres resulting in a core-periphery urban structure (Berliant & Wang 2007). The core-periphery is arguably less polycentric because the degree of dispersment is such that, on the periphery, centres of scale do not form. Glaeser and Kahn (2001) examined the shares of population and jobs in the densest areas of the inner and outer rings of USA metropolitan areas and concluded that on the whole, suburban employment was best thought of as being decentralised and not polycentric. The findings were that the index was strongly (partially) correlated with the degree to which industry employment was decentralised. In the 24 USA metropolitan areas, there were at least twice as many jobs in the central city centres than in the suburban centres. In many of the metropolitan areas, the ratio of jobs in the central city to jobs in the suburban areas was more than three to one. The ratios for population were generally smaller, with jobs being more densely centred (Glaeser & Kahn 2001). Wheaton (2004) argued that the evidence showed that actual employment in USA cities turned out to be almost as dispersed as residences.

McMillen and Smith (2003) defined a sub-centre as having:

- Significantly higher employment densities than surrounding areas.
- A significantly large enough effect on the overall spatial structure of the urban area, to lead to local rises in population density, land prices, and perhaps housing prices.

⁶⁴ Boston, Washington and San Francisco metropolitan areas strongly outperformed Philadelphia, Detroit and St Louis in terms of unemployment. Sprawling cities were spread among some of the best performers (Salt Lake City, Dallas-Fort Worth-Arlington and Houston-Sugar Land-Baytown) but also among the worst (notably Las Vegas-Henderson-Paradise, Los Angeles-Long Beach-Santa Ana, Atlanta-Sandy Springs-Roswell).

⁶⁵ Although city type is still relevant for unemployment levels within occupational grouping, i.e. worse performing cities generally have higher unemployment across all occupational categories including in 'management, professional and related'.

⁶⁶ Rajan (2010) has argued that much of the population consumption activity in the USA has been credit fuelled (as distinct from productivity driven) and therefore prone to decreasing and increasing dependent on the cheapness or otherwise of money.

This definition seeks to limit sub-centres to those of a particular scale and gravity. Inherent in their definition is an acceptance that a sub-centre of status will have some level of agglomeration attraction of its own beyond that provided by the city region itself. It also delineates between cities with population scales and those without sizable populations. The definition of sub-centres arose from McMillen and Smith's (2003) research identifying sub-centres in 62 large urban areas in the USA. Their conclusions suggested that an urban area with low congestion levels developed its first sub-centre when its population reached 2.68 million and its second sub-centre reached a population of 6.74 million. This therefore meant that large metropolitan areas with high congestion levels were certain to have at least one sub-centre. A large metropolitan population, McMillen and Smith (2003) suggested, provided firms the opportunity to reproduce some of the agglomeration economies of the CBD in secondary employment centres while avoiding high commuting costs. This provided the incentive to form the sub-centres because wages could be reduced at a suburban location that saved commuting time for a firm's workers. Smaller urban areas, however, were estimated to have fewer sub-centres. Relevant to Perth, with most of its population growth occurring in recent decades (DTF 2004), was that cities with an older stock of housing also tended to have more sub-centres (McMillen and Smith 2004).

McMillen and Smith's (2003) research assists in the analysis of the relationship between the emergence of sub-centres and the potential for interactions among firms via knowledge spillovers. Theoretically, incumbent firms make their choice of location facing the trade-offs between the land rent, labour costs and the external benefit from knowledge spillovers. Rosenthal and Strange (2003) found externalities were, in reality, quite localised within centres. It could be assumed therefore, that knowledge spillover externalities would be stronger for firms in the same locations within a city. This suggests that below a certain population, cities could struggle to provide sufficient scale to create agglomeration economies in sub-centres. A polycentric city is dependent on the formation of sub-centres of sufficient scale. In smaller scale cities, (less than 2.68 million) this analysis would suggest that outside the CBD, there would be low agglomerative dispersed activity in and around lower density weak centres.

Rouwendal (1998), Glaeser and Kahn (2001), and Wheaton (2004) each noted that urban agglomeration was stronger in and around denser urban centre cores. This is consistent with the limited research and modelling of urban agglomeration within Australian cities that indicated low agglomerative activity dominating outside the central city cores (Trubka 2009, Rawnsley and Szafraneic 2009, SGS 2012a, Hensher et al. 2012, Kelly & Mares 2013, Kelly & Donegan 2014). This meant strong

agglomeration levels always gave rise to some degree of centrality of jobs and that, with a range of agglomeration functions, it could be optimal to have knowledge-intensive industries fully or at least partially centralised.

Wheaton (2004), in modelling a range of urban forms, had firms trading off a central-agglomeration force against the lower wages that accompanied shorter commuting distances in peripheral locations. Whatever the source of the agglomeration, if firms were all located at one centre, productive efficiency will be highest and production costs lower. This pattern will also lead to the longest commuter trips and hence congestion will be greatest as well. Alternatively, dispersed employment reduced congestion, but also productivity. This means that at one extreme, with employment centred, you would have very high agglomerative productivity with longer commute distances and high congestion levels. At the other extreme, lower agglomerative forces would have employment that is completely dispersed, providing commute distances of zero with the absence of congestion. The *degree* of employment dispersal, and hence land use mixing, Wheaton (2004) argued, would depend heavily on the level of agglomeration for a particular activity or how rapidly its productivity declined with distance.

Glaeser and Kahn (2001) notably concluded that the best predictor of centralisation appeared to be specialisation in services. Cities that specialised in services were relatively centralised. Conversely, cities that specialised in manufacturing tended to sprawl. As Bertaud (2004) had contended, cities could be monocentric and dispersed at the same time. Australian cities are arguably doing both – sprawling not so much on manufacturing but on consumption economic activity and centralising around their CBDs with knowledge service economic activity. The connection between manufacturing and decentralisation was also seen by Glaeser and Kahn (2001) with the cross-industry data demonstrating that manufacturing was more land intensive than service industries, which naturally gravitated to high-density areas. Further industries that employed the highly educated had a higher degree of centralisation, and industries that appeared to be idea intensive were more likely to locate in the central city. Glaeser and Kahn (2001) concluded that this may be because dense urban areas facilitated the speedy flow of ideas, and industries that are more idea intensive wanted to locate in denser areas. However, Batten (2005) saw that network cities, with creative networks, place a higher priority on knowledge-based activities like research, education and the creative arts. These cities developed cooperative mechanisms that may resemble those of inter-firm networks in the sense that each urban player stands to benefit from the synergies of interactive growth via reciprocity, knowledge exchange and unexpected creativity (Batten 2005).

Modern knowledge economies have also seen strong movement toward spatial and organisational separation or disintegration of the production processes within firms (Fujita and Thisse 1996, Leamer and Storper 2001, Gilli 2002, Spiller 2004, Castells 2005, Spiller 2005, Marin 2007, 2008, Kelly & Donegan 2014). Spatial disintegration can be seen as being either horizontal or vertical. It was horizontal disintegration if every unit of a multi-located firm hosted the same activities. It was vertical if all these units were specialised in different areas of productions or activity (Gilli 2002). Vertical disintegration therefore was where the management services function and production within a firm were separated physically, for example, where industrial firms externalised strategy and management to specialist consulting firms. The organisational and spatial vertical disintegration of production within firms is also occurring at the international level with increasing global trade within firms for intermediate goods and services (Helpman 2006, Marin 2007, Marin 2008). The increasing globalisation and disintegration of trade reinforces the importance of global connectivity and mechanisms of trade (i.e. ports, ICT infrastructure and airports) for knowledge-intense cities and centres.

The disintegration of production processes is also resulting in disintegration within the labour market and spatially between regions and within cities. Labour markets in the USA are now being defined by a bifurcation of low-paid service workers, and creative and knowledge workers, and this bifurcation is occurring spatially within regions and cities (Moretti 2012, Florida & Mellander 2013). Florida and Mellander (2013, p. 2) found that in the USA in recent decades:

As the middle of good-paying blue collar jobs has disappeared as a consequence of deindustrialization, globalization and automation, the job market has literally been bifurcated. On one side are higher paying, professional, knowledge and creative jobs that require considerable education and skill. And on the other are an even larger and faster growing number of more routine jobs in fields like personal care, retail sales and food service and preparation that pay much lower wages.

Forster (2006) and Kelly and Donegan (2014) have both argued that Australia's cities have, from the turn of the 21st century, started to display a bifurcation into 'two cities'. The 'cities' being the inner city/central core areas and the outer lying suburban areas. They were distinguished not only by their different employment structures, but also by population compositions and housing markets. The central cores had, by the start of the 21st century, increased or maintained their share of total metropolitan

employment. This reflected the strong growth in finance, business and employment associated with the producer services sector of the economy, which favoured central locations (Spiller 2003, Forster 2006, Kelly & Donegan 2014). The turnaround in central city employment also saw population growth in the city cores, albeit from a very low base. Outside the city centres, the location of employment within each of Australia's large cities was highly suburbanised with a multiplicity of locations scattered throughout the middle and outer suburbs (Forster 2006). Journey to work patterns were correspondingly dispersed, reflecting an increased pattern of complexity rather than the development of neatly planned centres, 'edge cities' or corridors. The preponderance of cross-suburban journeys between dispersed origins and destinations, lead to continued and very high levels of automobile dependence. The spatial complexity in the structure of Australian cities was found to be linked to the increased complexity and variability of how people participated in employment and business (Spiller 2003, Forster 2006, Kelly & Donegan 2014).

Forster (2006) contended that metropolitan planning strategies had been an attempt to re-assert the role for the urban policy concept of neatly structured suburban development organised around centres and self-contained urban realms. However, this was, he argued, an over-neat vision for the future that was inconsistent with increasing geographical complexity in cities. Houghton (1981) noted, a quarter of a century earlier in 1981, that the 'suburbanisation' of employment that had started in Australian cities in the early 1960s had failed to see, with one or two exceptions, the development of new sub-centres that supported a diverse range of activities. This failure in polycentric development centre has been ongoing in Australia over decades of urban development, at least since the mid 20th century. This was despite the strong population growth in metropolitan cities and the importance that planning policy had attached to polycentricity.

As previously stated, the increase in real estate land prices in the inner suburbs of Australia's major state capital cities from the 1980s and 1990s (O'Connor & Rapson 2003, Forster 2006, Dodson 2008, Kulish, Richards & Gillitzer 2011, Kelly & Mares 2013) is evidence of a trend back towards the monocentric city.⁶⁷ Kulish et al.'s (2011) analysis indicated that the increased land value in the inner city has risen with the upward movement in population size (income and borrowing capacity). Also supporting the monocentricity factor is the increase in housing density with proximity to the CBD, although this is uneven between cities and within cities (Kulish et al. 2011, Holz & Kane 2015). Looking at the period 1996 to 2006 for Australia's largest five

⁶⁷ In Perth and Sydney, proximity to the waterfront is the other increasingly positive factor increasing real estate prices (Kulish, Richards and Gillitzer 2011)

cities, the increase in housing density was greatest in the larger scaled cities, such as Sydney, Melbourne and Brisbane. It was lower in the smaller cities (and more primary cities) such as Perth and particularly in the mainland's smallest state capital city, Adelaide (Kulish et al. 2011).

Understanding the impact of the modern knowledge-intensive economy on city urban structures is essential for the urban and transport planning of cities. A model to explain how cities will evolve with an increasing reliance on knowledge and specialist services was proposed by Gilli (2002). The model looked at spatial disintegration and ultimately how industry relocated. It further addressed what the new urban configuration might look like when the economy evolved towards more specialised services, as well as the move away from industrial manufacturing to more service-oriented production.. The Gilli (2002) model sought to address how the evolution of the vertical relations between industry and services led from the industrial city, when the city was mostly industrial and monocentric, to the modern city where the city was surrounded with industrial clusters. While the original city concentrated services and industry in the centre, once there had been a vertical disintegration, firms chose the most appropriate location for their activity. For this, they took into account the need for land of their specific sector, whether services or industry (Gilli 2002). The industrial clusters tended to leave the centre (these industrial firms more valued affordable land over their interactions with each other). When the services were more and more specialised they remained in the centre (i.e. as seen with the clustering of consulting firms, usually in the CBD which enables agglomeration externalities, such as efficient communications with each other). This was typical of post WW II cities, where the CBD is located in the centre and the industrial clusters lie in the suburbs. Their location depended both on their need for land and on the transportation and exportation costs.

The Gilli (2002) model, however, foresees that in the post-modern city, industry would tend to re-cluster around the specialised CBD (whether a traditional or new CBD). The industrial clusters would locate back to the centre as the economy became more services oriented, with these services being more and more specialised. In the post-modern city, the location of services and industries, it was proposed, would tend to reconcile with the ever-increasing cross relations between services and industry, with production being highly externalised to specialised service firms. Ultimately, centres would become more important, and the more externalised or disintegrated economic activity there was, the more service firms would prefer a more monocentric configuration. To the degree polycentric formations can provide satisfaction, any sub-centres would be reliant on having high degrees of centrality and accessibility to the central CBD. Polycentricity, where sub-centres are dispersed and distant, will limit

agglomeration and knowledge spillover. This would suggest dispersed sub-centres are focused on population servicing rather than specialised or higher value servicing.

The lack of sub-centre formation has been examined in the USA by McMillen and Smith (2003). In particular, they considered how satellite sub-centres might form, as population grows, towards the outskirts of the USA metropolitan cities away from an original centre. McMillen and Smith's (2003) research attempted to fill the gap between theoretical and empirical research in understanding the transformation of monocentric cities to polycentric urban form by developing an empirical model of sub-centre formation in large urban areas. The Fujita and Ogawa (1982) polycentric model suggested that the equilibrium number of sub-centres was likely to increase with the population and the cost of commuting. This was strongly confirmed in McMillen and Smith's (2003) empirical research. Population growth and commuting costs explained most of the variation in the number of sub-centres across USA urban areas with congestion levels and population being highly correlated.

Economic evolution and population growth drive change in the urban structure of cities. The degree that suburbanisation drives dispersement of employment or polycentricity is worth noting. McMillen and Smith's (2003) research emphasises the importance of scale in developing sub-centres. It is evident that knowledge economic activity in cities is driving a demand for increased density and agglomerative centres. The lack of sub-centre formation and increased return to monocentricity in Australian cities, in particular with knowledge-intense activity, indicates that CBDs and their surrounds are the only place in Australian cities, to date, that are able to drive reasonable levels of urban agglomeration. This all suggests that Australia's sprawling consumption-driven metropolitan urban structures, dominated by car-based infrastructure, will provide limited advantages in a knowledge-intense economy.

7.5 Activity centres for knowledge intensification

CBDs perform as the sole or primary centres of knowledge intensity. If a city's CBD is the only knowledge centre within a city, then that CBD, will, as is the tendency of monocentric cities, develop overly high rents and congestion. These dis-economic pressures will eventually drive demand for a more polycentric city or alternatively stifle economic development driving it to other cities. If the future of any monocentric oriented knowledge city is to either develop a polycentric structure or to stagnate, then a type of new secondary or tertiary knowledge-intense centres need to be

considered. What drives knowledge agglomeration into city centres can be said to be a combination of size, scale, density, accessibility and human interactivity. Effectively, where knowledge-intense people are brought together in scale and density and allowed to undertake diverse economic activities in relative freedom, high levels of agglomeration are created. This provides a principle to guide the development of new knowledge-intense centres.

Across all cities in the USA, 231 employment centres or nodes have been identified and categorised by Levy and Gilchrist (2013) based on their levels of density. The 231 densest employment nodes were sorted into three broad categories, based on land use and major employment types. All three categories had employment densities significantly higher than the nationwide average. Notably, the 231 densest employment centres do not include industrial areas or centres anchored by shopping centres.

The three categories were:

1. Commercial downtowns and town centres (primary downtowns or CBDs⁶⁸)
- 63 per cent of dense employment nodes.
2. Urban education, cultural, healthcare, and research campuses (anchor institutions as secondary employment nodes⁶⁹)
- 21 per cent of dense employment nodes.
3. Office and research parks (in suburban-style, auto-oriented campuses⁷⁰)
- 16 per cent of dense employment nodes.

In Melbourne, Johnson (2010) found clusters of knowledge employment were based in similar categories (see **Figure 23**). These clusters being the Melbourne CBD, the surrounding edge of the CBD, particularly with creative industries and University of Melbourne, Alfred Hospital and Parkville Bioscience Precinct, inner city 'Knowledge Corner' east of the CBD, around Monash University at Clayton and smaller a 'Northern Campus' area centred around La Trobe University and

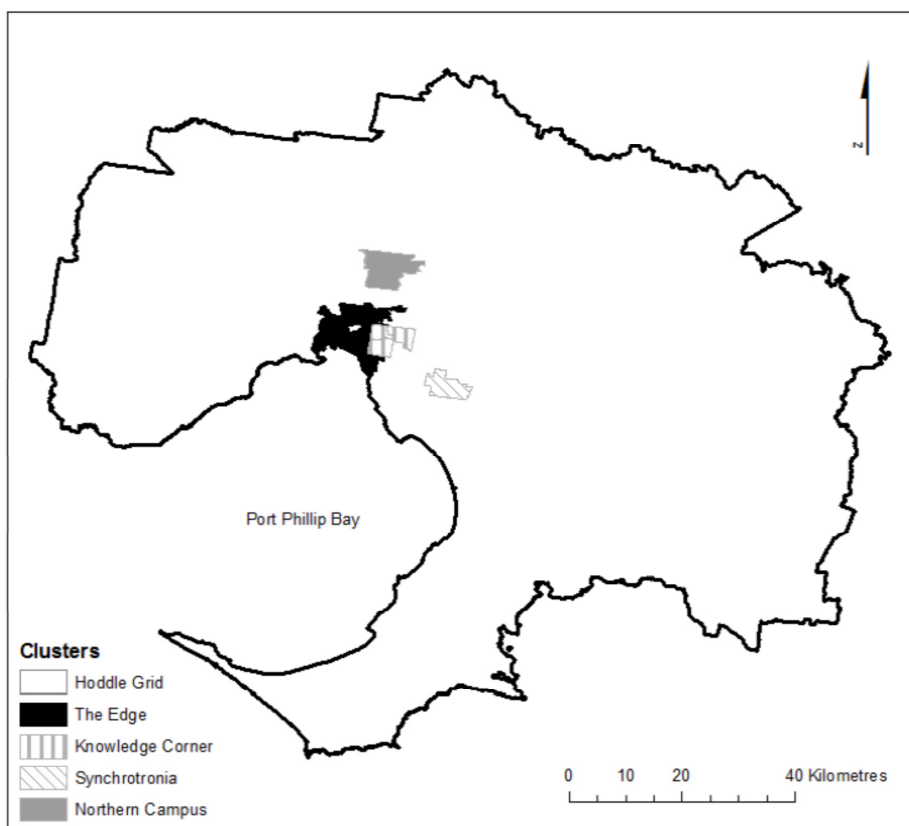
⁶⁸ Primary downtowns mainly consisted of professional, business, insurance, and financial services firms; real estate, communications, energy, and technology employers; as well as leisure, retail, and hospitality industries. These downtowns may include colleges, hospitals, universities, and cultural institutions, but these institutions do not usually constitute the largest employment sectors in these areas.

⁶⁹ Anchor institutions as secondary employment nodes included classrooms, dormitories, research and administrative buildings, museums, hospital beds, doctors' offices, treatment centres, and laboratories. These nodes included commercial offices, hotels, and retail but these uses were not the dominant employers.

⁷⁰ Office and research parks were usually the least diversified of urban employment centres. Nearly all of these were classified as secondary employment nodes.

commercial/research precincts 14km from the CBD. Notably, these knowledge economy clusters were themselves clustered centrally. Effectively, knowledge economy clusters demonstrated a high degree of centrality, that being, they had a strong 'gravitational pull' from the larger CBD and were generally located around the CBD within the inner or middle suburbs.

Figure 23 Location of knowledge economy clusters for Melbourne



Source: Johnson 2010

Urban employment density is a key characteristic of knowledge-intensive centres, facilitating opportunities for people and firms to interact and engage with each other (SGS 2012a, Kelly & Donegan 2014). This suggests an important role for the urban design of centres. Jacobs (1961, 1969) argued that agglomeration and activity in cities arrived from diversity of economic activity within cities and neighbourhoods (centres) with particular characteristics. For Jacobs (1969, 1969) this saw spillover and agglomeration happening in diverse cities between industries, this being more

important than the spillover within a particular industry. A key Jacobs (1961) argument was that the urban form and (accidental or otherwise) design of the city was crucial to the diversity and interactivity of agglomerative economic activity.

7.5.1 Urban design and public spaces within activity centres

The role of urban design for agglomeration can be seen to facilitate agglomeration through providing ease of access of labour to employment and to skills and services, and to facilitate interactivity and diversity and hence knowledge spillover. Arguably therefore, urban design that restricts rather than enables accessibility and knowledge spillover within and between public urban spaces, neighbourhoods, institutions and buildings needs to be questioned. Spaces and places and how they are designed and operate provide a key economic opportunity. According to Gehl (2007), the public spaces within cities have always served three vital functions, as;

1. meeting places,
2. marketplaces, and
3. connection spaces.

The exchange of economic and social information of all kinds occurs within meeting places. City spaces, operating as marketplaces, serve for exchange of goods and services. City streets, provide spaces for access to and connections between all these functions of the city while worthwhile destinations are important in generating street life and activity (Jacobs 1961, Montgomery 1998, Duany et al. 2000, Carmona et al. 2003, 2010). Channeling people into particular pathways (rather than dispersing people) means they are likely to interact and make similar choices of place to attend for social and economic activities. According to Jacobs (1961) the streets and sidewalks are the main public spaces of a city.⁷¹

To achieve the maximum benefit from any given local agglomeration (the higher the scale and density the better) there needs to be high levels of quality interaction between people within and outside of the centre to facilitate knowledge spillover. Increased levels of knowledge spillover will have beneficial economic and social outcomes for a society.

⁷¹ Jacobs (1961) argued that for exuberant diversity in a city's streets and centres, four conditions were indispensable:

1. Districts or centres (and their internal elements) must serve more than one primary function, preferably more than two.
2. Short block - so streets and opportunities to turn corners were frequent.
3. Mingled or mix use close-grained buildings varying in age and condition to increase the diversity of activity.
4. Sufficiently dense concentration of people.

Margaret Mead (1978 p. 118) expressed a classic quote on the city as a place for interaction in response to a question of whether cities had outlived their usefulness:

The city as a center where, any day in any year, there may be a fresh encounter with a new talent, a keen mind or a gifted specialist this is essential to the life of a country. To play this role in our lives a city must have a soul a university, a great art or music school, a cathedral or a great mosque or temple, a great laboratory or scientific center, as well as the libraries and museums and galleries that bring past and present together. A city must be a place where groups of women and men are seeking and developing the highest things they know. This can never be outlived.

The key to this quote is the pursuit of new and higher knowledge through a diverse range of experiences and interactions.

As a general premise, knowledge-intensive activity centres should be planned to be dense and of scale and should facilitate a multiplicity of interactions, organised and otherwise, from diverse knowledge-intensive people and locations. The aim of which is to lead to an intensification of activity and therefore increased knowledge spillover. This should be an important planning and design premise for post-industrial knowledge centres where economic success is increasingly dependent on knowledge advantage.

Chapter 8 Literature Review – Knowledge intensity and activity centres within Australian planning

8.1 Activity centres planning in Australia

Australia's capital city metropolitan regional planning schemes have overwhelmingly been developed on the premise of a polycentric approach, with a broad detailed hierarchy of activity centre types (Gleeson et al. 2004, Forster 2006, Dodson 2008, Bunker 2009, Johnson 2010). Generally, the types of centres have been defined in detail, with the CBD as the singular central centre, with a hierarchy of lesser principal or primary, major, secondary, district and neighbourhood centre types. Somewhat separate to the hierarchy has been the 'specialised activity centres', focused on airports and universities. It is often the case that for each type of centre, the actual centres are listed and named.

As noted previously, Sydney's *City of Cities* (Department of Planning 2005) was the first metropolitan planning scheme that identified global economy opportunities and sought to have urban conditions within activity centres that would attract advanced business activities (Gleeson et al. 2004, Bunker 2009). *Plan Melbourne* (DIPLI 2014) however, was the first Australian metropolitan plan to explicitly reference knowledge-intense economic activity and agglomeration as being a key to a metropolitan city's future. Not only did it recognise the transformation in the city's economy from labour-intense industries to knowledge-intense, it noted the importance of knowledge-intense employment centres (p. 3) and the role that knowledge-intense jobs would increasingly play in driving Melbourne's economic future (p. 5). The Plan moved away from the traditional planning activity centre approach of seeing specialist centres excluded from the urban hierarchy. The Plan identified 'National Employment Clusters' as being key job drivers, along with the CBD and lower density industrial areas. 'National Employment Clusters' were effectively recognised as knowledge-intense precincts, along with the 'Expanded CBD', but unlike their previous categorisation as 'Specialist Centres' they were viewed as being clearly mixed-use with residential, retail and commercial (DIPLI, p30). Further, there was a clear inclusion of 'National Employment Clusters' in the urban structure of city (secondary only to the 'Expanded CBD' in terms of their economic importance), rather than separated out of the urban hierarchy.

Plan Melbourne can be contrasted with Perth's more traditional distributed polycentric sustainable transport focused *Directions 2031* (WAPC 2010a) and the draft implementation strategy - *Perth and Peel @ 3.5 Million* (WAPC 2015). For the Perth metropolitan area, *Directions 2031* (and *Perth and Peel @ 3.5 Million*) specifically note the need for a focus on activity centre to create a more efficient region for economic development and a reduced need for travel. This is to be achieved through a number of the key activity centres (needing to be) well connected by public transport (WAPC 2010b, p. iii). In particular there is a stated aim of having a more 'equitable distribution of jobs' throughout the metropolitan area (WAPC 2010b, p. 3). The planning policy instrument that supports planning for activity centres in Perth and Peel is the State Planning Policy 4.2 (WAPC 2010b). The key stated aims of the policy are to reduce overall need to travel, support active transport and produce a more energy efficient urban form. The focus on sustainable transport largely follows the direction set in the previous metropolitan scheme *Network City* (see Bunker 2009). The implementation strategy for *Direction 2031*, the still (as of August 2016) draft *Perth and Peel @ 3.5 Million* (WAPC 2015) continues the focus on sustainability and self-containment. It however does make reference to 'agglomeration' and 'knowledge-intensive industries' in a cursory way but does not, in any substantial way, address their impact on urban form. It appears that planning for the 'knowledge economy' is restricted to particular industries and precincts with the stated strategies and actions being, to provide '*new specialised knowledge and innovation hubs at strategic, highly connected locations*' (WAPC 2015, p. 64). The focus in *Perth and Peel @3.5 Million* on urban population consolidation, particularly within the central region, will provide city-scale agglomeration benefits compared to continued urban sprawl. This, however, is not noted as an objective or benefit.

There are no stated aims in *Directions 2031* or State Planning Policy 4.2 as to economic development through increased agglomeration or knowledge intensification. Nor is there any recognition as to the changing nature of the economy. This is addressed in a limited way within the draft *Perth and Peel @ 3.5 Million*. The Activity Centre strategy, as per the State Planning Policy 4.2 (see **Figure 24**), provides for the following hierarchy:

- Perth CBD being 'Capital City Perth',
- Primary Activity Centre(s) (no activity centres were identified as performing this role),
- Strategic Metropolitan Centres,
- Secondary Centres,
- District Centres and
- Neighbourhood Centres.

Higher order activity centres are noted as being strategic metropolitan, secondary and district centres. Specialist Centres are separate to the hierarchy and are seen as principal specialised centres which are recognised as having regionally significant economic or institutional activities that generate many work and visitor trips requiring a high level of transport accessibility⁷². Specialist centres are noted to include Curtin University/Bentley Technology Park (with a primary function of education/technology campus), UWA/QEII (health/education and research), Murdoch University (health/education/research) and the two metropolitan airports, being Perth and Jandakot.

While it is recognised that specialist centres provide opportunities for complimentary activities, particularly knowledge based businesses, land use that compliments the primary function of these centres is to be encouraged and only on a scale that does not detract from other centres in the hierarchy. Major office development is to be located in the CBD and in strategic metropolitan, secondary centres as well as specialised centres but only where appropriate. Notably specialist centres are not referenced with respect to residential density targets, diversity of land uses, nor urban form requirements. This indicates a satisfaction with the campus model.⁷³

The main focus of metropolitan regional planning policy in Australia, in terms of non-CBD activity centres, has been shopping centres and older suburban town centres based on retail. Yamashita, Fujii, and Itoh (2006 p. 9.13) have identified four types of activity centres anchored by retail in Melbourne. These types of shopping centres are also recognisable in the Perth metropolitan area (Perth examples are in brackets⁷⁴):

1. Older inner or middle suburbs shopping street where medium size shopping centres without department stores were subsequently added in more recent times, (Fremantle, Subiaco, Peppermint Grove, Victoria Park Forum, Claremont),
2. Stand alone, large suburban shopping centres which subsequently attract other functions around them (Morley Galleria, Booragoon, Whitfield, Stirling/Innaloo, Karrinyup),

⁷² Universities in Perth as major regional trip generators is confirmed by the analysis for UWA by Shannon, Giles-Corti, Pikora, Bulsara, Shilton and Bull 2006

⁷³ The campus is the commonest spatial form of the Australian university, and the campus, as an institutional single purpose function, limits a university's capacity to act as a mixed-use 'activity centre.' The campus model will be addressed in detail within Chapter 9.

⁷⁴ Under the State Planning Policy 4.2 Activity Centres for Perth and Peel (WA Government Gazette 2010) Joondalup, Stirling/Innaloo, Cannington, Rockingham, Morley Galleria, Armadale, Fremantle and Midland are identified as Strategic Metropolitan Centres. These centres are represented in the last three activity centre types identified by Yamashita et al. (2006).

3. Traditional town centres in lower density outer suburbs around train stations where large shopping centres with department stores were developed (Armadale and Midland though these centres lack department stores),
4. Newer constructed outer suburban centres with larger shopping centres, usually with train stations (Joondalup, Cannington, Mandurah Forum – with stations, Rockingham – no station).

The key part that retail and shopping centres play in Australian cities and their economy cannot be dismissed, regardless of their role or otherwise in the knowledge economy.⁷⁵ The efficiency and effectiveness of the retail industry is important to ensure consumers have access to the widest choice of goods at the best prices and receive service consistent with their preferences (Productivity Commission 2011b). This explanation of retail places the industry firmly within the household consumption part of the economy.

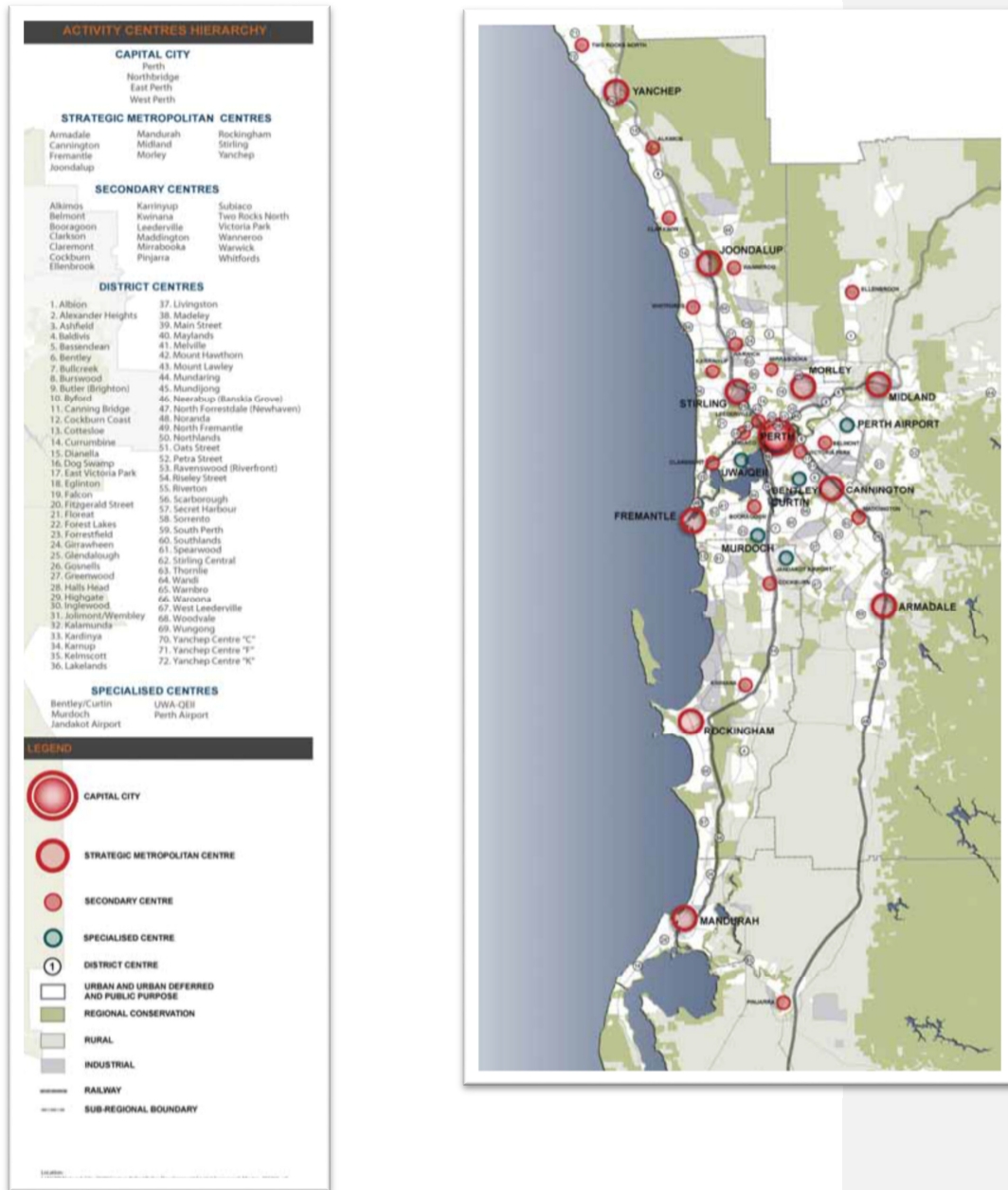
Generally speaking, expenditure is influenced by disposable income.⁷⁶ Not all consumption however is retail related. The growth rate of retail sales has generally trended down over the past two decades, due to long-term or structural changes in the economy and consumer behaviour (Productivity Commission 2011b). This has been partly to do with the increased expenditure on services, but also because of the relative reduction in prices of imported goods. The shopping centre has also very much been a suburban phenomenon underpinned by private motor vehicles. The essential function of shopping centres in Australia has included the provision of large parking facilities that have promoted one-stop shopping by car (Yamashita, Fujii, & Itoh 2006, Productivity Commission 2011a). Much of the population growth of Australian cities was post WW II (largely limited to within the expanded metropolitan areas of Australia's major cities). The development of the shopping centre reflected this post WW II rapid population growth in suburban areas and the significant increase in car ownership, with retail and consumption expanding away from central business districts into shopping centres in suburban areas (Gillette 1985, Conner 1997, Productivity Commission 2011a, Productivity Commission 2011b). This transformation of Australia's retail scene reflected the import of the American shopping mall (Conner 1997, Productivity Commission 2011a) though with some differences in typical store composition between larger USA and Australian shopping centres (with the inclusion of major supermarkets as anchors in Australia) (Yamashita, Fujii, & Itoh 2006). This has meant that the larger Australian shopping centres function as 'central places' in that they provide for consumers from far suburbs in terms of shopping goods (fashion)

⁷⁵ There were, in 2009–2010, almost 140,000 retail businesses in Australia, with about 1.2 million people or 10.7 per cent of the total working population employed in the industry, and generating 4.1 per cent of Australia's GDP (Productivity Commission 2011).

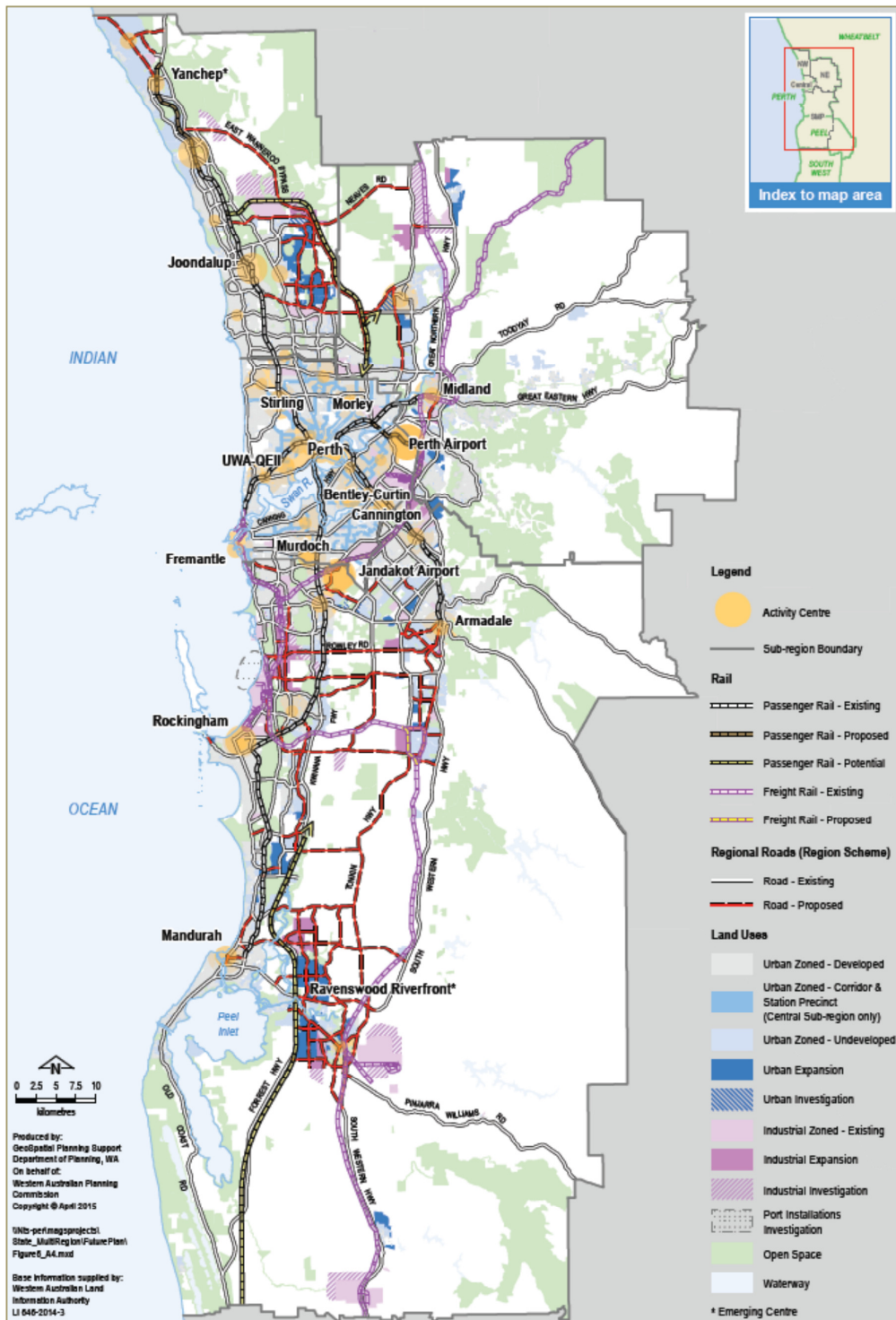
⁷⁶ Australian state capital cities generally have higher incomes and therefore higher expenditure than the balance of their states (ABS 2011c). Average incomes in the capital cities are 25 per cent above those in the regions, with all states recording higher capital city average incomes.

and closer consumers for convenience goods (supermarket food stuffs) (Yamashita, Fujii, & Itoh 2006).

Figure 24 Gazetted Activity Centres Hierarchy for Perth and Spatial Plan for Perth



Source: WAPC 2010b, Activity Centres in Perth and Peel, State Planning Policy 4.2



Source: draft Perth and Peel @ 3.5 million (WAPC 2015)

The Activity Centres for Perth and Peel (WAPC 2010b) reflect the traditional planning practice in Australia that supports the dislocation of the university campuses from the perceived mainstay of spatial economic activity. This traditional view can be traced back to at least the 1950s Hepburn and Stephenson Plan for a polycentric city, which was underpinned by a motor vehicle consumption based suburban form (Davis & Hartford-Mills 2016). This approach in the 21st century has failed to adapt to the changing nature of the Perth and wider Australian economy that has been increasingly changing towards a greater level of knowledge intensity. A detailed consideration of activity centres and their potential for knowledge-intense centres will be addressed in subsequent sections.

8.2 Activity centre types and knowledge intensification

In researching what activity centres²² would be best suited to knowledge-intense economic activity and industries, it is proposed to analyse the spatial characteristics of shopping centres and universities through the prism of the three elements of knowledge intensification:

1. Knowledge economic activity,
2. ICT, and
3. Human capital.

Before considering activity centre type and knowledge intensification, it is worth contrasting the economic roles of universities and shopping centres, particularly in respect to Australia's tradable economic activity. Tertiary education's export income earning role,²³ both in terms of international education services and underpinning the supply of knowledge workers for a wide range of export oriented knowledge-intense industries, contrasts with the more import-focused role of the retail and consumption economy underpinning shopping centres. Consumption goods were, for the quarter ending June 2013 (being a reasonably indicative quarter²⁴), the second highest category, seasonally adjusted, of the total goods imported into Australia (ABS 2013f). While shopping centres cannot be said to be the sole trading post of imported goods, it is trite to note that goods consumption has a large import component (Dark &

²² In Perth under the State Planning Policy 4.2 Activity Centres for Perth and Peel (WA Government Gazette 2010) Perth's centres anchored by universities and by major shopping centres are categorised as 'Specialised Centres' and 'Strategic Metropolitan Centres' respectively. In the absence of any nominated Primary Activity Centres as second tier centres in the centre hierarchy 'Specialised Centres' and 'Strategic Metropolitan Centres' have been identified as the most likely centres to be best suited for knowledge-intense economic activity.

²³ *Education* exports are composed of *Education-related travel services* (including fees and living expenses of foreign students studying in Australia) and *Other education services* (including the non-travel related education services such as consultancy services).

²⁴ Being 28 per cent for the June quarter 2013 and averaging 28 per cent for the previous 5 year period (ABS 2013 Cat. No 5302.0)

Hawkins 2005) and notably, consumption goods, other than rural food commodities, are a relatively minor export function compared to imports (ABS 2013f).

Even on this high-level economic consideration it can be argued that to increase the planning focus on centres anchored by universities is to assist in increasing the export income generation for cities and the nation. In contrast, a priority for activity centres anchored by shopping centres is to favour the import function of consumption over the export function of knowledge-intense centres. This is not to diminish the value of consumption (though goods are arguably less important than services in terms of attracting people including knowledge workers to a city: see Glaeser et al. 2001, Florida 2001, Yigitcanlar 2007) but a city ultimately needs to have higher levels of production than consumption to be economically viable.

Chapter 9 Universities as potential knowledge-intensive centres

9.1 Universities and knowledge economy intensification

This section will first consider the extent of knowledge (economic activity, human capital and ICT) intensification occurring with universities. It will then examine the urban spatial characteristics of universities with particular regard to Australian universities²⁵ and their potential as knowledge-intensive urban centres (the background to university types in Australia is set out in **Appendix 5 Australian university types and their spatial characteristics**).

The recent worldwide knowledge economy reform agenda for the university sector has focused on delivering national competitiveness in a globalising economy (Bradley Review into Higher Education (the Bradley Review) 2008, OECD 2013, ATN 2015). The knowledge economic role of universities can be seen as part of a long-term historical trend. Etzkowitz, Webster & Healey (1998) contended that the Humboldtian reforms in the 19th century (the German model of universities conceived by the philosopher and educationalist Wilhelm von Humboldt) were when knowledge production became a core university mission. Internationally, the national university sectors, Takeuchi (2008) has argued, have been increasingly about global economic functions, (that is, being parties in the global economy rather than just national economies). These global economic functions require high levels of specialised knowledge and information relating to technology and economics as well as broader cultural, political and social research that add to the knowledge economic agglomeration. Takeuchi (2008) contended that universities have proven themselves effective in the supply of the special knowledge in these areas and further, that in a global economy, specialised activities are provided on a global basis. This lends itself

²⁵ Marginson and Considine (2000) have identified and categorised five university types in Australia that not only suggest spatial characteristics but also historical and socio-cultural characteristics. These university types, which are used in this thesis, are:

- *sandstone* (superior economic resources, classic sandstone architecture, strong networks with their alumni, the professions and international scholars),
- *redbrick* (more corporate and modernised than the sandstone, generally the second university in capital cities, the *redbrick* term being adopted from early 20th century urban UK universities built generally in red brick),
- *unitech* (post WW II formed from institutes of technology with strong professional cultures),
- *gumtree* (from the 1960s and 1970s, bushland settings featuring natives flora and gumtrees, nationalistic, usually the school leaver's second, third or fourth choice), and
- *new universities* (formed post 1986 from merger of Colleges of Advanced Education, often a number of branch campuses across metropolitan regional and rural areas).

to global networks of which universities can contribute to and as Takeuchi (2008 p. 109) stated:

A university can contribute to the knowledge economy activities of an urban area with a network that transcends a city or national boundary.

In Australia, the primary purpose of the university has been to create, acquire, apply and transmit knowledge (DETYA 1998). Universities produce teaching, research and community service outputs and they do this as multi-output organisations (Abbott & Doucouliagos 2003, Wiewel & Perry 2008). Teaching and research (and even community service) can be considered knowledge outputs. While they are urban organisations and institutions, the degree that their campuses are part of multi-player centres will be considered in the research section. The link between universities and national economic development in Australia has been in federal government thinking for at least half a century (Marginson & Considine 2000).²⁶

The Bradley Review (2008; p. xi-xii) argued that Australia's economic future was tied to being able to compete in the new globalised economy. This meant an increasing need for universities to be at the heart of the national strategy for research²⁷ and innovation, which was a critical foundation of Australia's response to a globalised world. ATN (2015) has noted however, that Australia continues to rank poorly on university-industry innovation collaboration despite Australia having a well-regarded research sector which ranked ninth in terms of research output per capital within the OECD. ATN (2015, p. 7) contend that innovation within the global economy is increasingly relying on partnerships with a shift away from proprietary models of knowledge creation.

The university economic development linkage worldwide has, as Pinheiro, Benneworth and Jones (2012) argued, moved to a new level in recent decades with the recent period being a second academic revolution largely pushed by governments, with the emphasis increasing on the exploitation of knowledge in commercial ways. The government driven policy focused on universities and industry working closer together to maximize the benefits from the commercialisation of new knowledge which led to the development, in mid 1990s, of the 'triple helix' model of university-industry-

²⁶ Starting with the 1957 Murray Report, then 1964 Martin Report, the (Minister) Dawkins Reforms (1987) and subsequent 1988 West Report (see Marginson & Considine 2000) and more recently the Bradley Review (2008) there has been a regular and ongoing consideration of university sector as being more connected to the (government's prescribed) national economic mission by various Australian Federal governments.

²⁷ The Excellence in Research for Australia (ERA) Report (ARC 2012) provides an indicator of the knowledge intensity of Australian university research, which, collectively for 2012, reported 413,477 publications and other research outputs, \$8,767,725,070 of external research income and 781 patents.

government relationship (Etzkowitz & Leydesdorff 1995).²⁸

The greater level of economic and commercial engagement by universities (pushed and pulled by either government or industry) has led to a neo-institutional model of universities, the “entrepreneurial universities” or the “enterprise university” (Clark, 1998, Etzkowitz et al. 1998, Marginson & Considine 2000, Etzkowitz, 2002, 2008; Mirowski & Sent, 2007, Pinheiro et al. 2012). Bastalich (2010) however, has argued that the economic development role of universities in the national government led narrative has been applied overly narrowly. This is both in terms of disregard for the wider social and culture role that universities play in a society and the (now more formal) corporate linkages. Bastalich (2010) contended that corporate linkages, which it was claimed had largely already been highly permeable and mutually co-dependent, had, as they became more formal, created issues relating to undue secrecy, lack of autonomy and intellectual property conflicts. Davis (2002), in reviewing the history of the arguments over the nature of universities in the UK and Australia, concluded that most eminent thinkers emphasised the need for balance between intellectual academic freedom and the practical necessities of life, though he saw in Australia, as in other countries, that balance appeared to have been lost in the 21st century.²⁹ Bastalich (2010) had also questioned the links necessarily between innovation causing growth and progress, arguing that the deeper inventiveness of slower, more specialised research has been sidelined for more ‘creative’, immediate and short-term focused research as well as a focus on generic skills.³⁰

Despite the attention of successive Australian Federal governments to include the university sector in the national economic narrative, the Australian Technology Network of Universities (ATNU) has questioned the effectiveness of Australian university-industry innovation collaboration (ATNU 2015). ATNU has noted that Australia ranked 29th out of 30 in the OECD in terms of the proportion of businesses collaborating with universities on innovation, despite Australia ranking ninth in terms of research output per capita amongst OECD nations.

²⁸ The Triple Helix model sees an alternating set of relationships between bilateral and trilateral spheres of activity between government, industry and universities. A different ‘triple’ model from that of Etzkowitz and Leydesdorff (1995) is the three pillar European model of Thierstein et al. (2006), where the three interplaying parties in the knowledge economy are universities, advanced knowledge producers and industry (with government being absent).

²⁹ Michael Oakeshott (1950), the British political philosopher, made a similar point much earlier when the post-war role of universities was being reviewed in the UK. Oakeshott (1950:p. 24) argued that an over prescription as to role and function of a university missed the point of a university, stating that: “A university is not a machine for achieving a particular result; it is a manner of human activity.”

³⁰ Bastalich's (2010) arguments are consistent, with an acceptance of a Jacob's (1961, 1969) approach to agglomeration; i.e. based on diverse (and largely unmanaged) economic activity. For a national government to become over prescriptive as to the economic narrative (and policy strategies) in relation to the knowledge economy is to assume a potentially ineffective or negative economic control approach to what is a competitive, largely uncontrollable, and constantly and quickly evolving set of economic activities.

Pinheiro et al. (2012) have contended that there are now three economic 'missions' of new enterprise universities:

1. Research into intellectual property,
2. Direct contribution of universities to economic development, and
3. Management of knowledge transfer into industry.

The third point obviously raises the question of how best to transfer this knowledge. The consideration of this requires recognition of the often informal and unintentional, face-to-face nature of knowledge transfer of tacit knowledge, which, particularly in urban areas, has a strong spatial context. This means that the economic role of universities, while part of the state and national agenda, has to be seen in the context of where the interaction is actually occurring i.e. in the localised and regional spatial spheres.

Universities and research bodies, internationally, have been seen as engines of economic growth for regions through the creation of such knowledge economic outputs (Marginson & Considine 2000, Varga et al. 2003, Ponds et al. 2007, Mayer 2007, Wiewel and Perry 2008, Andersson, Quigley and Wilhelmsson 2009, Wyn 2009, Lendel 2010, Raciti 2010, Howells et al. 2012, OECD 2013, ATN 2015).³¹ For Australia, the earning of export income through teaching foreign students is a major national economic activity, with education services being Australia's largest service export industry.³²

There are a number of well-known economic regions of scale that traditionally have strong links to research universities. Some of the best known are the Greater Cambridge 'high-tech' cluster associated with Cambridge University (Hayward 2008), Oxford University and biotechnology cluster (Lawton Smith, Romeo and Bagchi-Sen

³¹ The economic roles of universities for regions are numerous and include:

1. Attracting talent to a region or a country;
2. Providing a skilled and technology adept workforce for industry and positively influencing a region's employment growth rates;
3. Invention of new products i.e. and technologies and patents;
4. Originating new innovation and knowledge for use by industry, particularly in the light of continued decline of corporate research and development;
5. Spin-off firms and the founding of new companies (by university researchers or as a result of their knowledge development);
6. Supporting global networking to boost knowledge inflows and commercial links;
7. Providing sources of innovation information;
8. Partners in innovation collaboration; and
9. Earning export income from education services.

(See Mayer 2007, Takeuchi 2008, and Lendel 2010, Howells et al. 2012, and DET 2014b).

³² In Australia, for the year 2012, tertiary education earned \$9.7 billion in export income (67.0 per cent of total on-shore education earnings) (Australian Educational International 2013, ABS 2013g). By 2014 education services had become Australia's fourth largest export industry and largest service export industry (DET 2014b).

2008), 'Route 128' in Boston, Massachusetts, Silicon Valley (Saxenian 1994), and the TAMA (Technology Advanced Metropolitan Area) Region which comprises the prefectures of Tokyo, Saitama and Kanagawa (Carvajal and Watanabe 2004).³³ However, looking beyond these notable examples, the impact of universities on cities and regions is more complex and nuanced. Moretti (2012) has argued that a key driver of successful innovative high-tech industries, in particular, successful high profile clusters, was the alignment with 'star' academics within research universities in particular regions and the associated first starter advantages that this provided. Once a cluster was established, universities played a key role in fostering growth, becoming a key part of the ecosystem (Moretti 2012). Mayer (2007) and Moretti (2012) have both cautioned that the regional environment's ability to absorb a university's spillover effects is as important as the institution itself. Rather than "engines of economic growth," Mayer (2007:p. 50) has argued that universities should be seen as a part of the regional knowledge-creation infrastructure with the *"university's economic role being much more complicated, subtle, nuanced, and complex"* This is supported by Varga et al.'s (2003) findings that in the USA, the impact of universities on local new technical knowledge was variable and that there would appear to be a range of factors for beneficial impacts (see also Turk-Bicakci and Brint 2005, Lendel 2010). Moretti (2012), examining the role universities played in economically successful US cities, concluded that they were most effective when they were part of a larger ecosystem of innovative activity. A key part of this larger ecosystem was being part of a larger or thicker market for specialised labour and intermediate services. This conclusion is similar to that of the three-pillar 'ecosystem' model of Thierstein et al. (2006) where universities play a role in the wider knowledge economy within cities such as Munich.

The evidence from the USA, according to Lendel (2010), suggested that the presence of research universities has a positive effect on metropolitan economies above cyclical economic changes. The effect differed however, depending on the scale of university R&D expenditures. Lendel (2010) has noted that knowledge spillover from universities also occurred through positive externalities of agglomeration economies of scale. This suggested that the most prominent and larger research universities had stronger impacts on their regional economies. Similarly, Turk-Bicakci and Brint (2005) found that successful industry-university technology partnerships tended to be concentrated in the larger major USA research universities. The ingredients for success were defined as:

- good technologies,

³³ As with the spatial concentration of the knowledge economy within particular regions worldwide, the top 50 universities with the highest relative impact over 2007-11 are highly concentrated geographically. Overall, 34 of the top 50 are located in the United States with the remainder being in Europe, and, for the first time, two are in Chinese Taipei, outside the OECD area, (OECD 2013, p.14).

- well developed regional 'high-tech' infrastructure,
- national reach, and
- dedicated and skilled technology transfer staff.

Siegfried, Sanderson and McHenry (2006), again with respect to the USA, noted that many of the local impact benefits claimed by universities consisted of activity relocated from other places, with little effect on the national aggregate.

The limitations on the national and local economic impacts of universities have been considered across a number of regions and nations. It is widely understood in the UK that there are substantial barriers to successful collaboration and knowledge exchange between universities and industry. In a UK study, by Bruneel, D'Este and Alter (2010), of the attitudes of firms that actively engaged in industry-university partnerships, it was found there were a number of 'classic' barriers to university industry collaboration. In particular, the university's long-term orientation and intellectual property (IP) related barriers that had become more prevalent as a consequence of policies designed to encourage universities to increase their commercialisation. Notably, older and more informal systems of exchange were coming under increasing scrutiny from university administrators. Such efforts to bring exchanges and interaction 'in from the cold' could have the effect of raising transaction-related barriers to such interactions. An important finding from this study was that inter-organisational trust was one of the strongest mechanisms for lowering the barriers to interaction between universities and industry. Bruneel et al. (2010) suggested that the traditional system of informal reciprocity and exchange, which dominated university-industry exchanges post-war, should continue to be an important part of any attempts to support and build collaborations. Bruneel et al. (2010 p. 867) further argued that building trust between academics and industrial practitioners required long-term investment in interactions, with a focus on:

face-to-face contacts between industry and academia, initiated through personal referrals and sustained by repeated interactions, involving a wide range of interaction channels and overlapping personal and professional relationships.

Similarly, Howells et al. (2012) found, in their UK research on business-university collaboration, considerable diversity and differences in the way collaboration occurred. In part, the nature and effect of the collaboration was dependent on the type of business and their location. Little difference was found on business innovation performance with either informal or formal linkages, though significantly less collaboration occurred in more regional areas. However collaboration was valued, more by firms in Wales, as the most regional area researched (Howells et al. 2012).

This was possibly due to the difficulty of identifying and maintaining contact. Effectively, the relative rarity of knowledge spillover made it highly valued.

Further limits on university knowledge spillover have been identified in European research, with spillovers also being shown as geographically localised (Ponds et al. 2007, Brostrom 2009, Andersson et al. 2009). Andersson et al. (2009) examined the result of Swedish government policy decentralising post-secondary education throughout the country. This policy delivered local innovation, increased local creativity and aggregated increased productivity, although the spillover of university investment, while substantial, was very localised. It was estimated that the productivity spillover gains in regions that had received larger university-based investments were higher in terms of output per worker and greater with the awarding of patents. Notably though, spillovers were concentrated with roughly 40 per cent of the cumulative gain in productivity being within 10km of the institution. For the newer universities, where the estimated effect on productivity was larger, the local effect was more pronounced, with 33 per cent to 50 per cent of the total effect upon productivity being within 5km of the university. Notably, for patents, there was greater productivity where the new institutions specialised more narrowly in technical specialties than the more traditional institutions of higher education (Andersson et al. 2009). In another Swedish study by Brostrom (2009), based on interviews with engineering company R&D managers, it was found that spatial proximity was more likely (than distant linkages) to generate, at the firm level, significant learning benefits and motivation to innovate. Similarly, spatial proximity and interaction were more likely to successfully contribute to R&D projects where there was a short time to market. Spatial proximity was generally seen as a less critical factor for long-term R&D projects. This suggests that time-critical knowledge in the modern knowledge-intense city would relate more to commercial knowledge than to scientific knowledge. This is consistent with CBDs being the epicentre of urban density and knowledge-intense commercial activity.

Other European empirical studies at the micro-level have found localised spillover through labour mobility or spin-off firms, however, for research collaboration, there is evidence of knowledge spillover occurring over longer distances as well as at institutional level (Ponds et al. 2007). Ponds et al. (2007) found that knowledge spillovers from university R&D occurred between universities at multiple spatial scales (local and international). This finding is consistent with the 'technopole' argument of Banister and Hickman (2006) and the (national and international) networking of the knowledge economy over varying scales and distances (Johansson and Quigley 2004, Castells 2005, Devriendt et al. 2008, and Kane 2010). It would appear, however, while local spillover is localised, the international or national spillover is through cultural,

institutional or firm networks³⁴, which may also be spatial, localised or anchored at the ends of the network linkages.

For regional and suburban Australia, local economic benefits of universities have largely been limited and focused on providing educational opportunities for outer suburban and regional populations whose participation trails the population as a whole or the impact on regional economies (see Gunasekara 2005, Bradley Review 2008, Birrell & Edwards 2009, Daley 2012). Gunasekara (2005) looked at the potential impact of regional universities on agglomeration with three universities based in peri-urban provincial and rural settings. The findings indicated that these universities play a limited, though varied, role in agglomeration. The universities were found to perform a largely developmental role, with limited evidence of a generative role in animating regional systems. The study confirmed that a university's presence or absence does not necessarily determine regional agglomeration effects. A university's impact was not sufficient to trigger networking or firm concentration. Gunasekara (2005) concluded that agglomeration required both demand and supply side responses, and there was a lack of interest by firms in fostering agglomeration. This could be because the industries that have located in regional or peri urban areas do not benefit from higher levels of agglomeration in the first place, rather they may benefit from being in dispersed locations and disagglomeration. Similarly, Daley (2012, p. 7) questioned the impact of regional universities and their contribution, beyond their direct economic spend impact, to long-run regional economic productivity. Daley (2012, p. 7) further noted that patenting rates, being a partial if not perfect proxy for innovation, were not materially higher for university regional cities in Australia than for non-university cities of a similar size. However Daley (2012) fails to recognise the importance of regional universities in developing regional and national labour market capacity, as identified by the Bradley Review 2008).

Formal links between industry and universities in Australia have been found to be weak (Moodie 2004, Spiller 2005, Martinez-Fernandez 2010 and Tedeco & Haseltine 2010, OECD 2013, ATN 2015). Spiller (2005) also questioned the importance of formal links over more informal network links, arguing a more continuous, interpersonal, networked engagement was preferred and more valuable in terms of delivering organic innovation. Spiller (2005) also noted the impact of distance decay, in terms of diminishing innovation knowledge transfer with both lower quantities and qualities of transactions and contacts with increased distance. The issues of distance decay means that the spatial characteristics and location of universities, in relation to

³⁴ This is also consistent with the findings on growth in global intermediate trade within firms and corporations (Marin & Verdier 2007, Helpman 2008).

commercial knowledge-intensive activity, becomes important. In the USA, Levi and Gilchrest (2012) identified universities as key elements of the denser employment centres in and around the CBDs of major cities as well as often being the anchor institutions in the employment dense secondary centres.

9.2 Universities and human capital intensification

The strong links between national productivity and high proportions of the population with high-level skills arising from university (and other forms of) education are well accepted (Lucas 1988, OECD 1996 and 2013, Lundvall et al. 2002, Abbott & Doucouliagos 2003, Lewis 2004, Knudsen et al. 2007, Montgomery 2007, Goebel et al. 2007, Bradley Review 2008, Takeuchi 2008, Cutler 2008, Centre for International Economics 2009, Smith et al. 2011, Moretti 2012, Abel et al. 2013, Florida & Mellander 2013, OECD 2013, ATN 2015).

National investment in Australia in post school education and training, particularly since the 1980s, has been linked with the development of human and social capital (i.e. increasing national labour market capacity) in sustaining national economic growth and competitiveness (Bradley Review 2008, Wyn 2009, ATNU 2015). The Bradley Review noted that the production of skilled workers was essential for a competitive Australian economy (and noted that demand from industry for knowledge and skilled labour was not being met). In Australia, there is an expectation that young people will participate in post-compulsory education, with tertiary education becoming the new mass education sector (Wyn 2009). Wyn (2009) notes however that while the overall evidence shows a positive long run correlation of educational credentials with job security and income levels for the majority of people, the actual relationship between education and employment is somewhat uncertain. This uncertainty is especially so at the level of the individual. Wyn (2009) has argued in particular that education is a broad responsibility and that the labour market is increasingly complex, effectively meaning, education and vocations or careers are not always linear.

More narrowly, universities provide an education that delivers a skilled and technology adept workforce for particular industries and the immediate region as well as attracting skilled workers to a region (Mayer 2007, Lendel 2010). For example, for the mining technology service industry, Martinez-Fernandez (2010) and Tedeco and Haseltine (2010) found that the most important role that universities provided to the sector was provision of skilled labour (though the lack of research and development linkages was also notable, most likely due to MTS/MTSE largely being SMEs). Universities also

develop human capital through collaborative research and development links with diverse industries. In the USA, new patent grants and inventors are spatially concentrated in larger cities associated with the major research universities (Turk-Bicakci & Brint 2005, Bettencourt et al. 2007, Knudsen et al. 2007). As previously noted, Tedeco and Haseltine (2010) found the larger mineral companies favouring funding public research centres on the basis that it was more productive to undertake collaborative research with a range of universities, public research centres and MTSE companies rather than with individual MTSE companies. International links for teaching, collaboration and research are also notable characteristics of the university human capital development role (Ponds et al. 2007, Raciti 2010, ATNU 2015).

The role of universities in assisting in the knowledge intensification of the labour market has a spatial context. It is well accepted that there is a link between urban density and the density of human capital (Raphael and Stoll 2010, Davies 2011, Kneebone 2013), with higher productivity being realised from the increasing physical interaction of highly skilled people compared to lower skilled people (Knudsen 2007, Abel et al. 2012, Florida & Mellander 2013). Effectively, a denser labour market yields significant productivity benefits by improving the efficiency of the labour exchange. The link between universities and higher density employment in the USA is also evident from the research by Levy and Gilchrist (2013) where universities were found to be associated with all three types of dense urban centres: 'Commercial downtowns and town centres (primary downtowns or CBDs)', Urban education, cultural, healthcare, and research campuses (anchor institutions), and 'Office and research parks'. Johnson (2010) similarly found in Melbourne, an association between universities and knowledge worker labour markets, in part because workers' residences and workplaces tended to be associated, i.e. knowledge workers tended to live close to the CBD or to university anchored employment clusters where they worked.

The spatial context of universities and knowledge intensification has a transport factor. An examination of metropolitan travel patterns indicates the broad metropolitan wide reach of universities, which contrasts with other non CBD activity centres with more localised catchments (see Shannon et al. 2006 regarding University of Western Australia, Johnson 2010 regarding Melbourne, Daniels and Mulley 2011 regarding Sydney). With tertiary student recruitment, the top tier universities compete for students at broad catchments; for the top high-school leavers it is at the national level and for the remaining students at the state level (Marginson & Considine 2000). Amongst universities worldwide, the competition and catchment for international

students, researchers and academics is international (or national amongst Australian universities) (Marginson & Considine 2000, Abbott & Doucouliagos 2003, Raciti 2010, Rauhvargers 2011). However, for lower socio-economic areas, the local presence or absence of a university campus or facility is a notable predictor of participation (in Australia see Bradley Report 2009, Birrell & Edwards 2009, Benneworth, Conway, Charles, Humphrey & Younger 2009 and in the UK see Marks 2005, Tight 2007, Dickerson & McIntosh 2013). This broader labour market catchment is notable when compared to other major non-CBD centres such as shopping centres whose labour markets are considered later. The broad catchment of universities also indicates a need for an increased scale of (potential) student or labour markets as the level of specialisation or competitiveness increases.

9.3 Universities and ICT intensification

ICT intensification has already been noted as being linked to larger cities and key centres such as CBDs and universities. This is because access to newer communication technologies follows a hierarchical diffusion pattern: starting first in large cities with the highest connectivity to other key cities (where the largest markets are found), and then subsequently to smaller places (Malecki 2001, Gorman et al. 2003, Moriset 2003, Rutherford et al. 2004, Schintler et al. 2005). However, Australia does not always follow this pattern in respect to regional areas (ACCA 2006 and IEAust 2010). Universities were one of the key early adopters of demand for increased data intensification (arising from research and scientific instrumentation) (JISC 2004, Benson and Anand, Akella and Zhang 2010). This meant an early and ongoing requirement for various ICT network infrastructures and technologies to manage the high levels of data (and a subsequent need for data storage and accessibility through large consolidated data centres) (JISC 2004, Ranganathan & Jouppi 2005, Benson et al. 2010).

The early and on-going requirement for increasing ICT intensity with Australian universities is best demonstrated by a consideration of the development of the Internet in Australia, and how Australian universities developed the dedicated high speed, high capacity network called Australian Academic & Research Network (AARNet).³⁵ The

³⁵ The background to the AARNet is as follows: The Internet emerged in the U.S. engineering research community between 1969 and 1983 (Clarke 2004). Computer science specialisations and then departments appeared in Australian universities at this time, and from this point, irregular connections to the Internet were first made. Australian computing researchers adopted the Internet protocols from the mid 1980s onwards (Clarke 2004). In 1988, the Australian Vice-Chancellors' Committee (AVCC) took the decision to implement a national network, and the AARNet was subsequently developed (Clarke 2004). By the early 1990s, the AARNet linked all Australian universities, CSIRO Divisions, and a large number of other organisations under the Affiliate membership program (Clarke 2004). International Internet links were also

AARNet is now described as “a high-speed, high-capacity, high-performance network dedicated to meeting the data-intense and specialised needs of Australia’s research and education communities” (AARNet 2014). The purpose of the network, as expressed on the AARNet website is to “support collaboration and innovation, connecting researchers and educators around the nation to each other and to their peers in the rest of the world across multiple ... links” (AARNet 2014). The network includes several international high-speed links and network infrastructure in the United States and Asia, including dedicated links for research and education through joint initiatives with overseas bodies (AARNet 2014).

While AARNet ultimately reflected the wider university research and academic demand for ICT infrastructure, a more specific example, demonstrating the depth of the relationship between intensification of ICT and universities, is the academic discipline of ‘information systems’.³⁶ Information systems academic programs first appeared in Australia in the late 1960s and grew steadily to be available in almost all Australian universities (Pervan and Shanks 2006). In a longitudinal study of information system academia, Pervan and Shanks (2006) noted the diversity and range of research undertaken. Notable was the breadth of experience most information system researchers brought with them from their background in industry and their grounding in practitioner activity. The study also found that the type of university³⁷ was relevant, with sandstone, redbrick and unitech universities particularly strong in information systems teaching and research. This, they found, was consistent with the research-intense nature of universities in the sandstone/redbrick category and the historical location of IS schools within the unitech universities (Pervan and Shanks 2006). Effectively, the established major city universities, with their early-adopted Internet backbone connections and their well-established broad academic research and teaching performances, demonstrated a far greater level of ICT intensification over other universities and over many non-CBD centres.

9.4 Spatial concepts of universities as or within activity centres

The spatial sense of a university is intrinsically linked to its identity and its sense of itself as an institution (Marginson & Considine 2000, Marks 2005). The spatial sense of the university is as much a part of university institutional identity as are societal and

progressively upgraded, and connections established to most Australian universities and the CSIRO by May 1990.

³⁶ ‘Information systems’ being the way organisations use ICT and the interactivity of ICT in support of business processes (Kroenke 2008).

economic factors (Marks 2005). Similarly, city identity can also be linked to their universities as a key feature of the diverse city (Mead 1978). Within Australia's state capital metropolitan regional schemes, major universities have generally been allocated into a separate category of 'specialist centres' and not identified as part of the metropolitan activity centres hierarchy. This, in itself, is an indicator of how Australia's major cities have valued and identified themselves with knowledge-intense activity.

The role that universities potentially play in activity centres raises firstly consideration of the spatial distribution of university campuses and facilities. There are good public policy and economic reasons for university teaching and research functions occurring across a range of universities, both in urban metropolitan areas and regional areas (Moodie 2004, Bradley Review 2008, Birrell and Edwards, and Wyn 2009). Proximity to tertiary education facilities is a factor influencing tertiary education participation rates, particularly with lower socio-economic and regional demographics (Marks 2005, Tight 2007, Bradley Review 2008, Birrell & Edwards 2009, Benneworth, Conway, Charles, Humphrey & Younger 2009, Dickerson & McIntosh 2013). Notably, all nations' tertiary education sectors are largely inequitable in terms of participation from lower socio-economic and regional populations (OECD 1996). Therefore, a distribution of university facilities, including campuses across metropolitan areas and regions, can be justified to improve tertiary education participation rates. This is not just a matter of social equity. In an increasingly competitive global knowledge-economic environment, limits and impediments on labour market participation and skills development will negatively impact national economic performance (Bradley Review 2008). Simply put; few nations, particularly those with relatively small national populations, can afford to have their university participation rates limited through societal structural factors. The questions raised therefore in this thesis (on the role of universities as centres) are not aimed at questioning the spatial distribution of university campuses or facilities across metropolitan areas and regional areas. However, what constitutes the physical presence of the university: its shape, form, role in or as a 'centre' and its relationship with activities around it, is considered. In particular, the commonest spatial form of the Australian university is that of the campus, which, as an institutional single purpose function, limits its capacity to act as a mixed-use 'activity centre' (Marks 2005). As such, this thesis questions the relevance of the 'monastic' campus as a spatial mode.

In considering the spatial form of Australian universities, it is first necessary to consider the pre-capitalist monastic campus traditions that have so influenced the institutional and spatial characteristics of Australian universities. The monastic tradition that pervades much of English (and by default Australian) university culture,

tradition, identity and spatial construct is often seen as a source of prestige (Marginson & Considine 2000, Marks 2005). The monastic pre-capitalist university tradition is deeply rooted in many university cultures in the UK, USA and Australia (Marginson & Considine 2000, Cantor and Schomberg 2003, Marks 2005). The monastic tradition is strongly associated with Oxford and Cambridge (“Oxbridge”) universities (Marks 2005) and its influence has flowed strongly from the prestige of Oxford and Cambridge (Marginson & Considine 2000).³⁸ Notably, the monastic culture of Oxbridge, by its isolative, religious and hierarchical nature, resulted in limited knowledge exchange and obscurantist attitudes to science and new areas of knowledge (Davis, R 2002, Watson 2005).³⁹ The ‘Oxbridge’ knowledge spillover was therefore largely limited to the social and political elite network that ‘Oxbridge’ served (Davis R 2002, Marks 2005).⁴⁰

The monastic university tradition was, and is very much still, an English-speaking world construct. The older UK and USA universities had religious based origins, which explained in part their monastic traditions (Davis, R 2002, Watson 2005). However, the later 19th century (and subsequent 20th century) Australian monastic university culture is more one of mimicry (Marginson & Considine 2000). To understand the spatial context of the Australian university it is worth first seeking to understand the spatial development of the English universities. Marks (2005, p. 614-615) in his study of English universities and their spatial context uses a *Heideggerian* premise that ‘spatiality’ in the university context is less about physical dimensions and proximity than about the relation of the university to its social world and to its inherent ‘usefulness’. A university location within a space does not necessarily provide for a symbiotic relationship with its surrounding location. Spatial proximity does not necessarily mean knowledge spillover. That is, a university’s own physical dimensions and location has to be seen in its dynamic, evolving relationship to the social and economic world, and how the university identifies itself within this context.

Marks (2005), in terms of English universities, identified two broad historical phases

³⁸ Oxford and Cambridge universities’ origins were based, in many ways, more on early medieval guilds than actual monasteries, but their origins had strong involvement from friars and religious orders (Knowles 1943, Leader 1988). The ‘Oxbridge’ Halls of residences (set up by religious orders) and their collegiate-living also supported a distinctive monastic approach. Until recently, this spawned, at other universities, largely self-governing academic faculties (Marginson & Considine 2000, Marks 2005).

³⁹ Notably however, the early city based Scottish universities (Edinburgh, Aberdeen and Glasgow) and early continental European city universities (with their origins in the city municipal schools such as in northern Italy, and the city cathedral schools as in northern France) meant they developed a less hierarchical structure and distinctive urban tradition (Arthur 2005, Cantor 2005, Watson 2005). Also, being more urban, the Scottish universities, in the 18th century, developed into more egalitarian, community and industry oriented universities (Davis, R 2002, Arthur 2005). During the 18th and early 19th centuries, Oxford and Cambridge, because of their traditional religious and elitist focus linked to monastic spatial identity, fell behind in academic performance of the more scientific and industry focused Scottish and German universities (Davis, R 2002, Arthur 2005, Watson 2005).

⁴⁰ Oxford and particularly Cambridge universities although, did recover strongly in the sciences in the later part of the 19th century (Watson 2005).

which have reoccurred: starting with ancient 'exclusivity' to the civic 'localism' and then back to the Lord Robbins⁴¹ era of 'exclusivity' and hence to post 1992 'localism' once more. The pre-capitalist 'ancient' universities in England were 'useful' to the gentry and thus were 'closer' to them than to the excluded 'local' poor who lived in the institutions' vicinities. The 'civic' universities on the other hand, stressed 'localism' as part of their mandate – to educate the people of their locality. At first, and until the 20th century, these people were only those of the industrial capitalist era's new industrial middle class. The exclusivity of the ancient Oxford and Cambridge universities essentially combined two principles: elitism, and ecclesiastical Puritanism. This gave them a somewhat monastic character, with an attitude of hostility to outsiders (including females) (Marks 2005). Spatially, therefore, these ancient universities were both 'exclusive' in their intake (wealthy and English public-school-educated males) and 'excluding' in terms of the outside world both local and national (Marks 2005). Spatial context was purposeful to deliver, as Marks (2005) argued, a monastic approach that was about local 'exclusivity and exclusion'. In disregarding localised spatial knowledge spillover, the advantage that still remained for Oxbridge was their social and economic network connections (and their usefulness) to the English political, religious and class elites⁴². The 'civic' institutions of the late 19th and early 20th centuries resulted from a greater need for a more educated society with the advent of the industrial revolution (Marks 2005). As a 'produced space', the civic universities existed spatially within and served their host communities with the 'local' people (at least initially), being the sons of the new industrial middle classes. However, they often adopted an inward looking middle class culture, hostile to outsiders, and a 'colonial' approach to their immediate local communities, displacing local people as their need for space and land increased (Marks 2005)⁴³.

According to Marks (2005: p. 614), the post WW II English 'Robbins' universities model was a partial return to the 'ancient' notion of learning as a 'lived' activity, providing scenic landscapes on green-belt campuses where students could 'retreat' from the 'real world' for the duration of their studies. The Robbins universities are the result of two conflicting impulses. The first, based on 'inclusiveness' for new centres of learning to expand the university sector stimulated by post-war demographic trends, and the second, based on 'exclusiveness' to reassert the 'monastic' tradition of 'Oxbridge'. The 'spatial' quality of these campuses was a deliberate part of the higher

⁴¹ Lord Robbins, being the notable economist who chaired the 1963 UK Committee on Higher Education that produced the 'Robbins Report' that recommended the post-war expansion of the tertiary education system in the UK.

⁴² Scientific knowledge spillover role in the pre 20th century London arguably arose more from the urban based Royal Society and other similar science based societies such as the Linnean Society and The Royal Geological Society than university sector (see W.H. Smith 1984 and Sharpin 1994).

⁴³ The impacts of gentrification on surrounding communities arising from overflow activity from inner city universities have also been similarly noted in the USA and Australia (Davison 2009, Xiao 2013).

education as a 'lifestyle choice', where young people moved away from their locality to study. Whereas the civic universities were located within town centres, the Robbins campuses were often in greenbelt areas away from the majority of the local population. Marks (2005) and Tight (2007) contended that the social exclusivity of universities became magnified by their location and geo-spatial exclusivity.⁴⁴ The Robbins education reforms and the innovations and thinking that led to the forming of seven new UK universities influenced the Gumtree⁴⁵ universities in Australia (Moodie 2012). Whether intentional or otherwise, the Gumtree universities followed the Robbins universities greenbelt spatial campus model.

In the US, the monastic tradition has been a significant spatial influence. Jacobs (1961, p. 267) argued that 'big city' universities often pretended to be cloistered or countrified places, nostalgically denying their transplantation. The impact of this was the tendency towards massive single uses forming borders and vacuums of activity. The result of this inactivity was reduced diversity and circulation. Cantor and Schomberg (2003) Chancellor and Vice Chancellor respectively at University of Illinois at Urbana-Champaign similarly recognise the dichotomy identified by Marks (2005). Fundamentally, they see the essence of the university and its critical mission is to be a centre for vibrant exchange among people and ideas. However as Cantor and Schomberg (2003, p. 14) stated, universities were increasingly:

... poised, literally and metaphorically, between two worlds. In the world within, the world of the monastery or cloister, with its dedication to a higher purpose, universities think and "play" on problems of great intrinsic interest; yet universities must also strive to be responsible in, and responsive to, the world beyond—the world of the public square, with its notions of exchange and negotiations, and of the marketplace, with its apparent chaos of buying and selling in everyday life.

Cantor and Schomberg (2003), while arguing that universities needed the vibrancy and impulsive nature of the marketplace and public discourse, they also recognised inherent difficulties. The unregulated marketplace had a tendency, with its demand for short-term gains and immediate needs, to be given the loudest voice. This resulted in impatience with the hard work required to work through issues from multiple angles, allowances for expression of differences, and the need to experiment with a range of

⁴⁴ This contention is supported by research by Dickerson and McIntosh (2013) who found that for young people in the UK on the socio-economic margin of participating in post-compulsory education the greater distance to nearest education institution is seen to have a significant impact on the decision to continue in full-time post-compulsory education.

⁴⁵ Gumtree universities are generally 1960s and 1970s universities established in bushland area on the edge of metropolitan and regional cities (Marginson & Considine 2000, Moodie 2012).

possible solutions. Universities, it was argued, gained much of their vibrancy from engaging critical societal issues. Therefore, Cantor and Schomberg (2003) argued that universities needed to be in a world that was between the world of the monastery and the world of the marketplace. That being, while it was important to be engaged with the communities, universities should retain the character of an experimental proving ground—intellectually (as compared to the R&D of a company), socially (as compared to the structured rules and norms of a school), and psychologically (as compared to the automatic fulfilment of traditional roles and expectations) (Cantor and Schomberg p. 14).

The need to integrate the university spatially into the city is well accepted in the USA, with a rejection of the separation of the university campus from its surroundings (Kemp 2013). Sungu-Eryilmaz (2013) argued for two design principles for the physical design of universities including communicating values of the university through the built environment and finding points of intersection with the community. This was seen as a mixed-use approach with a focus on integration of the university into the community. However, much of the ‘town-gown’ planning as noted by Kemp (2013) as editor of the *Town and Gown Relations: Handbook of Best Practice* was aimed at ameliorating the impacts of expanding institutions on neighbouring communities (often residential neighbourhoods) and less about building wider knowledge economic agglomeration.⁴⁶

Jones (2005) has argued, in reference to US State Government funded universities, that while ‘town and gown’ integration opportunities existed, it had often not been realised. In other nations, the concept of the university as an economic driver in the spatial sense has been recognised. The Japanese experience with spatial distribution of largely private universities and their campuses since the end of WW II, reflected a historic preference for being in central locations and being developed as urban universities to benefit from agglomeration opportunities (Wiewel & Perry 2008). This was despite government policy from time-to-time seeking decentralisation.

9.5 Spatial development of Australian universities in the 21st century

The ‘monastic’ isolative spatial characteristics of the 20th century Australian university campuses are very much a re-created construct. The development of Australia’s 20th century universities saw the adoption of an isolative monastic spatial character borne

⁴⁶ Notably there is no specific mention of agglomeration benefits (such as relating to knowledge intensification and or spillover) arising from universities interfacing with cities in the *Town and Gown Relations* handbook (Kemp 2013).

by an uninformed romantic ideal of what universities were in pre-industrial times. Sandstone universities established in the 19th century (Sydney, Melbourne, Adelaide and Tasmania), while heavily influenced by other monastic traditions, largely ignored the spatial isolative monastic approach, possibly because of Australia's early urban concentration and the reliance on walking for city transport. This early sandstone university walkable urbanity, most notable with Melbourne and Adelaide universities, has been a subsequent advantage in the 21st century.

The urban re-engagement of Australian universities has been slow. The concept of knowledge precincts in Australia developed from the early 1980s with a focus on the technology park model (Yigitcanlar 2010). This was often in partnership with universities but with little understanding of the urban context opportunity. Spiller (2005) saw the development of the created technology precincts as part of a wider agenda to (over) focus on a formal ideas engine approach and try and link industry and university R&D activities. At the end of the 20th century there was an inkling of change in the approach to delivering university campuses. Benneworth et al. (2009, p. 51) has described examples in the growing urban fringe of the university campus as becoming “a focus for urban development.” The two examples provided were the ‘new university’, Sunshine Coast University, which was located away from the existing town centres and was planned to become another, new, urban node (with schools, a hospital and commercial space being developed around it). The other example was also in Queensland, near Ipswich in the Springfield new master-planned community with a campus of the University of Southern Queensland. This was described as an “anchor tenant of its town centre” and a “marketing symbol of the quality of local services and quality of life” Benneworth et al. (2009, p. 51).⁴⁷

Into the 21st century, there have been some examples of an intentionally different approach to the spatial planning of universities in Australia⁴⁸, despite the dominant metropolitan planning approach⁴⁹. Yigitcanlar and Martinez-Fernandez (2010) identified the rise of the knowledge community precinct concept, which were more

⁴⁷ The other two fringe-town-centre developments, where a university campus was a focus for urban development, were the Joondalup Town Centre with Edith Cowan University (Kerry 1989, Wood-Gush 2003) and Mawson Lakes Town Centre with University of South Australia (Henderson, Castles, McGrath & Brown 2000). Joondalup was planned in the mid 1970s as the major regional centre for the Perth northern urban corridor, and the campus was developed very much as a separate entity within the broader Joondalup strategic regional centre, which had notably separate retail, hospital, education, commercial and recreation precincts. Mawson Lakes town centre, with its origins in the 1980s, while not on the same scale as Joondalup, saw an integration of the existing University of South Australia campus into the main street of the new master-planned residential community.

⁴⁸ This can be distinguished from the unintentional or reactive planning of university campuses which are in response to needs for growth and encroachment into urban areas – arguably this has been the case with sandstones universities – see Davison (2009) with Melbourne University.

⁴⁹ The traditional approach in metropolitan planning policy and instruments was for the university campuses to be seen as ‘specialised centres’. This has reinforced the spatial concept of the university as a campus specific entity.

about mixed-use activities, lifestyle, public accessibility and education, as well as commercial activities. The knowledge precinct model superseded the technology park model, which focused on business and education only. Ultimately, the knowledge precinct concept was premised on the potential development of sufficient scales of knowledge production and spillover in knowledge communities to give rise to knowledge cities (Yigitcanlar and Martinez-Fernandez 2010). However, this concept was at odds with prevailing metropolitan planning doctrine. The increasing complexities of market-based knowledge-intensive activity that underpinned the knowledge precinct concept did not meld well with traditional non-responsive separatist planning.

Benneworth et al. (2009) identified examples of knowledge precincts in Australia with the approach of integrating university 'shared sites' with community facilities in a themed urban village. The most notable example was in Brisbane with the Kelvin Grove Urban Village, included within the Queensland University of Technology (QUT) campus. The redevelopment of the large site, on the edge of the city centre adjacent to the QUT campus, involved the Queensland government and saw the development of a new high-tech education and creative industries mixed-use urban village (Byrne 2011, Carroli 2012). The aspiration for the development was based on a shared commitment to openness by the key partners, including QUT, providing for an open or 'un-walled' university and an open and mixed community (Klaebe 2006, Carroli 2012). The openness development strategy was a reflection of QUT's changing attitude and its policy recognition that engagement involved being part of an "ecology of sustainable interaction" (Carroli 2012, p. 7). Carroli (2012) has argued that this shared vision, which represented a departure from the traditional university land use to an understanding of the university as an integrated urban institution, was essential for the project's realisation.

Understanding the extent of the success of the Kelvin Grove Urban Village development, Carroli (2012) argued, is somewhat difficult because it lacked longitudinal performance evaluation and assessment mechanisms. Yigitcanlar (2010) has argued that Kelvin Grove and the other few Australian precincts, such as the Parkville Knowledge Precinct (the greater Melbourne University area), had not measured up to the success of more established, larger international knowledge precincts. Arguably, the concept of an 'urban village' highlights the lack of appreciation of the importance of scale and connectivity to a large, thick labour and service market.

Kelvin Grove Urban Village was one of the first deliberate attempts to remake a campus into an integrated urban development (as distinct from those originating from an unintended integration, as with Melbourne University, as noted by Davison (2009)). In this sense, Kelvin Grove stands out as a lead university urban development in Australia. Byrne (2004, 2011) noted that the realisation of Kelvin Grove Urban Village had more to do with chance circumstances than with wider longer term spatial strategic planning. Influenced in part by the 'exemplar' Kelvin Grove project, the Queensland Government's 2007 Smart City Report saw the Kelvin Grove Urban Village as part of one of four super precincts within a 4km radius of the CBD (Carroli 2012). This Smart City concept developed further with the release of the Smart Communities strategy in 2009, with a spatial focus on design and place making as a critical element in delivering an urban environment to attract and retain knowledge workers as well as promoting interactions for innovation and idea generation (DEEDI 2009, Carroli 2012). The Smart Communities strategy was part of a wider Queensland Government Smart State Strategy, identified strongly with the Beattie and Bligh State Labor Governments (Bowden 2012), which did not survive Labor's political demise and the 'return to the basics' four-pillar economy of the Newman Liberal National Party Government in 2012 (C Newman 2012).

Other Australian campus-based universities that have identified more explicit urban integration intentions are still relatively rare. ANU (2012) has started planning and developing the border area with the Canberra Civic Centre or CBD, referring to the development area as the 'ANU Exchange'. The ANU Exchange concept is based on it being a place that facilitates innovation and collaboration between the university and businesses. The aim, as stated on the website, was to "create a vibrant mix of university, arts, scientific, educational, residential, and community facilities unique in Australia" (ANU 2012). Curtin University has also signalled its intention with a masterplan to remake its Bentley campus into an urban setting (Curtin University 2014b, 2014c and 2014d). The masterplan proposed that, by around 2031, 'Greater Curtin' would be expected to accommodate around 6,700 staff, 44,200 students and 13,700 non-academic jobs. Around 73,000 visitors would be expected to visit Greater Curtin daily (Curtin University 2014b). Similar to the mixed-use integrated vision of ANU Exchange and Kelvin Grove, the Greater Curtin masterplan aimed to support a mixed-use urban economy based on education, business, technology, housing, public transport, the arts and recreation (Curtin University 2014b and 2014c). The planning philosophy behind Greater Curtin is that of a mixed-use urban centre rather than a university campus. The Greater Curtin masterplan (2014b and 2014c) recognises that spatially, the university had to become a knowledge hub with synergies of research, business and entrepreneurial enterprise. Further, in the masterplan, it was proposed that successful universities needed spatial environments characterised by high

amenity, diversity of services and attractions, with excellent accessibility and networking. Ultimately, the campus was to be transformed from suburban to urban, with the walkable core retained and new modes of activity created around it on excess open space or at-grade parking. Notably, the ANU Exchange and Greater Curtin concepts are underpinned by a city urban sense of scale rather than a village sense of scale.

These examples of the new approach to university spatial planning are, at least in terms of rhetoric, about positioning the university campus as integrated into the larger and wider metropolitan economic-city ecosystem. The realisation of the rhetoric is likely to be dependent on wider community and state government support, particularly with respect to investment in public transport (and in terms of Greater Curtin's acceptance as a significant mixed-use activity centre within the metropolitan planning scheme). Yigitcanlar (2010) noted that the rhetoric on knowledge urban development in Australia tended to focus on the means of attracting knowledge workers and industries – arguing that a more nuanced and detailed understanding of knowledge-intense activity beyond strategic use of land was required. This included government policy support for the development of knowledge networks including the fostering of conditions for intellectual vitality through intense collaboration. This would also mean a better understanding of urban design, the commercial and competitive nature of knowledge-intense industries, knowledge industry interactivity, and physical infrastructure that supported innovation (Yigitcanlar 2010, Yigitcanlar and Martinez-Fernandez 2010).

Chapter 10 Shopping centres as potential knowledge-intensive centres

10.1 Shopping centres and knowledge economy intensification

The potential for knowledge intensification in activity centres anchored by shopping centres can be considered through examining the essential business model of the shopping centre. This business model is effectively a concentration and intensification of retail experience leading to an agglomeration of scaled retail offerings (with some associated complementary entertainment functions and uses). The modern shopping centres are not mixed-use in that they are overwhelmingly a singular function focused on household consumption (du Gay 1993, Conner 1997, Voyce 2006, Productivity Commission 2011b). The contention is that the singular focus of the shopping centre business model on agglomerating intensified consumption is not consistent with the purpose of shopping centres as diverse activity centres, as desired by planning policy makers.

Voyce (2006) has argued that a key notion of the modern, corporately owned suburban shopping mall is coterminous with safety and consumption. This means that any activity detrimental to consumption must be limited and that all disruptive activities should be removed. This provides for a lack of activity diversity in shopping centres. As Voyce (2006) argued, the mall is constructed to form a predictable controlled environment, which keeps deviant behaviour out and creates a consumerist form of citizenship inside. The emphasis of activity and culture within the shopping centre is on consumption (du Gay 1993, Davis, M 1992, Voyce 2006, Mansvelt 2008). Du Gay (1993) proposed that the out-of-town shopping centre experience has created consumption as the premiere leisure activity in contemporary UK consumer society. This has seen shopping centres transformed into 'major cultural sites' (du Gay 1993, p. 566). Davis, M (1992 p. 155) described the shopping mall as "fortified cells of affluence" that filter the people from "unnecessary influences and interruptions to the *intensity of their spending*" (emphasis added). Hence, rather than places for the intensification of knowledge, shopping centres are best described as intensifiers of consumption. This business model of intensifying consumption can be expressed in industry terminology as maximising 'demand externalities' or spending benefit spillovers (as distinct from knowledge spillovers) from concentrating retail transactions or activity in a single location (Sen, Shin and Sudhir 2012).

Understanding 'demand externalities' and 'business value' are key to comprehending the economic purpose of shopping centres. For shopping centres, the business value

is more than their raw real estate values, and includes entrepreneurial profit, going concern, and goodwill (Eppli & Benjamin 1994, p. 21). This business value can arise from operating agreements, tenant mix, and promotional acumen. This is similar to understanding how rents for individual buildings vary with location, quality, management, tenants and other characteristics of particular buildings (Glascock, Sirmans & Corgel 1989). Effectively, there are competitive advantages for shopping centres as against unmanaged shopping areas or strips that struggle to control or manage the quality of the shopping experience (for example through creating attractive tenant mixes).

Agglomerated shopping centres are a concerted means of increasing the business value of managed centres. Understanding the positive value anchor tenants have on smaller specialised tenants ensures an on-going desire to maximise retail demand externalities (Eppli & Benjamin 1994). The business value in shopping centres is clearly based in the 'present value' of current and future lease obligations, i.e. maximising demand externalities (Eppli & Benjamin 1994). In practice, this is about optimising foot traffic that maximises positive demand externalities through appropriate placement of anchor stores and smaller speciality stores (Sen et al. 2012). More recent research by Sen et al. (2012) in the US on demand externalities from retail co-location re-confirms the importance of externalities in retail. Sen et al.'s (2012) research confirms the long-held understanding that increased retail spending is likely to occur due to the lower travel costs associated with one-stop shopping. This sees a focus on building shopping loyalty to create a spending spillover (rather than a knowledge spillover). These spending spillovers are likely to be economically and managerially significant (Sen et al. 2012).

Not surprisingly therefore, the introduction of new collocated products and services that encourage spending spillover is a ubiquitous phenomenon among retail firms (Sen et al. 2012). This supports a strong active management approach to centres with control over tenant mixes, promotional strategies and a dedication to the task of consumption. Maximising demand externalities, through an on-going evaluation of inter-store demand externalities and tenant mix, is the key interest of shopping centre developers and managers. This would suggest that a 'one stop central place' shopping centre approach is not suited to diverse economic activities (inclusive of competing non-consumption related activities such as knowledge-business-to-business services).

The advantage the car provides to the shopping centre model is flexible and affordable transport within both a local and wider regional area for consumption at larger agglomerated shopping centres. Within this consumer agglomeration provided by larger shopping centres, there is a high order of homogenous retailers because of the efficiency of comparison-shopping with reductions in costs relating to information, uncertainty and searching (Eppli & Benjamin 1994). Shopping centres as 'centres' have evolved into professionally managed, agglomerated shopping centres, which now reflect complex consumer shopping patterns and matching retailer behaviours (Eppli & Benjamin 1994). The extent of agglomeration however is important to note – it is occurring within a metropolitan sub-regional scale and relating to a specific form of activity. Effectively the extent of agglomeration is largely relating to providing efficiencies in the localised or sub-regional consumption process.

The shopping centre business model also largely explains the extent of catchment or economic reach of shopping centres. In contrast to universities, shopping centres tend to have more localised catchments depending on their size. The exceptions to this would be shopping centres located in tourism destinations where there is a wider catchment created by external factors. The catchment of shopping centres, while localised, can be overlapping depending on where they sit in the retail hierarchy (based on size and extent of the retail offerings) and their levels of attractiveness relative to competitive centres. At the basic level of attractiveness, the accessibility of activity centres depends on their proximity to residential populations, while their economic viability depends on having sufficient population within their catchments (Goodman and Coote 2007). In the UK, Dennis, Marsland and Cockett (2002) adapted previous simple systems based on retailer counts to include attractiveness measures. The results supported the prediction of 'central place' hinterland boundaries based on the attractiveness measures. Factors determining catchments include transport links, parking, tenant mix (including the choice of major stores) and atmosphere (Dennis 2005, Teller & Retterer 2008). The interplay between these factors can also vary for different customer groups (Teller & Retterer 2008).

The business model of the typical shopping centre maximises demand externalities within a reasonably localised catchment with a singular focus on consumption. It also provides a strong reason for resistance to diversification of centre activity away from both consumption and activity that is unmanaged by the shopping centre. In the USA, J. Jacobs (1984) argued that this single-minded purpose resulted in centres that were basically boring and unstimulating (and in no way could be seen to be fulfilling Mead's

(1978) view of what a city centre was about)⁵⁰. Similarly, Goodman (2005), in looking at outer Melbourne shopping centres, found that the corporate shopping centre, by its nature, both economically and culturally, provides the blandest representations of a monoculture and adds very little to sense of place. This standardised environment is not conducive to a diversity of economic activity or people that is essential to the economic intensity that drives innovation or agglomeration. This leads to a clear conclusion that the singular focus on agglomerating intensified consumption, means the purpose of shopping centres, as sought by their owners, is not necessarily consistent with the purpose of shopping centres as diverse activity centres, as desired by planning policy makers.

Suitability, or otherwise, of centres anchored by shopping centres for knowledge-intensive centres can be understood by looking at the extent of innovation in the retail industry. A key business process innovation in the retailing and fast food industries in recent decades has been franchising (Conner 1997, Quinn & Alexander 2002, Franchise Council of Australia 2014). However franchising, by its very nature, is characterised by the standardisation of products and processes (Helfferrich, Hindelaar & Kasper 1997, Dant & Gundlach 1999, Quinn & Alexander 2002, Cox & Mason 2007, Thompson 2007). The International Franchise Association has defined franchising as a "continuing relationship in which the franchisor provides a licensed privilege to do business, plus assistance in organising training, merchandising and management in return for a consideration from the franchisee" (Franchise Council of Australia 2014). Business format franchising is the largest and fastest-growing segment of franchising in Australia (Franchise Council of Australia 2014). The business format franchise is the use of a format, or a comprehensive system for the conduct of the business, including such elements as business planning, management system, location, appearance and image, and quality of goods. Business format franchise is about "standardisation, consistency and uniformity across all aspects" (Franchise Council of Australia 2014). While a speciality retail niche can be provided by franchising, it is within a standardised method. The retail industry and shopping centres historically have not exhibited high levels of leadership in innovation (du Gay 1993, Clodfelter & Overstreet 1996, Lowry 1997, Toner, Marceau, Hall, & Considine 2004).

⁵⁰ The shopping centre has been seen as an expression of neo-liberal affront to local identity, as well as a privatisation of public space and democracy (Mansvelt 2004, Voyce 2006). Kirby (2008) has rejected much of the view that idolises the public 'democratic space' of old with its opportunity for free public expression, noting the uses of public spaces by oppressive governments and anti-democratic mobs (i.e. public lynchings of African Americans in the South of the USA). Kirby (2008) sees the public private spaces of the shopping mall and other public private spaces as less different than is claimed.

In Australia, retail has been identified as a low-innovation industry (Toner et al. 2004)⁵¹. Toner (2011) looked at innovation in Australia from innovation surveys of private businesses. While the benefit for firms in developed economies engaging in innovation has long been recognised, only a minority of firms actively pursued technological or non-technological innovation. For example, over the three-year period 2001–03 in Australia just 34.8 per cent of firms undertook any form of innovation. This was despite the broad scope of activities included under the definition of innovation and the generous period over which such activities could occur. This average, however, hid the considerable diversity in the propensity to innovate across industries. Just over 30 per cent of firms in the construction and retail industry sectors innovated. Notably, these industries were prominent in the suburban consumption economy. Further, retail has been found to have a low propensity to either innovate or train, compared to other industries such as property and business services, manufacturing and telecommunications (which have a higher propensity for both activities) (Toner et al. 2004).

For retail, much of the innovation was in product or service innovation, processes, non-technological and marketing innovations (Toner et al. 2004). Levels of R&D were very low in retail, with a greater emphasis on organisational innovation. In terms of recruiting for innovation, retail focused on general business skills and marketing, with engineering and scientific skills almost non-existent. Innovation that did occur in retail and shopping centres was in three broad areas: technological (which will be addressed in the ICT section), business processes (such as with franchising), and the development, construction and operation of shopping centres. Lowry (1997) has argued that shopping malls have a life cycle: birth, growth, maturity, and decline – even rebirth, and therefore regeneration and adaption to innovation are part of the market forces. However, the innovation phase for shopping centres is when they are in ‘birth form’ with limited competition from similarly new shopping centres (Lowry 1997). With the development and construction of shopping centres, innovation happens incrementally with large capital investment requiring returns to justify initial investment before further investment and regeneration (Lowry 1997). This said, shopping centre models and types have continually evolved over the decades, with older shopping centres forced to regenerate because retail is slowly but constantly changing and evolving (Lowry 1997, Eppli & Benjamin 1994, Taylor 2002, Kocaili 2010).

⁵¹ Along with personal services; cultural and recreational services; health and community services, and construction industries (Toner et al. 2004).

Taylor (2002) has argued that there are four strategies for regeneration of shopping malls: externalising, mixing and multiplying, 'going green', and adding public transport. Externalising means reintegrating the mall back into the settlement fabric that has grown up around it, effectively integrating back into the local grids and shopping mall accesses, designing for the pedestrian instead of the automobile, and finding new ways of utilising public transport (Taylor 2002). There was evidence of this with Melbourne's shopping centres that developed since the 1980s due to state activity centres planning policies (Yamashita, Fujii, & Itoh 2006), though seemingly to a lesser degree in the outer suburbs in the 2000s (Goodman 2005). This would suggest that innovation trends in shopping centre development do not always take hold as common practice.

The overwhelming commitment to standardisation in retail, increasingly within suburban shopping centres, is consistent with Leamer and Storper's (2001) concepts of the two opposing forces – *commodification* (transforming of complex transactional tasks into routine standardised tasks with dispersement to cheaper and remoter locations) and *specialisation* (with central agglomeration for new activities requiring high levels of complex and unfamiliar coordination). The logical extension of this standardisation and commodification of retail is its decentralisation to the suburban shopping centre, followed by further dispersement to cheaper suburban locations (not necessarily in centres) with lower rents, and beyond this, to Internet shopping using further cheaper offshore locations.

To the extent that innovation occurs within retail, it has generally spilt *into* retail from outside industries. This is particularly with technology (du Gay 1993, Clodfelter and Overstreet 1996, Hopper 2000, ILO 2006, ILO 2015) but also with one of the key creative and innovative aspects of modern retailing: the transformation of mass merchandising based around price-to-product differentiation (i.e. brand loyalty). Du Gay (1993) described this transformation as moving away from 'numbers to souls' and relying upon unique image, identity and atmosphere, to effectively build a symbolic relationship between consumers and brands. This required creativity, innovation and skills in design, marketing and advertising underpinned by consumer research. Notably, this knowledge and technique was not developed or originated 'spatially' at shopping centres, but as part of the business-to-business service sector located in and around the CBDs and inner city areas (Spiller 2004, 2005, Johnson 2010, Florida & Mellander 2013, Kelly & Mares 2013, Kelly & Donegan 2014).

Notably, the development of shopping centres in Australia has followed a relatively rigid and regulated approach rather than the neo-liberal world of competition. The Productivity Commission's (2011b) report, *Performance Benchmarking of Australian Business Regulation: Planning, Zoning and Development Assessments*, found that spatial planning guidelines regarding where retailers could locate were extremely complicated and often prescriptive and exclusionary. In effect, they made it difficult for both new entrants to find suitable land and enter the market, and for existing businesses to expand or alter formats. Therefore, it interfered with the market's ability to allocate land to its most valued uses. Specific restrictions on competition noted by the Productivity Commission (2011b) included: zoning overly prescriptive local planning rules which inhibited entry; and inappropriate protections for existing businesses and activity centres through adverse impact tests. This had the effect of evenly dispersing shopping centres across suburbia to ensure the economic viability of centres or to limit their competition (depending on which side of the 'regulatory fence' one considers this debate). Conner (1997) also noted that the very nature of the planning system influenced the location and form of new shopping centres, as their large single use areas were far easier for the planning systems to deal with than fine-grained mixed-use developments (see also Arnott 2011 for the USA planning system's tendency to separate land uses through zoning, partly because it was easier to implement).

The Shopping Centre Council of Australia (SCCA) represents the interests of the owners and managers of Australia's shopping centres (SCCA 2013) and takes a different view from the Productivity Commission. The SCCA (2010, 2013) has strongly supported state and local government non-competitive 'even playing field' regulatory planning policies, which it considers has encouraged unconstrained retail development in designated centres of population and commerce (and constrained retail development outside the designated activity centres). The SCCA's (2013) stated position on the desired activity centre planning policy was as follows:

By seeking to concentrate retail and commercial activities and public facilities in a network of urban centres with public transport access, 'centres' policies not only ensure sustainable development but also:

- *protect the private and public investment in existing centres and encourage full use of infrastructure,*
- *provide greater certainty for investment decisions on shopping centre development and redevelopment, and*
- *ensure there is a level playing field for all retail developments.*

This debate highlights the difficulty of activity centres anchored by shopping centres being knowledge economic activity centres. Where larger centres are protected by planning policies, this can restrict competitive activity in adjacent centres through restricting competitor centre size (often leading to competitor retail dispersing into surrounding areas). This protective planning, allowing the larger centres to increase their retailing size in the absence of competition, has the potential to increase public transport use and accessibility. However, these larger retail agglomerated centres, which are mainly managed centres due to the investment required to establish and expand such centres, are able to use the absence of competition to inflate lease values and therefore restrict competition, new entry and innovation (Productivity Commission 2011a, 2011b). The higher cost centres are also only effectively viable for particular established higher performing retail businesses where externalities are best delivered, therefore restricting start-ups.

Allowing more dispersed retail in a range of centres or zonings within a catchment provides for more competition and possibilities of new entry. The Productivity Commission (2011a, 2011b) has argued that retailers should be free to locate (within the constraints of good planning practice, addressing congestion and the viability of nearby existing or planned centres) where they deem best for business, whether this is in a zoned centre or other commercial or industrial area. However, this dispersion limits agglomeration opportunities, and subsequently limits justifications for public transport investment and urban density. Either model for retail-based activity centres (agglomerated non-competitive centrally controlled centres *or* de-agglomerative dispersed and competitive) are ultimately unsuited to the development of knowledge economic activity.

10.2 Shopping centres and human capital intensification

The impact of the adoption rather than the creation of new technologies within retail are also worth considering in terms of the impacts on workforce profiles and skill levels. In terms of recruiting for innovation, retail focused on general business skills and marketing, with engineering and scientific skills almost non-existent (Toner et al. 2004). In Australia, taken as a whole, innovation-intense industries had a higher share of managers, professionals, tradespeople and advanced clerical occupations than the medium and low-innovation-intense industries such as retail (Toner et al. 2004). The Productivity Commission (2011b) has noted that skill levels, pay, and labour productivity are relatively low in retail compared to other Australian industries or to

international retail industries. However, the retail industry in Australia is highly labour intensive with high levels of base-award workers (Productivity Commission 2011b). This is consistent with retail labour markets worldwide (du Gay 1993, ILO 2006, ILO 2015). Because retail is labour (rather than knowledge) intensive, labour costs are key considerations for productivity (Du Gay 1993, Productivity Commission 2011b). Du Gay (1993) also found that labour intensity has in the past seen increasing levels of casualisation and part-time workers to increase labour flexibility. Low skill levels mean shopping centres are able to recruit locally rather than across a wider metropolitan area, providing for reduced commute times and potentially more sustainable transport. Labour flexibility has also resulted in increasing levels of turnover in the industry (which has not encouraged investment in training). In recent years, a number of larger, low-priced retail firms have increased training as a means of operating with fewer staff, which has also led to increased internal promotional opportunities (ILO 2015). The trend for fewer support staff controlling more stores and a consolidation of ownership has been ongoing since the 1970s and is a key means of increased productivity (du Gay 1993, Hopping 2000, ILO 2015).

Notably in Australia, there has been a long-term decline in the share of spending on goods and this has seen an increase in the share of spending on (non-housing) services (Lowe 2011), particularly in health, education and a range of household and personal services. While these increases are partly explained by the rise in the relative prices of many of these services, the volume of consumption of these services has also increased (Lowe 2011). The explanation for this is that there has been a gradual shift in household preferences away from goods and towards services and 'experiences'. People and countries also often redirect discretionary income towards education services as they become wealthier and grow national income and this has occurred in Australian households (Productivity Commission 2011a). In 2006–07, education expenditure accounted for 5.3 per cent of Australia's GDP (ABS 2012c). Within five years, it had risen to 7.1 per cent in 2010–11 (ABS 2012c). This shift to services helps explain the increase in knowledge service workers in the suburban economy (see Davies 2013) with increasing numbers of services, particularly in education and health, requiring university-qualified knowledge workers.⁵² However, this does not seem to have diversified the focus of shopping centres from consumption to education or health services, although the inclusion of libraries in or near shopping centres has become a relatively common occurrence in the UK and Australia (Lowe 2000, Forsyth 2006).

⁵² Local government is a good example of increased service delivery by an increasingly professional workforce in the often low-density dispersed suburban economy (Martin, 1999, Dallery, Crase, Johnson 2006).

10.3 Shopping centres and ICT intensification

There is little to suggest that shopping centres are particularly ICT intense relative to other industries. The output of retail as a low-tech industry is 'commodities' (i.e. retail services and goods). While retail production processes employ advanced IT or automated systems, they are sourced from 'high-tech' industries (Toner 2011, ILO 2015). However, it was noted by the ILO (2015) that with increased ICT adoption, a small number of higher skilled jobs were being created in the retail sector (though not necessarily at shopping centres). Similarly, the creative industries – which help drive the retail industries, design, marketing and advertising – are also spatially separate from shopping centre environments. Shopping centres and the retail industry are adopters and consumers of technology, rather than creators. In outlining the history of technology in the retail industry in the USA, Hopping (2000) of IBM noted that retailing had always taken advantage of technology. This was not always as an early adopter, but whenever it turned out to be advantageous. Hopping (2000) forecasted (correctly) that the volume of information that could be collected by a retailer would grow exponentially and that retail would continue to adopt technology, particularly with the sharing of information.

Chapter 11 Part D research on urban structures for knowledge-intense cities

11.1 Methodologies

The research in Part D used a variety of research methods. For the creation of the Australian 'system of cities' model, various ABS Census population statistical information, including historical, data was used. Determining historical levels of primacy and comparing them to modern day information has some difficulties as the capital cities were not the 'metropolitan areas' they are today (i.e. the WA Government Department of Treasury and Finance's (2004) primacy figures for Perth's early 20th century population differ somewhat from the ABS (2008) figures for Perth for 1901). Nevertheless, the overall historical trend for all of the capital cities is distinctive, and an increase in capital city primacy over the course of the 20th century is evident. The 'system of cities' model also requires a combining of the states of NSW and Victoria into a single entity so as to form Australia's national core agglomeration. There are no doubt arguments as to the validity of this as an approach, in the sense that the Victoria/NSW combination is an artificial creation. Arguably, state boundaries are equally artificial historical boundaries.

Brisbane and (more so) South East Queensland (SEQ) could possibly be seen as part of the national core agglomeration. This particular argument will become increasingly stronger, if (and when) SEQ's population overtakes that of the Melbourne metropolitan area. However, even if SEQ was added to the regional agglomerative core it would not lessen the peripheral status of the other capital cities. Therefore, the essential argument would still be valid.

A method used in the research to further test the combined centrality of Melbourne and Sydney is the use of airplane passenger movements between Australia's major cities. This demonstrates the relative dominance and attraction of major city activity through passenger movements between core cities (Melbourne and Sydney) and peripheral cities (BITRE 2012a). The use of passenger movements for a specific year to consider the core and peripheral cities is obviously limited, however, it is used as a means of testing a modern activity (commercial airflights) against the historical analysis of population changes over time.

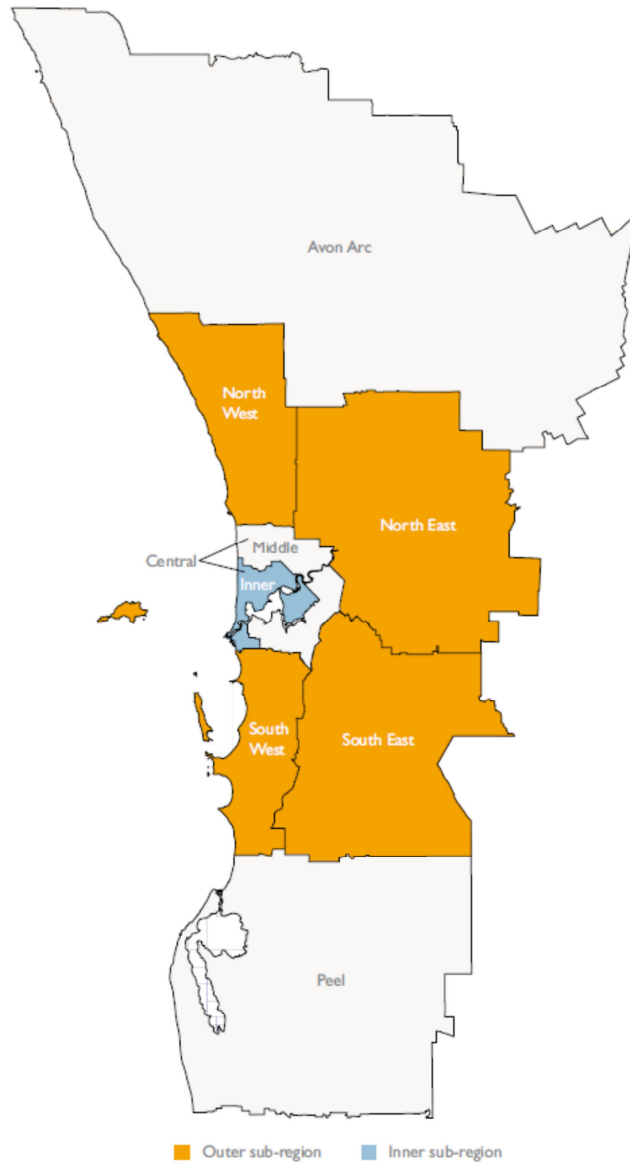
In determining whether Perth's urban structure was monocentric, polycentric or dispersed, an analysis of Perth and Sydney centres (in terms of employment density,

industry type and commuting patterns) was undertaken using the ABS 2006 and 2011 Census data. The benefit of comparing Perth and Sydney is that they have largely adopted similar planning polycentric approaches. Perth's population is also tracking Sydney's population growth (though at a somewhat faster rate of growth). The analysis of Perth and Sydney, relying on the ABS 2006 and 2011 Census, is somewhat dated, however, in terms of a broad historic analysis of two similar cities at different stages in their growth, it provides a valuable comparison.

ABS Census (2006 and 2011) population data and BITRE transport reports (2010 and 2012) were also used to understand the catchment characteristics of particular centres as to determine labour market thickness and knowledge intensification for both Sydney and Perth. Differing methods were used by BITRE (2010 and 2012) to provide an understanding of a centre or employment destination's catchments.⁵³ The analysis for Perth references a number of metropolitan regions, (covering a number of Statistical Local Areas (SLAs)) which are as per **Figure 25**.

⁵³ The Sydney analysis was based on percentage of workers from particular sub-regions. The Perth analysis was based on caches (of more than 2000 workers) commuting to and from differing Statistical Local Areas (SLAs). While this difference makes exact comparisons difficult it, does not reduce the essential capacity to make a conclusion as to which centres or employment destinations had the broadest catchments.

Figure 25 Map of WAPC planning subregions for metropolitan Perth



Note: The North-West, North-East, South-East and South-West subregions together make up the Outer subregion of Perth. The Inner and Middle subregions combine to create the Central subregion, with the Peel subregion making up the final planning subregion in *Directions 2031*.

Source: BITRE (2010)

A research comparison of Perth's Strategic Metropolitan Centres and Specialist Centres in terms of knowledge intensity characteristics was undertaken in **Appendix 6 – Knowledge Intensification Potential of Perth Activity Centres**. Specialised Centres and Strategic Metropolitan Centres (in the absence of any Primary Activity Centres being second in the hierarchy) were selected as the centres most likely to be developed as Primary Activity centres. These activity centres were examined in respect to the following criteria:

- Centre description – as per the State Planning Policy 4.2 Activity Centres for Perth and Peel (WA Government Gazette 2010),
- Centre description and uses – determining main and secondary uses,
- Key transport infrastructure – the major transport infrastructure (rail, freeway or highway) within 800 metres,
- Catchment and international role (international links and catchments identified from websites or from shopping centre category),
- Centrality - distance in kilometres to CBD and to three other nearest major centres using Google Earth distance calculator,
- Employing industry by employment zone,
- Research capacity and excellence – from Australian Research Council 2014, and
- Immediate LGA population with Bachelor degree and higher.

Centrality ratings and scores were given as a means of determining the potential for centres to be part of an agglomerative ecosystem of a thick labour and service market around the Perth CBD and the inner city. In this, it is inherently biased towards centres close to the CBD, however, this reflects the natural bias of agglomeration being driven by scale and density.

The results for 'catchments' section in **Appendix 6** are, to a degree, limited, as they arise from assumptions based on their main anchor (i.e. known and expected catchments of shopping centres based on their designation in the activity centre hierarchy) and do not rely on an extensive survey of actual linkages (such as the extent of potential linkages in non-retail activity in strategic metropolitan centres). This is an area of possible further research. However, based on the literature review on the catchment of shopping centres and universities, a more extensive linkages survey is unlikely to find a substantially different outcome.

11.2 Australia's 'system of cities' and understanding Perth's urban structure

The primacy of all of the Australia's state capital cities, as demonstrated in **Figure 26**, has increased notably since 1901.

Figure 26 Degree of primacy of Australia's state capital cities

State/region ('000) ⁵⁴	Capital city	City Population ('000) ⁵⁵	Level of Primacy 2013	Level of Primacy 1901 ⁵⁶	Rainfall ⁵⁷	Population density/scale ⁵⁸
NSW/ACT 7,762.8	Sydney	4.76 (1)	61% (4)	37% (3)	566 (4)	8.5 (2)
Victoria 5,713	Melbourne	4.25 (2)	74% (3)	42% (2)	654 (2)	22.6 (1)
Queensland 4,638.1	Brisbane	2.19 (3)	47% (6)	24% (5)	630 (3)	2.4 (4)
Western Australia 2,497.5	Perth	1.9 (4)	78% (1)	37% (3)	352 (6)	0.8 (6)
South Australia 1,667.5	Adelaide	1.28 (5)	77% (2)	45% (1)	236 (7)	1.6 (5)
Tasmania 512.9	Hobart	0.206 (6)	42% (7)	21% (6)	1,168 (1)	7.2 (3)
Northern Territory 237.8	Darwin	0.116 (7)	49% (5)		548 (5)	0.2 (7)

The ranking of the cities, based on the level of primacy, has changed little over 100 years, with most cities moving only one place, Perth being the exception (moving from being the third most primacy city to the first). The other notable feature is that Perth,

⁵⁴ ABS (2013h)

⁵⁵ ABS (2013e)

⁵⁶ ABS (2008f)

⁵⁷ National Water Commission (2006)

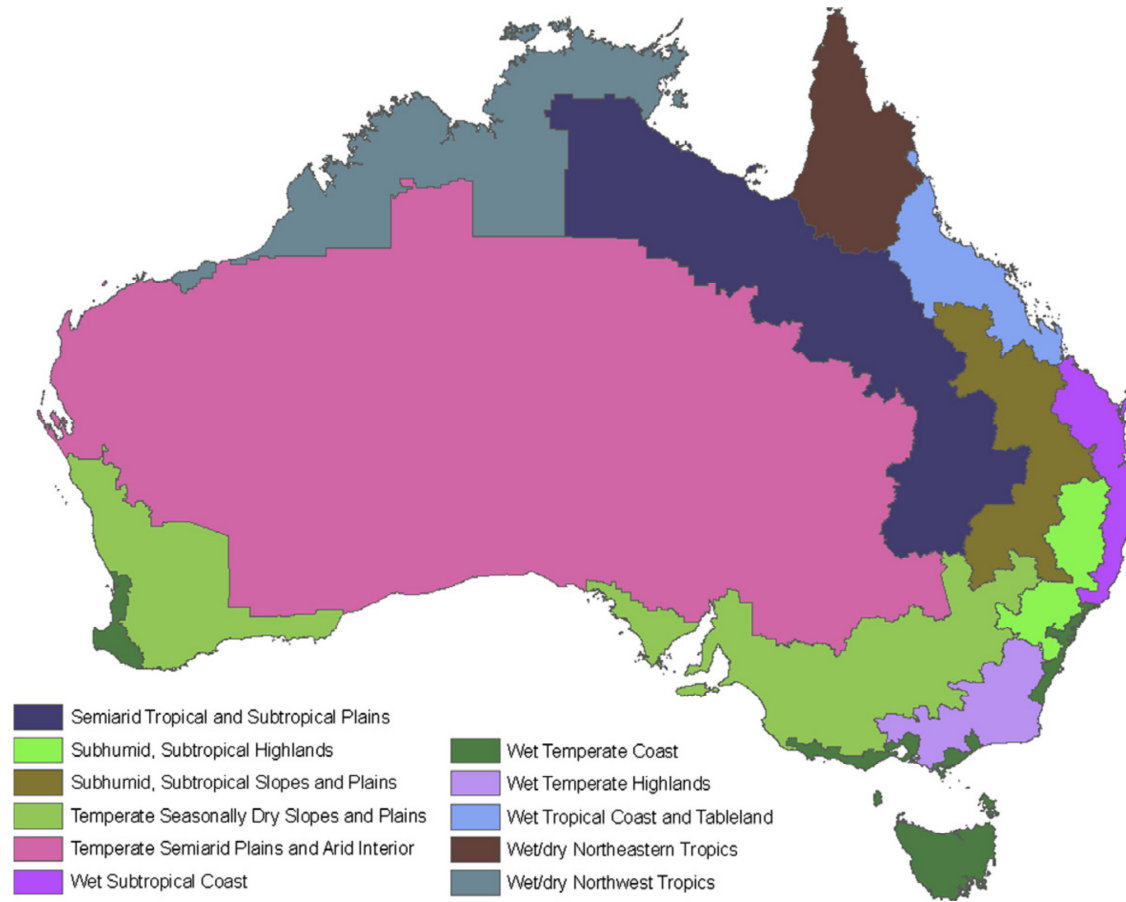
⁵⁸ ABS (2008c)

Adelaide and Melbourne now have higher levels of primacy in respect to their states population (78 per cent for Perth, 77 per cent for Adelaide and 74 per cent for Melbourne) compared to other state capitals (Sydney at 61 per cent is the next highest). What is also notable is that, over the course of the 20th century, all of Australia's state capital cities have increased their primacy as the rates of Australia's urbanisation have increased.

The reasons for the differing levels of primacy of Australian state capitals are not obvious. **Figure 26** provides consideration of some factors that may drive regional primacy differences. It would appear that while there are patterns explaining primacy, there are inconsistencies. Generally, there is a correlation between an increased primacy of a capital city where there is an increased level of aridness and physical size of a state, and a decrease in the state's population density. The exception is with Melbourne and Victoria. Perth and Adelaide are in large states (WA being the largest and South Australia the third largest state), with relatively low population densities, whereas Melbourne is in Victoria, the smallest mainland state with the highest population density of any state. Perth and Adelaide are both in states with the lowest annual rainfall whereas Victoria has the second highest annual rainfall. Rainfall influences primacy presumably due to its impact on agricultural carrying capacity of a city and its regional hinterland, as indicated previously. Hinterlands are key factors in determining a city's population size (Polese & Denis-Jacobs 2009). Notably, the states with the higher rainfall tend to have the higher population density, and regions with higher rainfall have higher agricultural profitability (see **Figure 27 Agro-ecological zones of Australia** and **Figure 28 Map of agricultural full equity profit 2005/2006**).

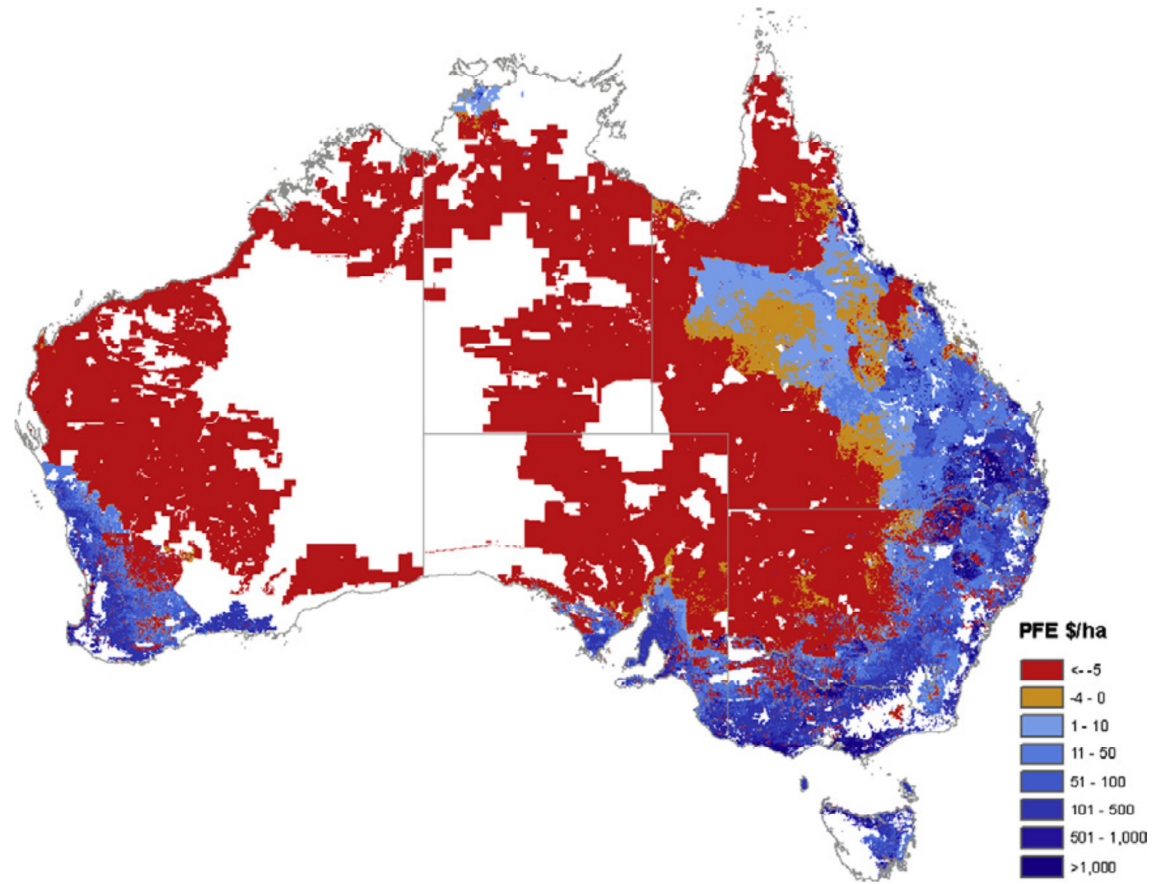
Population distribution and density in Australia, not surprisingly, is largely consistent with Australia's agro-ecological zones and the profitable agricultural areas, with clear superiority of the east and southeast coastal areas along with the southwest (i.e. compare **Figure 22 Remoteness areas and population distribution 30 June 2006** with **Figures 27 and 28**).

Figure 27 Agro-ecological zones of Australia



Source: Marinoni, Navarro Garcia, Marvanek, Prestwidge, Clifford, & Laredo 2012

Figure 28 Map of agricultural full equity profit 2005/2006



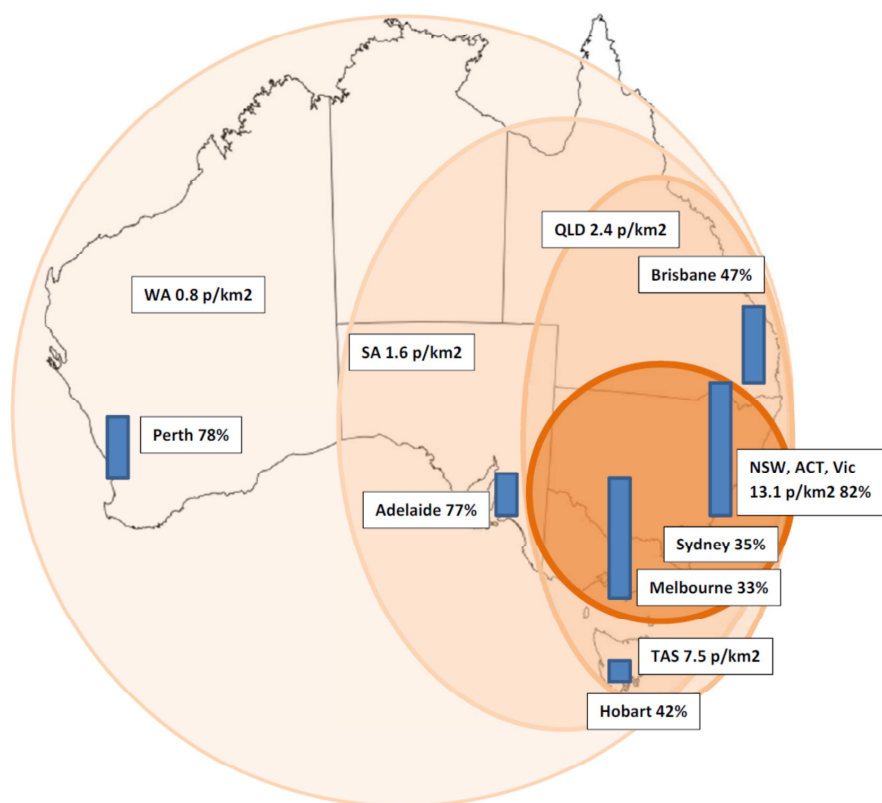
Source: Marinoni et al. 2012

Not surprisingly, all Australia's state capital cities are located in areas with hinterlands of reasonably profitable agriculture (as are the national capital, Canberra (in the Australian Capital Territory) and Darwin (which is in the only *blue* Northern Territory patch in **Figure 28**)). This suggests that agricultural productivity, for some agricultural products at least, is positively influenced by access and proximity to large urban areas. This could be due to a range of factors such as closeness to markets (on the demand side) and access to larger labour markets, intermediate and export logistic services (on the supply side). Historically, agricultural attributes such as soil, water and climate have influenced regional and national settlement patterns. This is of importance for Australia, as its national settlement patterns followed agricultural capacity, particularly in relationship to water and climate (with the more benign climates of southeastern Australia). The importance of this is evident in the first starter advantages provided to Sydney and Melbourne, as Australia's first two significant cities.

The increase in levels of primacy of all of Australia's major cities is consistent with a greater level of agglomeration being required in the economy even with (or possibly due to) the improved levels of ICT and transport technology over the course of the 20th century in Australia. This supports Butlin's (1994) and McLean's (2004) arguments that urban agglomeration and concentration in just a few cities is a key economic driver for Australia. Spiller (2005; p. 25) noted that advanced business services show strong tendencies to centralise into a relatively few 'command and control centres' at the international or national level. In Australia, the control centres were identified as Sydney and Melbourne, with the geographic concentration of advanced business services in Australia, according to Spiller (2005; p.25), seemingly cementing a 'core-periphery' pattern of regional development in Australia.

Therefore, using Spiller's 'regional core-periphery' approach, an alternative way of examining primacy of Australia's cities is to establish a core-peripheral framework, with Sydney (NSW) and Melbourne (Victoria) combined as Australia's core regional population and economic agglomeration. This core has a lower level of city primacy but with higher levels of regional population density (see **Figure 29**).

Figure 29 The Australian 'system of cities' looking at regional population density, state capital city population and primacy (with NSW (with ACT) and Victoria combined into the national core region)



Regions	Population ('000) ⁵⁹	Area (m2) ⁶⁰	Population density (km2) ⁶¹	City – (Population ⁶²) and degree of primacy 2012
NSW-ACT-Victoria	13,475.8	1,030,416	13.08	Sydney (4.67M) 35% Melbourne (4.25M) 32%
Tasmania	512.9	68,401	7.5	Hobart (0.205M) 42%
Queensland	4,638.1	1,730,648	2.4	Brisbane (2.19M) 47%
South Australia	1,667.5	983,482	1.6	Adelaide (1.28M) 77%
Western Australia	2,497.5	2,529,875	0.8	Perth (1.9M) 78%

⁵⁹ ABS (2013h)

⁶⁰ ABS (2008e)

⁶¹ ABS (2008e)

⁶² ABS (2013e)

From this agglomeration core there is, graduating out to the outer states, lower levels of population density and increasing levels of capital city primacy. As per **Figure 29**, outside the Sydney-Melbourne core there are three identifiable graduated peripheral rings which see, as you move further from the Sydney-Melbourne core, the population density declining, capital city primacy increasing and to a lesser degree city population decreasing. The first periphery ring is on the north-south axis from Brisbane to the north of the core and Hobart to the south. The second and third periphery rings are to the west, first around Adelaide and then Perth. The clear trend for the primacy of Australia's state capital cities is that the further cities are from the Sydney-Melbourne core, the higher their primacy.

In this 'system of cities' model, Australia's city population sizes are somewhat inconsistent, more so at the periphery than at the core. Melbourne and Sydney, as the core cities with over four million people each, have the largest populations of Australia's cities. They also have the most knowledge-intense labour markets, having more workers with university qualifications than the other state capital cities (ABS 2011a). The fact that Australia's two largest cities are 'adjacent' (in that in the context of location of state capitals there is no other state capital city between them), is an agglomerative factor. In terms of area, NSW and Victoria combined are only slightly larger than South Australia, yet still considerably smaller than Queensland or Western Australia. In terms of population NSW and Victoria combined account for 57 per cent of Australia's population (ABS 2013h). At the city level, Sydney and Melbourne are the nation's two largest cities, accounting for 37 per cent of the national population (ABS 2013h). In the immediate periphery ring around the Sydney-Melbourne core, Hobart's population is relatively small for a capital city though its primacy is 40 per cent, not dissimilar to Brisbane at 45 per cent. Both Tasmania and Queensland have state population densities in the middle range (7.5 and 2.4 persons per sq km).

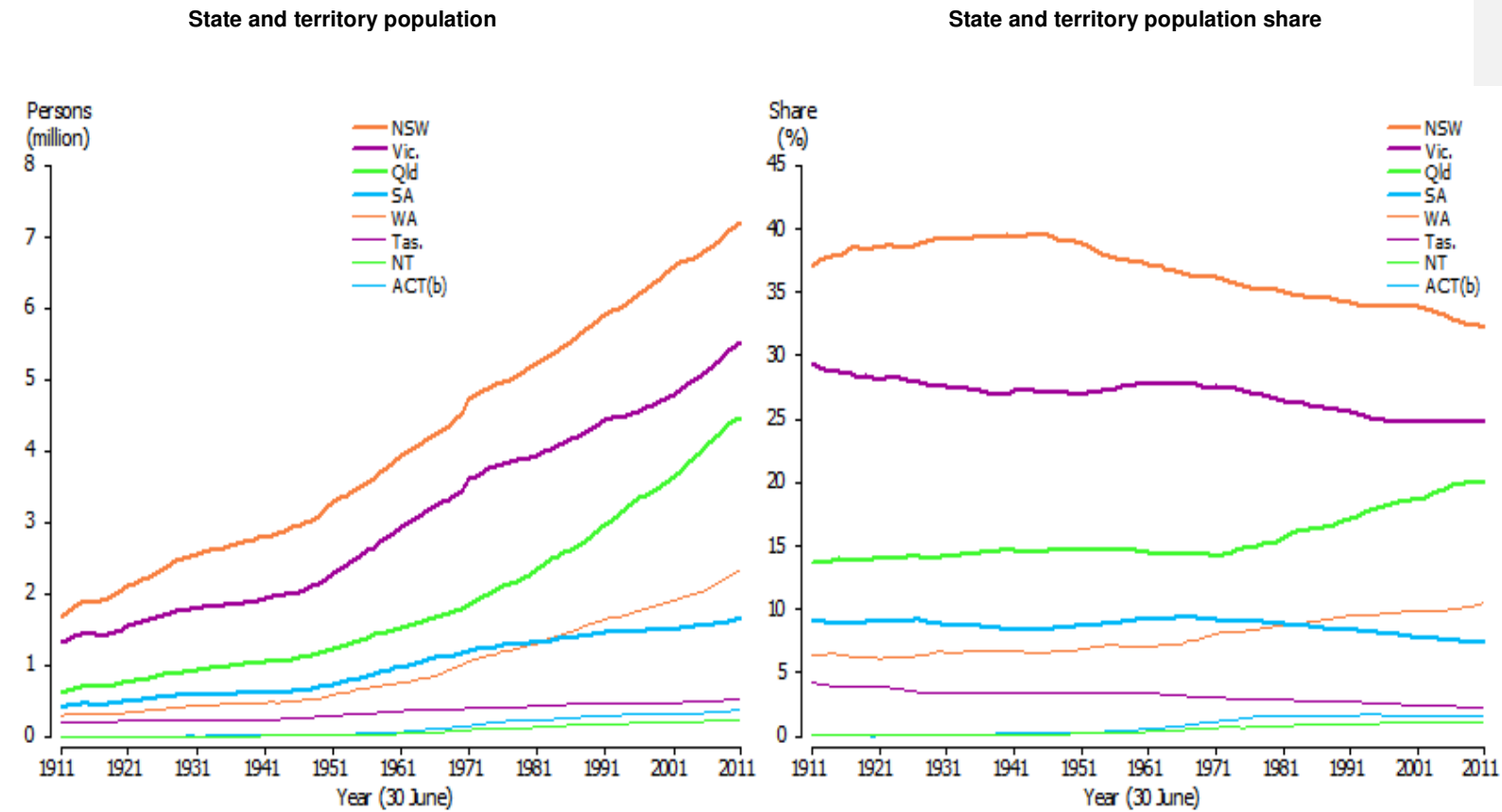
Adelaide, in the second peripheral ring, is closer in distance to Melbourne than Brisbane is to Sydney. However, Adelaide is a more peripheral city than Brisbane. Adelaide has a much greater level of primacy (77 per cent) than Brisbane or Hobart (45 per cent and 40 per cent) and South Australia has a much lower population density than Queensland or Tasmania. Arguably, the urban core in Australia is trending north. Queensland and Brisbane's populations have been slowly catching that of Victoria and Melbourne ((ABS 2008b, 2012a, 2015a) ⁶³).

The outer western peripheral ring beyond Adelaide and South Australia is Perth and the state of Western Australia. Perth is the most remote Australian state capital city, and while it

⁶³ Brisbane, as the third largest Australian city, has a population of over two million (notably though, Brisbane's South East Queensland hinterland also has a sizable population, meaning the total regional population is 3.18 million (ABS 2012a) and includes Australia's largest non-capital city, the Gold Coast.

has a higher population than Adelaide (and has had since the 1980s), it has a similarly high level of primacy to Adelaide (78 per cent and 77 per cent respectively). Western Australia and South Australia, as the relatively arid states, have the lowest population densities (0.8 and 1.6 persons per sq km respectively). Notably, Perth's and Western Australia's national population share is increasing, whereas Adelaide's and South Australia's is decreasing (see **Figures 26 and 29**). Both Western Australia and Queensland had a relatively (low) consistent share of the national population until the 1960s and 1970s, when substantial resource-led expansions of their economies began to occur. As Queensland and Western Australia's population rates grew, they were slowly capturing more of the overall population (see **Figure 30**). As a result of the growth, Western Australia's population exceeded that of South Australia by 1982 (ABS 2012a). This Australian northern and western urban expansion has parallels with 'sun chasing' southern and western urban expansion in the USA.

Figure 30 100 years of Australia population distribution by State



(a) Population estimates based on Census counts and other information.

(b) Includes Jervis Bay Territory from 1915 to 1993.

Source(s): ABS 2008f and ABS 2011d

Understanding Australia as an agglomerative core (centred on Sydney and Melbourne) with radiating peripheral regions is consistent with Fujita, Krugman and Venables' (1999) 'new economic geography' approach to understanding regional and international agglomeration. As previously noted, this approach emphasised the interactions between increasing returns, transportation costs and the movement of productive factors across various spatial scales, including urban, regional and international economic scales (Schmutzler 1999). The result is, some cities develop an early dominance, which persists and reinforces itself. This is evident with Sydney and Melbourne in Australia.

Sydney and Melbourne have been the two dominant cities in Australia since the European settlement, with an ongoing 'battle' between the two for the top spot of Australian cities (Wilkinson 2010). The international evidence is that the uppermost rung in national city size ranking over time tends to be relatively stable and this is borne out with the population top ranking of Australia's largest cities having not changed over the last century, with Sydney ranking first since the 1900s (Polese & Denis-Jacob 2009, Wilkinson 2010, Batty 2013)⁶⁴. Urban hierarchies tend to harden over time especially in nations that have completed the rural-urban transition (Polese & Denis-Jacob 2009), which happened much earlier in Australia than most countries (Butlin 1964, 1994).

Sydney, in the 21st century, has identified itself as the central 'global' Australian city (Gleeson et al. 2004). As of 2008, Sydney had 49.93 per cent of advanced business service export jobs (yet with 21.89 per cent of all jobs Australia wide) while Perth had only 5.94 per cent of advanced business service export jobs (with 7.31 per cent of all jobs nationally) (SGS 2008). This is consistent with the conclusion reached by Leamer and Storper (2001) that larger knowledge oriented cities are about specialisation and complexity. Similarly, in looking at the international population size ranking of cities within nations, Polese and Denis-Jacob (2009) found that specialised financial services exhibit a clear preference to larger cities and the hierarchical distribution varies only slightly.

Another way of highlighting the dominance of the Sydney-Melbourne core and its interrelationship with the peripheral urban agglomerations is to look at the thirty-two highest airport city pairs for air passenger movements, which demonstrates a classic power law

⁶⁴ Sydney was the first city of Australia, though it was overtaken in population by Melbourne during the mid 19th century Victorian gold rush. Melbourne, as a result, became the financial centre of Australia during the first half of the 20th century. Discriminatory tariffs saw Melbourne with the highest concentration of manufacturing amongst the capital cities of Australia, with, in the first half of the 20th century, a majority of companies locating their headquarters in Melbourne. However, this reversed during the second half of the 20th century and with the decline in manufacturing and the expansion in property and finance sector, the majority of large Australian companies located their headquarters to Sydney (Wilkinson 2010).

relationship (see **Figure 31** and **Figure 32**).⁶⁵ Sydney and Melbourne dominate with air passenger movements between the two cities being nearly double the next highest route (Brisbane – Sydney) and higher than the second and third highest (Brisbane – Melbourne) combined. All of the top ten airport city pairs involve Sydney or Melbourne.⁶⁶

⁶⁵ Using passenger numbers to produce hierarchies of cities and airports and traffic networks is well established (Fuelhart, Ooms, Derudder & O'Connor 2016, O'Connor & Fuelhart 2016), though O'Connor and Fuelhart (2016) have recently linked established classification of cities with the characteristics of air services, including type and size of planes used.

⁶⁶ The airport city pairs reinforce Adelaide's position in the secondary periphery behind Brisbane, despite Adelaide being physically closer to Melbourne than Brisbane is to Sydney.

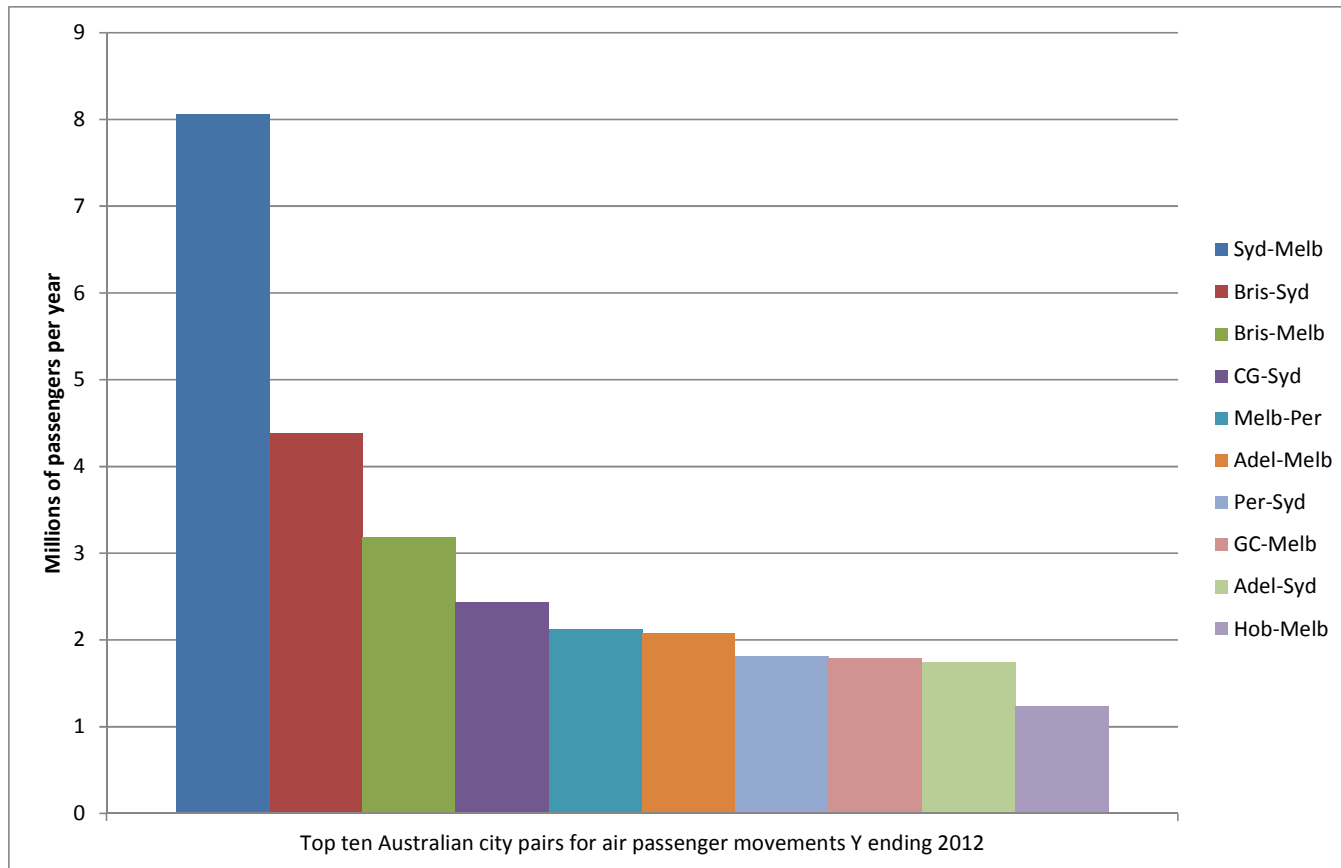
Figure 31 Map of top 10 Australian city pairs for air passenger movements year ending 2012



Overall Ranking	City-pair	Passengers year ending 2012 ('000)	Overall ranking	City-pair	
1	Melbourne - Sydney	8,056.0	17	Cairns - Sydney	937.6
2	Brisbane - Sydney	4,390.4	18	Launceston - Melbourne	835.6
3	Brisbane - Melbourne	3,189.4	19	Karratha - Perth	762.5
4	Gold Coast - Sydney	2,442.9	20	Adelaide - Brisbane	729.2
5	Melbourne - Perth	2,130.7	21	Brisbane - Rockhampton	644.4
6	Adelaide - Melbourne	2,085.2	22	Adelaide - Perth	621.7
7	Perth - Sydney	1,811.4	23	Brisbane Canberra	605.4
8	Gold Coast - Melbourne	1,790.8	24	Brisbane - Newcastle	591.8
9	Adelaide - Sydney	1,751.2	25	Cairns - Melbourne	581.8
10	Hobart - Melbourne	1,239.6	26	Port Hedland - Perth	494.4
11	Brisbane - Cairns	1,187.2	27	Hobart - Sydney	477.9
12	Canberra - Sydney	1,053.2	28	Sunshine Coast - Sydney	463.6
13	Canberra - Melbourne	1,003.1	29	Melbourne - Newcastle	425.2
14	Brisbane - Townsville	994.2	30	Brisbane - Gladstone	411.6
15	Brisbane - Mackay	964.7	31	Darwin-Brisbane	375.9
16	Brisbane - Perth	951.5	32	Newman - Perth	372.2

Data sourced from http://www.bitre.gov.au/publications/ongoing/files/domestic_airline_activity_2012.pdf Passenger movements shown for a city pair reflect total traffic in both directions. Passenger carried equals revenue passengers carried which is all passengers paying any fare including frequent flyer

Figure 32 Top ten Australian city pairs for air passenger movements year ending 2012



Source: BITRE 2012b [http://www.bitre.gov.au/publications/ongoing/files/domestic airlines activity2012.pdf](http://www.bitre.gov.au/publications/ongoing/files/domestic_airlines_activity2012.pdf)

Interestingly, Perth's air passenger movements are focused on Melbourne and Sydney, despite Adelaide being the closest major city. This is consistent with patterns in diffusion processes within urban systems, which are often very hierarchical, in that the adoption of innovation jumps from a large city to a very distant large one before going to the closest (Purmain 2004, referencing Pred 1977).

The general decrease in city population sizes and state population density as you move away from the Sydney- Melbourne population core to the periphery is self-explanatory, in terms of agglomeration. The increased primacy as you move to the periphery however requires consideration. Arguably, increased primacy is due to the need for greater localised urban agglomeration in the peripheral states (with their lower population density). Notably, as Australia's remotest city, Perth's primacy has increased to a greater degree than any other state capital city over the course of the 20th century (from 37 per cent in 1901 to 78 per cent in 2013). Perth's primacy in the 19th century and early 20th century was not particularly strong from a population or transport perspective compared to other capital cities (Major Cities Unit 2010). For international sea transport, Albany (on the south coast of Western Australia) was the key deep-sea port until the Fremantle Port expansion, lead by C.Y. O'Conner in the 1890s (DTF 2004). In terms of population, Perth was challenged following the 1890s gold rush, by the Goldfields (DTF 2004, BITRE 2014a). By 1901, 32 per cent of the Western Australia's inhabitants lived in the central and eastern regions (mainly in the goldfields in Kalgoorlie-Boulder) (DTF 2004). This was not much lower than Perth's population share of 37 per cent.

From 1911 to 1947, despite mining and agriculture being the significant industries in the State's economy, the urbanisation levels of the Western Australian population were high. Perth's population (as a proportion of the State total) increased over the period to just over 50 per cent (DTF 2004). Perth's primacy as the capital of Western Australia emerged post WW II. This period was characterised by Western Australia's increasing accessibility to communication and transport advances, bringing Western Australia much closer to the rest of the world (DTF 2004). This post war period also saw a steady increase in Western Australia's population growth rate, and at rates higher than the national average. Perth was the focus of this population growth, with continued growth in services and decline in agricultural employment.

The increasing primacy of the Perth metropolitan area continued to occur through to the mid 1980s following the resurgence of the minerals and resource sector in Western Australia, which started in the early 1960s (DTF 2004). From 1971-1996, Perth's population grew by

77 per cent, and this was consistent with the reinforcing of primacy of Australia's major cities growth since the 1970s (McManus 2005, Major Cities Unit 2010). By the mid 1980s, with continued increasing levels of transport and communication, 73 per cent of the State's population resided in the State's capital city (DTF 2004). With the recent turn of the 21st century resources boom, Perth's primacy continued and was 78 per cent by 2013 (ABS 2013e).

Notably, all the state capitals have increased their primacy over the course of the 20th century, even with (or because of) the rapid improvements in transport, communications and increased knowledge economic activity (BITRE 2014a)⁶⁷. As has been noted, the lack of population size in Australia historically and into the present has been a key factor on urban structures (Butlin 1964, 1984, Robinson 1961, Hugo 2002, Maclean 2004, McManus 2005, Major Cities Unit 2010, BITRE 2014a). The result is that Australia's population has increasingly agglomerated into just a few metropolitan cities and this concentration in urban agglomeration is particularly so with Australia's peripheral cities. Effectively, the lack of regional scale in Australia has been countered by increasingly maximising urban scale within major cities. As the primacy of Australia's cities has continued unabated, it is suggestive of increasing and continued benefits of agglomeration (despite the dis-agglomeration factors such as traffic congestion and real estate inflation).

The logical extension of this increasing need for agglomeration scale is that within the more peripheral, low population scale states of Western Australia and South Australia there has been an even greater agglomeration draw into the singular metropolitan city areas. This suggests that Perth and Adelaide (more than other Australian cities) have limited to no agglomeration spillover from surrounding hinterland areas and are therefore largely self-dependent for local agglomeration. Essentially it is concluded that, because Western Australia and South Australia have both had low population sizes and densities (arising from their land size, aridity and lower arable productivity), their populations have increasingly focused into a single (capital) city regional agglomeration.

At the national scale, an examination of the Australian 'system of cities', using the 'new economic geography' framework, further leads to a conclusion that (population demand and market forces in) Australia is concentrating population growth in just a few major urban areas capable of delivering agglomeration. This concentration would appear to be a combined natural result of Australia's large surface area, aridity, relatively low population

⁶⁷ Glaeser and Kolhase (2004) contend urban and regional economics is built on transportation costs for manufactured goods, and that in the USA over the 20th century the costs of moving goods declined by over 90 per cent in real terms. The transport cost reduction has also had significant effect in Australia over the same period – see BITRE 2014a.

and increasing need for agglomeration in a post-industrial knowledge-intense economic environment. This leads to a further conclusion that a knowledge-intense global economy nations requires urban concentrations at either the regional scale (i.e. regional core agglomerations such as with Sydney-Melbourne or the Randstad) and or at the more localised metropolitan urban scale (i.e. agglomeration in peripheral primary cities in the absence of regional hinterlands).

This requirement for concentration and agglomeration at the regional or local urban scale raises a number of questions. If the economic driver at the Australian national scale is for a dispersed population to agglomerate and concentrate in just a few coastal cities, and for the population at the regional scale in its most peripheral state (Western Australia) to agglomerate and concentrate in just one primary city (Perth); what is the agglomeration driver for urban structure at the city scale? Further, in examining increasingly knowledge-intense cities such as Perth, do their urban spatial structures reflect or support agglomeration that is evidently so influential at other scales of development?

11.3 Perth's urban structure – mono, poly or dispersed?

This research section examines the next levels down the urban development scale, the metropolitan urban structure and the urban centre scales. The research focuses on post-industrial metropolitan Perth. As a primary city (being the only major city of scale within the state of Western Australia), the Perth metropolitan area is largely reliant on its own agglomeration, and this makes the research of considering the effect of agglomeration on metropolitan urban and activity centre structure particularly useful. The question then arises as to what is the urban structure of the Perth metropolitan area – is it polycentric or monocentric? Alternatively, does the answer not fit within a neat dichotomy? Consideration will be given to a possible structure of a knowledge-intensive monocentric centre with dispersed population driven activity with weak centres.

The follow on question for the activity centre scale is, what centres in the Perth metropolitan area, outside of the CBD, would be (potentially) capable of providing sufficient urban density and knowledge-intense agglomeration economic activity? Perth metropolitan planning policy frameworks in the past have not provided activity centres with sufficient scale and gravity (Houghton 1981, Curtis 2005, Davis & Hartford-Mills 2016). Curtis (2005, p. 446) has contended that the Perth metropolitan 'regional centre' strategy has failed because employment self-containment has not been achieved. Ultimately, the proposition in this thesis is that a small number of interconnected, dense, knowledge-intense activity centres,

including the CBD, would best give effect to knowledge economic development. This would result in a polycentric metropolitan area but with a strong degree of centrality of activity to maximise agglomeration. The effective choice, for the type of development suited to being knowledge-intense activity centres, is between activity centres anchored either by universities (Specialist Centres) or by shopping centres (Strategic Metropolitan Centres).

First, a consideration of Perth's employment distribution and effectiveness of its planned activity centres is required. As addressed in Part 7.1, the Perth CBD has re-established itself, without question, as the key office-based knowledge centre for the resource industry, as predicted by Houghton (1981). This is consistent with the Glaeser and Kahn (2001) conclusion that the best predictor of centralisation appeared to be specialisation in services. This is evident in Perth, with the concentration of a number of knowledge-intense specialist industries including mining services in the Perth CBD (Department of Planning et al. 2009, Martinez-Fernandez 2012). Arguably, the rebirth of the CBD has seen the monocentric city re-establishing itself as per Gilli's (2002) model, with the knowledge-intense service centre increasingly at the heart⁶⁸.

The Perth CBD is the central and dominant centre within the Perth metropolitan area, and the CBD and its immediate surrounds are appropriately designated, within Activity Centres State Planning Policy, as the '*Capital City*'. There is, however, based on the 2011 Census, a lack of other activity centres with gravity and scale in Perth's metropolitan area (SGS 2015, Martinus & Biermann 2016, Davis & Hartford-Mills 2016). Commuting patterns are strongly oriented inwards, with the Perth CBD being the main centre of attraction (see **Figure 37**). The centrality of employment in Perth sees 51 per cent of jobs being within 10km of the CBD and 64 per cent within 15km (Davis 2016), greater than other major Australian cities. Generally, the further a SLA was from the CBD, the less likely it was that workers commuted to the CBD. In the 2006 Census, the western and middle northern SLAs (which in 2006 had rail infrastructure) were more likely to have commuted to the CBD than the middle southern SLAs (where rail was only provided in post 2007) (BITRE 2010). The limited nature of commuting between the outer suburban sub-regions is identified in **Figure 33** (looking at sub-regional flows or working residents to jobs) (Martinus & Biermann 2016).⁶⁹ Commuting, in 2011, was dominated by the attraction of the Central region. A majority of regions had more commuters flowing into Central than were jobs in the host region. Peel and the South West regions were the only exception.

⁶⁸ Further evidence of Perth as a monocentric city is the marked decrease, as you move away from the city centre, in residential land prices (Kulish, Richards and Gillitzer 2011) and residential density (Curtis 2009).

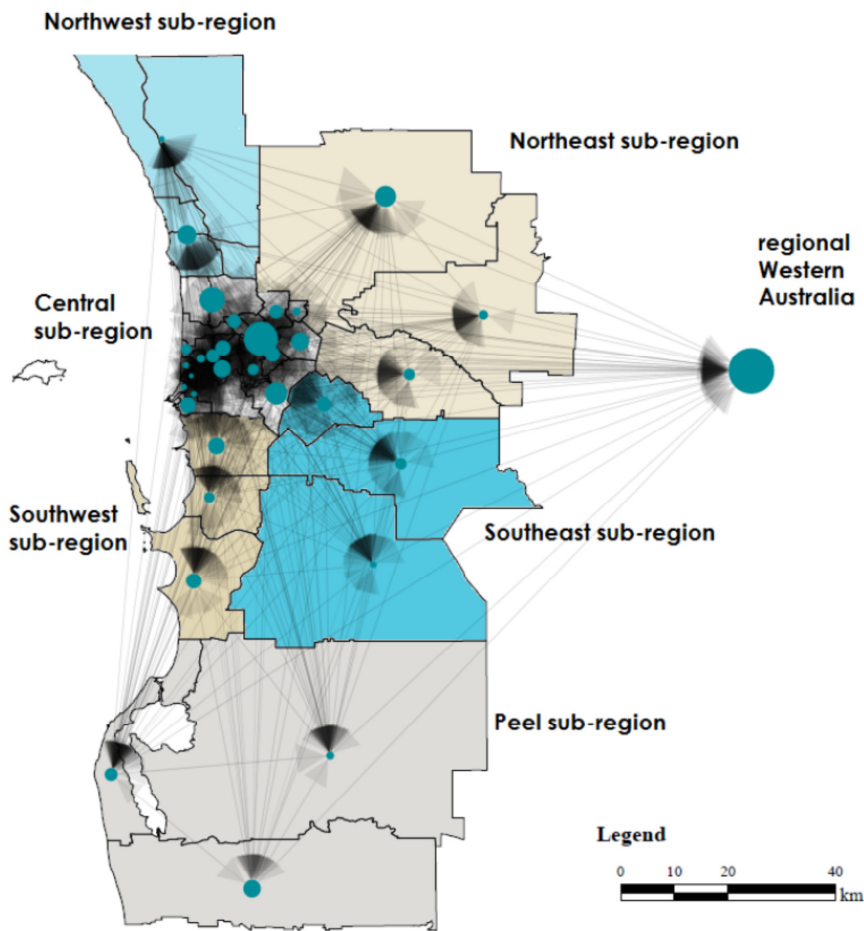
⁶⁹

Martinus and Biermann's (2016) analysis of Perth's urban structure, using the 2011 ABS Census, indicates a lack of employment scale in any LGA outside the CBD. The SLAs of Perth Inner, Perth Remainder and other inner suburban SLAs have the highest inward levels of commuting, with the Perth City council area attracting 123,440 workers while having only 8,496 resident workers (Martinus & Biermann 2016). Perth Inner and Perth Remainder SLA, not surprisingly, have the highest number of workers working in the CBD, and the next three highest LGAs, in terms of employment, (Stirling, Canning, Swan), despite their much larger area (see **Figure 15 LGA map**), have only 68181, 51,993, and 47,208 jobs respectively (Martinus & Biermann 2016). These key employment zones are dominated by retail or manufacturing (see **Appendix 6**). This helps explain their much lower employment and knowledge density. Population-consumption-driven retail and manufacturing employment (and an absence of business-to-business knowledge-intensive employment) dominate the middle and outer employment zones (i.e. outside the CBD and a small number of Specialist centres).

The extent of centrality with commuting in metropolitan Perth can be understood through examining sub-regional flows (Martinus & Biermann 2016, Martinus 2016). The concentration of inter-regional commuting into the central sub-region can be contrasted with the limited other cross-regional commutes, see **Figure 33**.

Figure 33 Sub-regional flows of working residents to jobs 2011 – table and illustrative map (size of arrows indicates number of commuters, size of circles is numbers of workers)

From	To	Regional WA	Central	Northwest	Northeast	Southeast	Southwest	Peel	Total residents
Regional WA		197,876	3,257	613	1,394	216	368	514	204,238
Central		7,495	281,403	10,055	15,379	6,079	10,682	470	331,563
Northwest		4,265	65,222	55,212	8,962	682	1,407	50	135,800
Northeast		3,395	39,804	3,271	36,309	2,218	1,133	58	86,188
Southeast		2,395	40,764	478	4,126	24,793	4,990	381	77,927
Southwest		3,720	38,497	424	1,637	2,634	43,201	2,888	93,001
Peel		2,582	3,464	100	243	407	3,216	19,593	29,605
Total Jobs		221,728	472,411	70,153	68,050	37,029	64,997	23,954	958,322



Source: Martinus & Biermann 2016, ABS Census 2011

A more detailed analysis, using commuting flows pairs between SLAs involving more than 200 employed persons from the 2006 Census, further illustrates the centrality of the Perth labour market (BITRE 2010). The CBD had the widest or thickest labour market attracting more than 2,000 workers from 11 different SLAs. Perth Remainder attracts more than 2,000 workers from eight different SLAs. Outside Inner Perth the SLAs that attracted 2,000 workers from multiple SLAs (i.e. more than three SLAs, include Stirling Central (from five SLAs) – mainly from SLAs to the north, Canning (five) – mainly from SLAs to the east and south, Swan (four) – from east, adjoining middle suburbs and the Northwest corridor, and Belmont (three) – from the east. The SLAs with the least draw from other SLAs are mainly in the southeast corridor. While not having a large enough population to register on the SLA pairs with over 2,000 commuters, the Inner Perth SLAs (and in particular the western suburban SLAs), which had the highest levels of university qualified workers, provided the high percentage of commuters into the CBD. These distinctive SLA pairs indicate a distinct 'labour market thickness' pattern; as the number of catchments decline (i.e. number of SLAs drawn from declines) so does the spatial distribution of the catchments (the spatial spread of SLAs decreases with SLAs pairs tending to be adjacent). Further, the closer the SLA is to the CBD the greater the catchment spread and greater the likelihood of commuting to Perth Inner.

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BITRE (2011) has noted previously, using the ABS 2006 Census, the dispersed and low density of employment outside of the Perth CBD and the inner city. The CBD had by far the highest level of employment density (33,949 jobs per sq km), with Inner Perth, Subiaco, and Victoria Park (4,423, 2,862, 1,096 jobs per sq km respectively) having the next highest level of employment density. Outside the inner core, other SLAs (even with sizable employment numbers) had employment densities per sq km of less than 700. The lack of employment density in Perth, particularly outside of the inner core, is also evident using an 'effective employment density' (EED⁷⁰) analysis from the 2011 ABS Census data (SGS 2015). The extent to which there was employment density outside of the CBD was found to be limited to inner city, however SGS (2015) found that even the Perth CBD lacked employment density compared to other major Australian east coast capital city CBDs and their inner city centres.

A key characteristic of metropolitan Perth's commuting patterns, that demonstrates the strong centrality or agglomeration of employment, is the movement of knowledge-intense employees, such as 'Managers' and 'Professionals', within or into the central sub-region (Martinus 2016) (see **Figure 34**). The central sub-region has the highest number of residing

⁷⁰ SGS (2015) uses a measure of Effective Job Density (EJD) as a measure of the relative concentration of employment, derived from the density and accessibility of all jobs across a region.

'Managers' and 'Professionals' (154,206, more than all the other sub-regions combined). Of these 77.4 per cent and 80.4 per cent, respectively, commute within the central sub-region. With all the other sub-regions, other than outer metropolitan Peel (which has the smallest percentage and absolute number of 'Professionals'), the central sub-region is the largest attractor for knowledge-intense 'Professional' commuters (with between 46.5 per cent to 54.9 per cent of non-central and Peel sub-region 'Professionals' commuting to the central sub-region). With 'Managers', only the southwest and Peel sub-regions retain more of their 'Managers' compared to those who commute to the central sub-region.

Figure 34 Sub-regional commuting patterns by occupation, absolute numbers 2011

From \ To		Regional WA	Central	Northwest	Northeast	Southeast	Southwest	Peel	Total
Southwest	Managers	849	3,809	60	231	285	4,223	278	9,736
	Professionals	1,374	6,867	66	255	518	5,097	577	14,754
	Technicians and trades	5,260	4,719	81	344	493	8,673	534	20,104
	Community and personal service	1,247	2,752	59	133	360	5,430	389	10,370
	Clerical and administrative	980	6,690	34	223	323	5,785	343	14,378
	Sales	795	2,462	29	78	188	5,124	321	8,997
	Machinery operators and drivers	2,370	1,874	38	250	215	3,547	226	8,520
	Labourers	2,684	1,907	52	110	238	4,924	203	10,118
Southeast	Managers	659	3,909	55	446	2,478	525	23	8,095
	Professionals	1,059	6,529	76	480	3,203	651	86	12,084
	Technicians and trades	3,921	6,023	110	894	3,961	1,301	85	16,295
	Community and personal service	906	3,410	54	304	3,371	372	22	8,439
	Clerical and administrative	945	8,552	38	589	3,411	663	24	14,222
	Sales	612	3,399	41	253	3,417	316	24	8,062
	Machinery operators and drivers	2,155	3,665	47	761	1,642	664	75	9,009
	Labourers	2,140	3,383	52	364	3,129	473	27	9,568
Peel	Managers	409	477	6	48	71	420	1,893	3,324
	Professionals	507	640	16	12	41	490	2,612	4,318
	Technicians and trades	2,304	572	11	56	75	763	3,240	7,021
	Community and personal service	483	246	5	12	39	298	2,525	3,608
	Clerical and administrative	349	681	16	21	42	392	2,595	4,096
	Sales	296	193	9	13	23	234	2,713	3,481
	Machinery operators and drivers	1,493	226	17	56	55	344	1,556	3,747
	Labourers	1,248	181	16	17	64	241	2,332	4,099
Northwest	Managers	1,521	8,766	5,467	1,306	100	228	3	17,391
	Professionals	2,542	15,983	9,101	1,162	97	213	14	29,112
	Technicians and trades	8,201	8,972	8,014	2,111	179	474	8	27,959
	Community and personal service	1,904	5,601	7,568	635	89	57	6	15,860
	Clerical and administrative	1,947	14,008	8,223	1,266	42	119	4	25,609
	Sales	1,288	4,970	8,325	656	47	67	3	15,356
	Machinery operators and drivers	2,704	2,373	2,409	998	67	113	10	8,674
	Labourers	3,531	3,236	5,798	777	56	117	3	13,518
Northeast	Managers	1,001	4,903	451	3,963	299	145	11	10,773
	Professionals	1,414	7,428	461	5,024	464	167	8	14,966
	Technicians and trades	4,321	5,931	596	5,617	406	318	18	17,207
	Community and personal service	1,072	3,533	375	4,299	257	60	7	9,603
	Clerical and administrative	1,186	8,540	471	5,636	288	131	3	16,255
	Sales	687	3,165	335	4,742	138	43	5	9,115
	Machinery operators and drivers	2,421	2,911	265	2,725	181	166	3	8,672
	Labourers	2,153	2,557	302	4,005	164	97	0	9,278
Central	Managers	4,344	36,261	1,294	2,208	820	1,823	76	46,826
	Professionals	10,007	86,296	3,116	3,107	1,799	2,846	209	107,380
	Technicians and trades	10,971	27,010	1,361	2,855	860	2,194	63	45,314
	Community and personal service	4,858	24,863	1,058	1,064	677	607	21	33,148
	Clerical and administrative	4,409	45,137	1,003	2,036	583	1,159	23	54,350
	Sales	3,118	24,486	990	1,083	567	585	31	30,860
	Machinery operators and drivers	4,235	8,541	417	1,539	335	673	24	15,764
	Labourers	6,200	15,844	824	1,430	427	776	32	25,533

Source: Martinus 2016, ABS Census 2011

Perth's centralised employment (BITRE 2010, 2011, SGS 2015, Martinus & Biermann 2016, Martinus 2016) leads to a conclusion, following the McMillen and Smith (2003) definition of a non-CBD activity centre⁷¹ (as having significant gravitational scale and higher employment densities), that there are no major activity centres outside the Perth CBD. This suggests that Perth's metropolitan urban structure is not polycentric (despite on-going planning intent) but monocentric with dispersed activity. As Curtis (2005) noted, the Perth CBD and many other dispersed employment locations drew people away from the metropolitan activity centres. In many respects, little has changed since Houghton (1981) looked at this question 25 years earlier. The agglomeration value of having a thick labour market, in a state and city with a limited population, would appear to be driving a high degree of centrality. To maximise labour market and broader economic efficiency, this labour market thickness should be maintained or strengthened. Arguably, it could be that Perth is yet to develop sufficient scale to achieve a polycentric structure and that the planning intent is correct. This could be addressed by looking at Perth's predicted growth over the next thirty to forty years (using ABS 2013b) and what Perth's urban structure may look like in these forthcoming decades. One way of doing this is by examining Sydney's growth and urban planning.

11.4 Population growth and activity centre planning: a comparison with Sydney

The relatively similar historic growth rates of Sydney and Perth, and Sydney's planning for activity centres, provides a worthwhile comparison for considering Perth's future urban structure. The similarity in growth rates for Sydney and Perth can be seen in **Figure 35**).

Figure 35 Sydney and Perth population comparison 1961-2051

Sydney		Perth		
		Series A	Series B	
1961	2.19 million ⁷²	2012	2012	1.90 million
1971	2.73 million	2022	2024	2.7
1988	3.59 million	2035	2040	3.9
2012	4.67 million	2043	2051	4.7 million
Sydney took 51 years to add on 2.51 million people		Perth is estimated to take between 29-37 years to add on 2.8 million		

Source: ABS (2013b) and Spearritt 2000

⁷¹ McMillen and Smith (2003) use the term 'sub-centre'

⁷² Spearritt 2000

Figure 35 uses a 2012 baseline for Perth and its population of 1.9 million. For Sydney the baseline is 1961 and its population of 2.19 million. Sydney's baseline grew to reach, in 2012, a population of 4.7 million. Perth is predicted to achieve a population of 4.7 million sometime between 2043 - 2050 (assuming Perth's population growth falls somewhere between the predicted ABS Series A and B predictions). Notably, the ABS (2013b) predicts that Perth will achieve a population equivalent to Sydney's present population within a much quicker period of time than it took Sydney. Perth is predicted to add on 2.9 million people within 29-37 years compared to Sydney taking 51 years to add 2.51 million. In demographic timeframes, Perth is 'hurtling' towards Sydney's present day population of 4.7 million⁷³.

It is therefore proposed that Sydney's growth, in terms of population and planning, provide a number of indicative learning opportunities for Perth. In terms of activity centre strategy planning terminology, Perth's Primary Activity Centres are effectively equivalent to Sydney's Regional Cities (Bunker 2008, WAPC 2010a). WAPC (2010a) noted in the report on submissions that, in seeking to determine the *Directions 2031* strategy, it was not able to determine any Primary Centres (being the centres only secondary to the Perth CBD). This was due to the questioning of the original proposed choices of the outer suburban centres of Joondalup and Rockingham as Primary Activity Centres. WAPC (2010a) proposed that Primary Centres would emerge and noted Sydney's *proposed* centres hierarchy (with a then population of 4.4 million) having only four 'regional cities' of Penrith, Parramatta, North Sydney and Liverpool.

The polycentric intention of the planning system in Sydney has had limited effect. NSW State Government policies from 1948 have sought to encourage suburbanisation and clustering of employment in metropolitan regional cities (Meyer 2005, Black & Doust 2008, Bunker 2008). NSW Government claims, that their centres policy had been successful, was rejected by Black and Doust (2008) who argued that careful analysis of the data suggested a more cautious interpretation. Parramatta, 30km west of Sydney CBD, had been designated as the planned second CBD and supported as the key alternative centre from 1968 (Cheung, Black, & van den Bos 2003, Department of Planning 2005, Black & Doust 2008). However, lesser designated centres closer to Sydney CBD had developed organically as larger centres of economic activity (Cheung et al. 2003, City of Parramatta 2013). Parramatta had struggled to establish itself as the second CBD for many decades (Black & Doust 2008, Hale 2013, City of Parramatta 2013). For Perth, it is worth considering that

⁷³ To understand the 'hurtling' speed of Perth's population growth it is worthwhile looking at Meyer's (2005) notes on the relative historic quick speed of Sydney's growth compared to London. In 1700 London, Meyer (2005) noted, had reached a population of 500,000, and by 1900, 5 million. Sydney reached 500,000 in 1901 and was expected to reach 5 million before 2031, that being 200 years for London and 130 years for Sydney. Perth's population reached at least 500,000 in 1947 and will, according to ABS (2013b) Series A or B, reach 5 million in 2046 to 2055 – 100 to 110 year timeframe; nearly double the speed of London's growth and 30 per cent faster than Sydney's.

when Parramatta was struggling as the second CBD in the 1990s, Sydney's population (3,245,225 in 1996) was much larger than Perth's present population (ABS 1996a, ABS 2013b). This suggests that the development of major activity centres remote from the CBD in Perth is unlikely.

Hale (2013) had noted that it was only into the 21st century, as Sydney's metropolitan population grew further (ABS 2006) and investment was made into its railway station centre⁷⁴, that Parramatta repositioned itself from a low-rent location into a major satellite activity centre with a mix of business, government, retail, cultural, entertainment and leisure activities (see also Department of Planning 2005, Rowe, Stevenson, Tomsen, Bavinton & Brass, 2008). Even these arguments however have their limitations. As will be addressed in subsequent paragraphs, Parramatta has continued to have a limited labour market catchment and its private sector knowledge-intensive employment has not grown (BITRE 2011, ANZSOG 2013). Parramatta, while the sixth largest CBD in the country, had prime office rents, as of 2013, significantly lower on average than not only North Sydney but also St Leonards and Chatswood (with all of these centres being much closer to the Sydney CBD) (City of Parramatta 2013). The limitations of planning policy success are recognised in the region with regional development body RDA Sydney arguing that a key strategy remained to develop the 'regional cities' at Parramatta, Liverpool and Penrith with a much stronger focus on 'advanced economy and knowledge sector jobs in the western regions of Sydney' (RDA Sydney 2013: p. 51).

The BITRE (2011) analysis of the Sydney labour market, which indicated a strong knowledge-intensive CBD bias, is supported by other analysis. As per **Figure 4 the ANZSOG Institute Global Competitiveness Index and map**, the spatial distribution of employees in (largely private sector) knowledge-intensive industries by centre across Sydney reveals a small number of knowledge-intensive centres (ANZSOG 2013). The results indicate that, in terms of market-driven knowledge-intensive private sector activity, Sydney, despite its population of 4.7 million, is largely monocentric. Outside of central Sydney, the highest concentration of private sector knowledge-intensive workers is in the northern rail corridor, including North Sydney, Ryde and Willoughby (including Chatswood), with the only centre in the top five not on the northern rail corridor being Parramatta. Particularly notable is the increasing strength in knowledge-intensive private sector employment in both the Sydney CBD and Ryde (around Macquarie University and on the relatively new Epping Chatswood rail link). This contrasts with the decline in private sector knowledge-intensive employment in Parramatta and Willoughby (including Chatswood, anchored by two major shopping centres). Further, the bus-serviced Randwick with UNSW, one of the elite Group of Eight

⁷⁴ Against the 2001–02 to 2009–10 trend of falling public transport use to and from Sydney's strategic centres, the Parramatta CBD, along with Sydney CBD, increased its public transport mode share (BITRE 2012a).

universities and 'redbrick' university with second starter advantages, has had little notable stimulating effect on surrounding private sector knowledge employment (ANZSOG 2013). SGS (2012a) has considered the effective job density and labour productivity for Sydney (and for Melbourne and Adelaide) and concluded that there is a clear relationship between higher inner metropolitan effective job density and higher labour productivity. Effectively, centrally located workers in Sydney have higher productivity than workers in the same industries located on the fringe of cities.

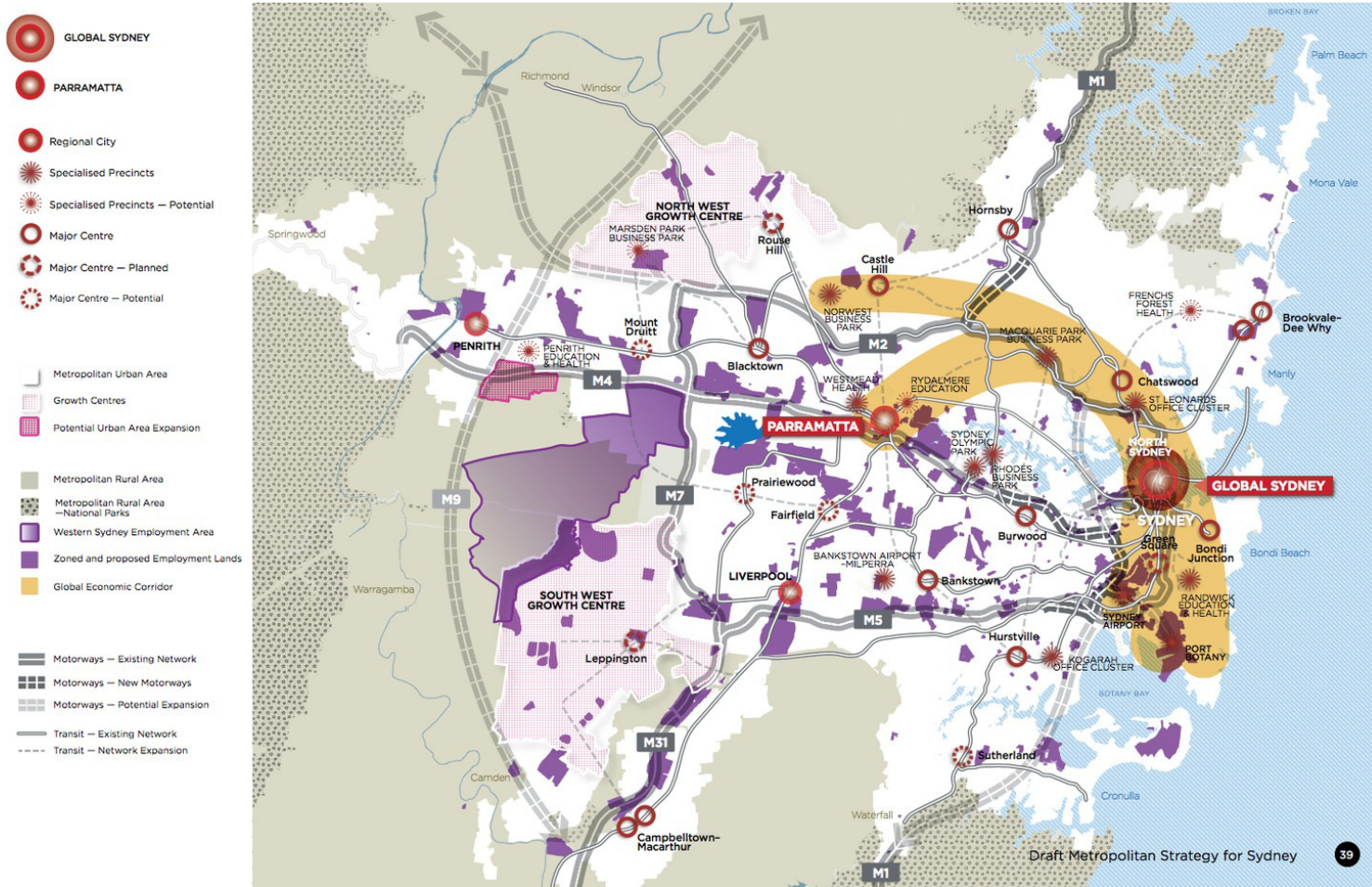
11.4.1 Understanding Perth and Sydney through their labour markets

To understand the tension between forces driving a monocentric city and the planning intent to achieve a polycentric city, an understanding of competing labour markets is required. Employment self-containment is a long-term policy objective of metropolitan planning (Houghton 1981, Curtis 2005, Bunker 2008, Curtis 2009, WAPC 2010a, BITRE 2010, BITRE 2011, WAPC 2015, Davis & Hartford-Mills 2016). This is in part due to the perceived benefit of providing local employment to reduce the transport tasks, which would have cost of living and environmental benefits. However, overly high levels of self-containment have limitations, particularly in respect to the knowledge economic agglomeration. With larger, thicker and more specialised labour and service markets aiming to provide agglomeration efficiencies and benefits such as knowledge spillover it is likely to be economically inefficient (Prud'homme & Lee 1999, Leamer & Storper 2001, Bertaud 2004, Moretti 2012, Pan et al. 2012). If it is desirable for a city's knowledge-intense economy to be able to maximise its labour and service market pool then strategies to increase the density of employment and residential populations are required. Density alone though has its limitations, and dense cities with poor transport management can end up with segmented populations and inefficient labour markets (Prud'homme & Lee 1999, Bertaud 2004, Pan et al. 2012). Therefore, high levels of mobility within and across local communities are required. The spatial characteristics of a city's labour markets are therefore an important consideration underpinning the strategic transport planning.

Commuting characteristics and the effect on labour market intensification is now considered for both Sydney and Perth. Not surprisingly, the CBDs of Perth and Sydney, with their historic first starter advantage and transport investments, have access to the thickest and largest labour markets. Sydney CBD and its immediate surrounds (Central Sydney inclusive of City of Sydney LGA) is effectively the monocentric heart of the Sydney metropolitan area (see **Figure 36** for a map of Sydney activity centres). Similar to Perth (BITRE 2010), Sydney CBD employment declined for a period (in the 1970s and 1980s). Sydney CBD's share of jobs has been rising since 1991, and in 2006, the City of Sydney sub region was notably the

strongly dominant centre, with 357,800 jobs. Other major employment centres were mostly close to Sydney CBD with North Sydney (35,800 jobs), St Leonards-Crows Nest (34,400), Macquarie Park (32,000) and Sydney Airport (28,200). Parramatta (34,200) was also in the top five, though the exception, being further afield (BITRE 2012a). The key job growth locations in the 2001-2011 period were Sydney Inner, Ryde, Sydney West and Baulkham Hills Central. Each added between 5,000 and 9,000 jobs. The specialised centres of Macquarie Park and Norwest also made important contributions to job growth (BITRE 2012a). The NSW Government has projected that two-thirds of Sydney's forecasted 1.7 million-population increase, from 2006 to 2036, will occur in the Outer sector, but with only 52 per cent of job growth (BITRE 2012a).

Figure 36 Sydney activity centres and metropolitan strategy map



Source:

The Draft Metropolitan Strategy for Sydney to 2031 (Department of Planning and Infrastructure 2013)

Dominating, in terms of employment size and access to the broadest and thickest labour market with 17 per cent of metropolitan Sydney's employment, was Central Sydney (BITRE 2012a). The workers in Central Sydney came from the full range of planning subregions, but particularly from the South (17 per cent), Inner North (13 per cent), East (12 per cent) and City of Sydney (12 per cent). In all, eight regions each provided at least seven per cent of Central Sydney's workforce. Central Sydney therefore had accessibility to the widest and the thickest labour market. North Sydney, also in 'Global Sydney', drew its workforce from a narrower catchment, mainly from within the home subregion of Inner North (24 per cent), but also from the North (12 per cent) and the South (11 per cent). It still however had eight subregions, providing at least seven per cent of its workforce.

Most other employment centres were typically more limited with a narrow range of catchments, with one or two subregions providing the majority of the workforce. Notably, a number of specialist centres (Olympic Park Rhodes, St Leonards-Crows Nest and Macquarie Park) with rail infrastructure⁷⁵ had access to thicker labour markets than most other non-CBD centres. These specialist centres had seven subregions supplying at least 7 per cent of their workforces. St Leonards-Crows Nest and Macquarie Park drew a high proportion of their workers from the Inner North and North, although Macquarie Park also attracted many workers from the North West subregion.

Shopping centre anchored 'Major Centre' designated Chatswood, on the rail corridor north on the Global Arc out from Central Sydney, also drew from a wide catchment with six areas providing at least 7 per cent of its workforce. The specialist centre, Randwick education and health precinct, home to UNSW, drew most of its workforce from only three areas. For Randwick, 53 per cent of workforce was from its home East subregion, and 17 per cent and 8 per cent were from the adjacent South and Sydney City subregions respectively (78 per cent were from within local or adjacent catchments, and no more than three sub regions provided over 5 per cent)(BITRE 2012a, p. 259). Randwick Education and Health precinct, without rail, had a very limited labour market catchment; effectively the same catchment characteristics of the shopping centre anchored designated 'Major Centres' like Bankstown or Bondi Junction. Parramatta, designated as the second highest centre in the urban hierarchy, only drew more than 7 per cent of its workforce from three regions, with the adjacent specialist centre of Westmead drawing from only two regions. In terms of activity centres in Sydney achieving 'thicker labour markets' to enable knowledge economic agglomeration, the key appears to be access to heavy rail.

⁷⁵ Macquarie Park station opened in 2009.

For Perth, the commuting analysis demonstrates, similar to Sydney, a clear CBD and inner metropolitan gravitational attraction (see **Figure 33 and 34**) (BITRE 2010, SGS 2015, Martinus & Biermann 2016, Davis 2016, Martinus 2016). The evidence is clear, in both cities, that the knowledge-intense labour markets are characterised by agglomeration through the maximising of labour market thickness and scale. BITRE (2010) noted that in *Network City Action Plan* there was a stated aim of improving the public transport system's commercial viability by encouraging two-way flows. However, as an economic strategic aim this is questionable. The explanation of the scale and diversity of the CBD's commuting catchment and the general inward commuting bias is that its central location attracts more knowledge economic activity because it is the most accessible location for the greatest number of workers within the metropolitan area. Effectively, the CBD provides the highest agglomeration and productivity because of its access to labour market thickness and scale.

With Sydney and Perth sharing a number of similar characteristics in their commuting patterns, it is possible to conclude that Perth's future economic and population growth and polycentric planning approach, which are both similar to Sydney's growth and policies, are unlikely to achieve a different outcome. It is likely that with increasing levels of knowledge intensity, both in economic activity in inner Perth (SGS 2011) and human capital in terms of university qualified residents (**Figures 16, 17 and 18**), the commuting patterns trends are unlikely to change in subsequent decades. The continued inward bias towards Perth of higher paid knowledge-intense employment will continue to attract commuters as the demand for knowledge workers in the labour force continues to increase (even with the likely continued increase of knowledge-intense workers in dispersed industries). A polycentric planning approach that seeks to ignore the strong centrality or agglomeration core in Perth is bound to fail. Further any such policy that fails to recognise the benefits of the strong central agglomeration is likely to limit broader economic and job growth in Western Australia.

11.5 Perth's primary activity centres – a review for potential knowledge intensification

The analysis of Perth and Sydney indicates that, despite the differing population scales, there is clear evidence in both cities of strong mono centric forces in respect to the knowledge-intense labour markets. This suggests that a different approach to planning activity centres is required. Based on McMillen and Smith's (2003) analysis it would appear Perth exhibits many of the characteristics found in car-dominated USA cities. The highest densities for employment centres in these comparison cities are in the knowledge-intense centres – downtowns (CBDs) and nearby institutional (hospital and university) anchored centres (Levy and Gilchrist 2012). Perhaps the obvious conclusion is that the most likely

activity centres to achieve knowledge intensity with employment density and scale are universities and hospital precincts.

Appendix 6 examines the knowledge intensity characteristics and potential of Perth activity centres including Specialised Centres and Strategic Metropolitan Centres (being second in the hierarchy, in the absence of any Primary Activity Centres, only to the Capital City). The activity centres were examined in respect to the following criteria:

- Centre description,
- Type of activity,
- Key transport infrastructure,
- Catchment and international role,
- Relative centrality,
- Employing industry by employment zone,
- Research capacity and excellence, and
- Immediate LGA population with Bachelor degree and higher.

Specialised centres were dominated by generally more than one type of institution or land use even if they were spatially separated – UWA/QEII and Murdoch precincts had universities and tertiary hospitals, whereas Curtin University was adjacent Bentley Technology Park. Perth Airport was adjacent the Kewdale-Hazelmere industrial area (WAPC 2006). Strategic Regional Centres were largely dominated by traditional shopping centres, with other retail uses surrounding or traditional main streets adjacent. The exceptions were Joondalup with a dominant shopping centre but adjacent ECU Joondalup, and Subiaco and Fremantle with grid-street type town centres with mixed retail, commercial businesses and hospitals. The commercial office was; however, substantially lower in Fremantle, which also had the relatively small Notre Dame University.

In terms of transport infrastructure, only three of the centres considered had both rail and freeway infrastructure (Murdoch, Stirling and Edith Cowan University/Joondalup). These centres (and all the other centres considered with rail) only had a single radial rail line, which indicates that no strategic metropolitan specialist centre was a hub for high order rail public transport. Effectively, Perth CBD had the exclusivity on the role of being the metropolitan area's public transport hub, which reinforced its monocentric knowledge intensity. It also weakened any opportunity for polycentricity, with other centres having limited capacity to provide a thicker labour and service market.

The limitations of polycentric planning in Perth are apparent when considering the metropolitan wide catchment of specialist centres with their limited transport infrastructure.

The State Planning Policy 4.2 on Activity Centres recognises the broad metropolitan catchment and role of Specialist Activity Centres in Perth only in part. Universities operate in an international marketplace in a way that arguably only the CBD or an international transport hub do. Universities operate beyond their localised spatial context – operating in an ex-spatial sense (Marks 2005, Kane 2010). Each of the Western Australian universities reviewed in **Appendix 6** had international teaching and research roles with services specifically dedicated to overseas markets. In contrast, there is little to suggest that shopping centres within the key anchors in Strategic Metropolitan Centres are anything but limited to localised and sub regional catchments – effectively focusing on local agglomeration strategies.

The 'centrality' ratings and scores of activity centres in **Appendix 6** provides a means of understanding the potential for centres to be part of an agglomerative ecosystem of a thicker labour and service market centred around the Perth CBD. Centrality was scored on spatial connectivity with the CBD and the nearest three Strategic Regional Centres or Specialist Activity Centres⁷⁶. This was in terms of distance measured as the 'crow flies' direct between centres with the result being expressed as an average kilometre figure. The centres that were the most central in this respect were not surprisingly the inner city centres of Subiaco, UWA/QEII, and Curtin University (averaging scores from 5.3 to 6.7km) with a second band of centres between (7.9 and 10.5km) being the middle ring centres of Stirling, Cannington, Fremantle, Perth Airport, Morley and Murdoch. Not surprisingly, the outer suburban centres scored poorly with Midland, Edith Cowan Joondalup, Armadale and Rockingham scoring from 12.4 to 30.1km. The other spatial centrality score was more 'multi-connectivity' based, being the number of times a centre was scored as being in the top three closest non-CBD centres for other centres.

The standouts for 'centrality' in terms of multi-connectivity was Curtin University (eight); with Subiaco (five), UWA/QEII (five), Murdoch (four), and Stirling (four) also scoring relatively strongly. Notably, the two centres (Joondalup and Rockingham), considered as possible Primary Activity Centres in the draft Activity Centre policy arising from the draft *Directions 2031*, received a zero score in terms of 'multi-connectivity'. The outer suburban strategic metropolitan centres centrality ratings were weak in comparison to centres closer to the Perth CBD, which indicates a lack of 'gravity' for outer suburban centres and a lack of agglomeration in outer suburban areas (which is consistent with agglomeration research in Australia by Trubka 2009 and Kelly & Donegan 2014). The outer suburban economy is likely oriented to industries favouring lower levels of agglomeration (Trubka 2009).

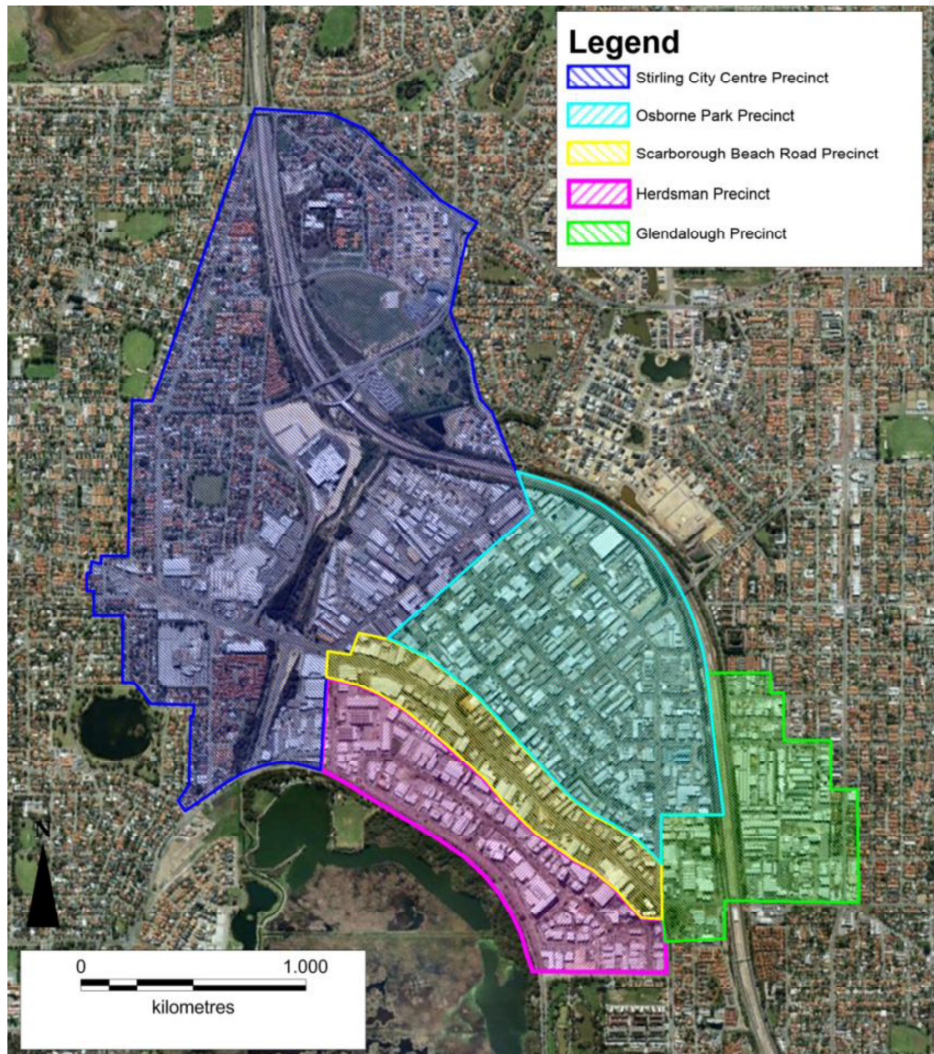
⁷⁶ With Subiaco being included despite it being categorised as a 'Secondary Centre' under the State Planning Policy 4.2 Activity Centres for Perth and Peel (WA Government Gazette 2010) because of its relatively high employment density and major hospital cluster (BITRE 2010).

In terms of the knowledge intensity criteria, specialised centres dominated, particularly UWA/QEII, which scored highly across all the criteria. For research performance and capability, using the 2012 Excellence in Research rankings for Australia, UWA was the only Western Australian university in the top 10 (as well as the only one in top 20). Further, for 2010, UWA had a research income (\$172,754,470) greater than the combined research income of all other WA universities, with Curtin University being the second highest on \$54,472,280. This is consistent with the long-term performance of national sandstone universities and their high levels of performance in terms of research (Marginson and Considine 2000). Similarly, reflecting its historical first starter advantage, UWA/QEII (and, to a lesser degree, Curtin University) are located in inner suburban locations with high levels of human knowledge capital intensity within surrounding populations. Further, they both have, in surrounding SLAs, relatively higher knowledge-intensive (ANZSIC) industry profiles. Both UWA/QEII and Curtin University/Bentley Technology were two of only three activity centres examined not to have retail as one of the three dominant industries in the surrounding SLAs (BITRE 2010). The third was Perth Airport where the adjacent Belmont SLA industry profile was dominated by low knowledge-intense and low density logistics industries such as Transport, Storage and Warehousing; Manufacturing; and Wholesale Trade. All of the Strategic Regional Centres had surrounding SLAs that were mainly focused on population servicing industries, with Retail and Health Care and Social Assistance being the two most dominant industries. Only three centres had Property and Business Services as a top three industry in their surrounding SLA and they were unsurprisingly UWA/QEII, Curtin and Subiaco. This was despite the bias of the Activity Centres State Planning Policy (below the Capital City/CBD centre level) towards Strategic Regional Centres for office accommodation (Western Australian Gazette 2010).

The overall knowledge intensity of UWA/QEII, added to this spatial centrality, means that UWA/QEII's capacity to deliver knowledge intensity outcomes is high. Notably, the transport infrastructure for this key specialist centre, despite its metropolitan wide catchment being recognised in the Activity Centres State Planning Policy (Western Australian Gazette 2010), is poor. Similarly, the transport infrastructure for Curtin University is inadequate. In terms of a consideration of the other knowledge intensification criteria in **Appendix 6**, the other Specialist Centres do not perform to the same level as UWA/QEII – they do, however, generally outperform Strategic Regional Centres. Transport is where there are, however, mixed results across the board. For example, Curtin University scores highly in 'Centrality' and moderately strongly in knowledge intensity (surrounding SLA industry and university education), yet has no major transport infrastructure. Murdoch scores well on knowledge uses (university, a tertiary hospital and a private hospital) and highly on transport infrastructure (with rail and freeway connections). Stirling, as a Strategic Regional Centre, is

worth a special mention as it has relatively high levels of transport connections, relatively high levels of centrality. Stirling also has the most diverse adjacent mix uses, with the Scarborough Beach Road Activity Corridor and the Osborne Park Industrial Centre, Herdsman Specialised Centre and the Glendalough District Centre (SGS 2013, see **Figure 37**). Stirling's potential has been recognised and is subject to an extensive planning exercise through the Stirling Regional Centre Structure Plan Review (SGS 2013, WAPC 2014). Stirling's level of employment, compared to other Strategic Metropolitan Centres, is high, though its residential population is low (BITRE 2010, SGS 2013). It also performs relatively poorly compared to the Specialist Centres on the knowledge intensity criteria, though a detailed consideration of the surrounding uses suggests a stronger level of performance compared to other Strategic Regional Centres.

Figure 37 Five Precincts in the Stirling/Osborne Urban Area



Source: SGS 2013 Stirling Osborne Park Centre – Draft Positioning Paper Final

Employment was dominated by retail, construction and manufacturing, though knowledge based employment was also relatively high compared to other Strategic Metropolitan Centres and metropolitan industrial centres, though most of the knowledge employment was in the Herdsman Specialist Centre (effectively an office park) (SGS 2013, Department of Planning & WAPC 2015). Arguably, this diversity of employment in Stirling is an underutilised asset. The absence of a knowledge-intense anchor stands out as the 'missing link' for Stirling.⁷⁷

If it is accepted that the universities provide the best opportunities for knowledge-intense activity centres, then are at least two limiting characteristics for Western Australian universities (as previously noted); a lack of transport infrastructure and urban design. Western Australian universities, with the exception of the newest and the smallest, Notre Dame University, are all notable examples of single use monastic campuses (See **Appendix 7 University Design Characteristics**). As per Jacobs (1961) view of many US universities, Western Australian universities similarly have sought to be cloistered or isolated countrified places, with the impact being massive single uses forming borders and vacuums of activity, reducing diversity and circulation. The monastic green belt campuses in WA are also notable for their single purpose land uses with a lack of integration with surrounding land uses (see **Appendix 7**). Car parking dominates the campus edge, providing the border vacuums even before adjacent uses and borders are considered. For Perth monastic universities, these adjacent border vacuums are often low-density non grid pattern suburbia. Other forms of border vacuums include regional and other parks (UWA, Edith Cowan University), the Swan River (UWA), a golf course (Curtin University) and wetlands (Murdoch University). Notably, all Perth's monastic universities have no urban integration with their adjacent potentially complimentary uses (hospitals – UWA, Murdoch University, Edith Cowan University, technology park – Curtin University, and shopping centre or civic centre - Edith Cowan University). Generally, there are wide road reserves separating directly adjacent uses (Murdoch University separated from Fiona Stanley and St John of God hospitals by Murdoch Drive, and Curtin University separated from Bentley Technology Park by Hayman Road, Edith Cowan University separated from Joondalup shopping centre by Grand Boulevard).

The border vacuums for Perth's monastic style universities can be contrasted with the grid

⁷⁷ The only metropolitan university campuses not categorised as being either a specialist centre or strategic metropolitan centre are Edith Cowan Mount Lawley and Murdoch University Rockingham. Edith Cowan Mount Lawley is within 5km of Stirling. The longer-term strategic question (to benefit both Stirling and Edith Cowan in the longer term) is, should Edith Cowan Mount Lawley be relocated to Stirling? Besides the obvious advantage of being on a direct rail link to ECU Joondalup and the Perth CBD, it would provide the Stirling Centre with an opportunity to develop a knowledge intensity that it presently lacks. It would also provide a university with close spatial links to a range of diverse business types including construction and manufacturing firms.

integrated universities from the 19th century, in particular Melbourne and Adelaide universities (**Appendix 7**). As noted previously, sandstone universities established in the 19th century, while heavily influenced by other monastic traditions, did not follow the spatial isolative monastic approach. This 19th century approach is probably best seen with the 'edge of CBD locations' for Melbourne University and Adelaide University and their campus edges being integrative street grid urban design (Sydney University is also CBD edge and walkable from the somewhat misnamed Central Station). The two sandstone universities established in the 20th century, University of Queensland and UWA both relocated from their respective city CBDs to isolated river locations. Other WA universities follow the isolated monastic green belt location favoured by the 'gumtree universities' and the 'new universities'. The 'unitech' city campus, as seen in other Australian cities, is absent from Perth's CBD or inner city. This means that, uniquely for an Australian capital city, all the major universities in Perth are isolated 20th century re-creations of the monastic campus myth.

The spatial reality of Western Australia's universities is consistent with the Heideggerian spatial context, identified by Marks (2005) that 'spatiality' in the university context is less about physical dimensions and proximity and more about inherent 'usefulness'. That is, universities that are spatially isolated and separated (i.e. considered as single use type 'specialist centres' outside the urban hierarchy of centres) reflect a lack of relevance and usefulness in a consumption and car-focused city. Arguably, as the nature of the Perth's economy and urban structure changes as it becomes more orientated around knowledge-intensive industries, the spatial nature of Perth's universities will need to be reconsidered.

As per **Appendix 7**, the other notable characteristic identified with Perth's greenbelt campuses and their surrounding non-residential suburban uses, is their relatively large size, generally similar in size to the central Perth CBD. The land area of the inner central CBD, being the *Perth (C) – Inner SLA*, is 1.8sq km ABS (2011). The university campuses of Perth reflect the 'countrified' greenbelt scale. This is relevant if a university campus or adjacent area was to change through redevelopment to operate as a knowledge-intensive activity centre with high levels of 'face-to-face' knowledge spillover. If the high density central CBD only requires 1.8sq km of high level development, then it is necessary to identify the potential key intense focus point of mixed-use development within or adjacent to a possibly redeveloped campus. Notably, the ANU Exchange and the Kelvin Grove Urban Village both developed urban centres adjacent to the campuses, spatially, though with an urban design integrating the university campus and the centre. In **Appendix 7**, the potential development opportunities for possible focus points for the redeveloped WA universities are noted. For Murdoch University and UWA, the proposed urban centres seek to link the universities and

the tertiary hospitals. For Curtin University, the proposed urban centre seeks to link the university with the Bentley Technology Park.

With regard to transport, the lack of private sector investment (ANZSOG 2013) into knowledge-intensive industries around UNSW, one of Australia's 'Group of Eight' high performing universities, indicates that, without high-order transport infrastructure, factors such as city population scale, surrounding human capital and institutional knowledge intensity are insufficient to stimulate private sector investment into knowledge-intensive industries. This suggests that for UWA/QEII and Curtin University, any redevelopment that aims to attract major private sector commercial investment will be unsuccessful without investment into high-order public transport.

The comparative analysis of Perth with Sydney and USA cities (based on McMillen and Smith 2003, Levy and Gilchrist 2012) suggests the present focus on a hierarchy based activity centres strategy will not deliver a polycentric city outcome that the planning system has sought for a number of decades. Notably, Parramatta, at 24km from the Sydney CBD, has had the advantage of being in the physical centre of the Sydney metropolis, (being the only Sydney centre with a true 360 degree catchment (City of Parramatta 2013). This though does not seem to have been a sufficient advantage to attract knowledge economic activity away from Sydney CBD. Assuming Perth followed the population growth pathway of Sydney metropolitan area in achieving a population of 4.7 million, if the polycentric development pathway set by Parramatta was followed in the Perth metropolitan area, the projections for Perth achieving a second weak regional CBD would be sometime around 2040 to 2050. With Perth CBD having the additional advantage of being centrally located within the metropolitan area, this arguably would further delay a sub-regional (Parramatta type) second weak CBD in Perth metropolitan area.

The likelihood that more than one sizable dense strategic metropolitan activity centre will develop, with sufficient agglomerative gravitas of its own accord, outside the inner or middle Perth regions within the next three to four decades is extremely unlikely. In addition to the Parramatta example, McMillen and Smith's (2003) research indicates that a USA style urban area with low congestion levels develops its first sub-centre when its population reaches 2.68 million and its second sub-centre when it reaches 6.74 million. If McMillen and Smith's (2003) sub centre premise were accepted (and accepting that Perth achieved low congestion levels), Perth would be expected to have the sufficient population to justify a first major sub-centre when it reached 2.7 million, which would be somewhere 2022 - 2025⁷⁸. Perth's population would justify a second major sub-centre on the high projections by 2053

⁷⁸ Using the ABS (2013b) high (Series A), medium (Series B), and low (Series C) population projections by 2022 - 2025 respectively.

and under the medium projections sometime post 2061. Based on both the Sydney/Parramatta analysis and the McMillen and Smith (2003) scenario, the development of successful knowledge-intensive sub-centres in Perth is likely to need the leverage of the central agglomeration around the Perth CBD. This suggests developing knowledge-intensive centres closer to the inner Perth region with further ongoing development of knowledge-intensive centres out from this inner core over time.

11.6 Alternative urban structure and activity centre strategies

Australia's major capital cities have largely adopted similar metropolitan planning frameworks. These frameworks have all included similar policy elements including a focus on sustainability, various constraints or targets on metropolitan expansion/containment, dispersed mixed-use polycentric activity, integration with transport planning, and increased urban densities (Gleeson et al. 2004, Forster 2006, Dodson 2008, Bunker 2009, Black and Doust 2008). The 21st century metropolitan planning frameworks have largely focused on self-containment and on polycentric structures without sufficient regard for agglomeration and the knowledge intensification in the economy. The recognition of the increasing dominance of knowledge-intensive economic activity and networking in underpinning economic, communication and transport systems has influenced spatial planning theory with the notions of a 'network city', 'connected centres' and 'networked cities'. This is reflected in European planning policies (Klaasen et al. 2007) but has only, in a very limited sense, influenced Australian metropolitan planning policies in the 2000s (notably the Sydney's *City of Cities*, Perth's *Network City*, and *Melbourne 2030* (prior to *Plan Melbourne*)).

While poly-centricity for population servicing (providing local population driven jobs) in the non-tradable economy for local residents in local catchments is equitable and sensible (including for knowledge-intensive population servicing jobs), the same logic does not apply to tradable (knowledge) economy intense employment, which is generally highly correlated to density and high levels of agglomeration. A key consideration also needs to factor in the wider employment multiplier effect of the knowledge-intensive industries, which provide benefits across the tradable and non-tradable sectors (Moretti 2010, Moretti and Thulin 2013). As Arnott (2011) contends, there is a broad consensus that economic policy (generally) and metropolitan planning (in particular) should harness or rechannel market forces rather than oppose them (see also Bertaud 2002). This first requires an understanding of the market forces in play within cities, particularly those relating to the 'tradable economy', which earn cities their income. It would be illogical and counterproductive to promote the dispersment of population to outer edges of cities with 'self-containment policies' with an intention of providing knowledge-intensive employment

(other than what is required to service the population itself). The market (the private sector) will not sustain such employment patterns and any public sector strategy will be inherently inefficient. Any equity policies would be better targeted at supporting knowledge and skills development, and social access into the dense and intense knowledge economy rather than encouraging the development of inefficient urban labour and service markets.

Bertaud's (2004) argument, that efficiency in cities can be delivered through good city management, can be taken a step further. Scale and density within a city agglomeration without efficient interaction capacity (transport infrastructure and good urban design) to facilitate interactivity and knowledge exchange is somewhat pointless. Urban design and urban planning, from a knowledge economy perspective, should aim to efficiently increase the scale and efficiency (through the quality) of human interaction to create larger, thicker and more knowledge-intense labour and service markets.

The challenge for post-industrial cities in an open trade 21st century, particularly those low population density cities and regions with relatively low populations (less than 5 million), will be how they value the combination of urban density, human capital and agglomeration. Ultimately, this comes down to how these cities plan and develop their urban activity centres within their metropolitan areas. Activity centres with shopping centres as the main focus are fundamentally about consumption, imported goods, technology adoption (rather than technology development), localised labour markets, low skills and low wages. The corporate shopping centres, as Goodman (2005) found in respect to newer outer suburban Melbourne shopping centres, are by their nature, both economically and culturally, the blandest representation of a monoculture and add very little to sense of place. In this sense, shopping centres do not provide environments for innovation or development of the knowledge-intense economy. As Kane (2010) argued, activity centres anchored by retail will be limited by their origins and are unlikely to evolve into mixed-use knowledge-intense centres. Arguments over the role of activity centres anchored by shopping centres, while important for the consumption economy's efficiency and sustainability in cities, do not address how cities are going to be competitive in the knowledge-intense economy.

The evidence strongly indicates that the knowledge-intense economy is most likely to naturally develop and thrive in and around the city centres, universities and/or health precincts and not in shopping centres precincts dispersed around metropolitan areas. It may be that the corporate managed shopping centre, regardless of their lack of diversity, are delivering efficiency and effectiveness for many retail consumers by providing access to 'the widest choice of goods at the best prices and service consistent with their preference' (the purpose of retail as per the Productivity Commission 2011). This thesis however argues that

what is clear is that shopping centres are not capable of being mixed used centres of sufficient density or (knowledge) intensity to be knowledge economy centres.

The on-going, demonstrated lack of high-density employment centres identified in metropolitan Perth, outside of the CBD, calls into question the public policy designation of suburban shopping centres as *major* activity centres. For Perth, the obvious conclusion is that it has, at this point in its development, a dual urban structure; a monocentric knowledge-intense CBD and inner city surrounded by dispersed suburban consumption and population servicing activity with naturally weak 'centres'. The absence of non-CBD activity centres of density, scale and activity in a post-industrial city like Perth, despite the intention of planning schemes and gazetted policy (Houghton 1981, Curtis 2005, BITRE 2010, WAPC 2010a), suggests the development of such centres has been poorly targeted. An alternative approach to developing urban metropolitan structures, underpinned by knowledge intensification, is required. Arguably, the ideal urban structure model for post-industrial metropolitan cities is for cities to be planned and designed to operate in two modes (the post-industrial highly compact city focused on centres with key infrastructure/industrial with a global reach and catchment, and a somewhat more dispersed consumption and industrial/logistics city). In this ideal model, a key planning aim would be to provide for a city that is both structurally efficient and socially equitable (if for no more reason than to ensure on-going efficiency and scale in human capital).

Post-industrial low-density cities such as Perth should embrace higher levels of knowledge intensification and density within a small number of larger, spatially-close, interconnected, knowledge-intense urban centres with high levels of agglomeration providing a global reach. Surrounding the knowledge-intense centres should be the denser urban residential and suburban areas to maximise the human capital agglomeration. The dispersed mode would operate outside and around this denser populated urban core. The dispersed mode would benefit from the agglomeration of a large, knowledge-intense city, yet also gain from the minimisation of disagglomeration factors such as lower congestion and access to a suburban workforce seeking localised work. Both of these modes should provide desirable and attractive amenity, and both should promote the development of high levels of knowledge development through education (primary, secondary and tertiary).

Effectively viable secondary knowledge-intense urban centres, in absence of large metropolitan population scale, will need to 'borrow' agglomeration from the CBD and from each other. Rather than struggle as isolated centres without sufficient scale and internal local agglomeration, these centres need to be connected through high-level public transport to the CBD, with each other, and to the wider metropolitan area. In this way, the core

metropolitan level agglomeration would be maximised providing for a competitive city on the national and global stage. Therefore, a revised urban network (as distinct from hierarchy) is proposed as per **Figure 38**.

Figure 38 Proposed new urban network for post-industrial cities

Centre	Catchment	Agglomeration values
CBD/City centre	International, national, state, and regional	High, knowledge-intense
Global metro centres (previous Specialist Centres)	International, national, state, and regional	High, knowledge-intense
Global metro infrastructure/industrial areas – Port/airport/key tradable industrial areas	National, state, and regional	Mid-level dependent on industry, with elements of knowledge-intense workers
Strategic Metropolitan Regional Centres	Regional and sub-regional	Mid-level sub regional retail agglomeration
District/local centres	Sub-regional and local	Low with elements of population/community service knowledge-intense workers
Dispersed employment	Local and sub-regional	Low, with elements of knowledge-intense workers

In determining the appropriate activity centres for development as knowledge-intense activity centres, the following factors need to be considered:

- Human knowledge capital
- Density/Scale
- Centrality (as greatest potential sharing of agglomeration of the CBD)
- Connectivity and accessibility (to create interactivity for knowledge spillover within the widest/thickest labour and service markets).

However, while universities provide the best opportunity for knowledge-intense activity centres, Australian universities, with their tendency to single use institutional campuses (i.e.

the monastic campus) are not without their limitations. The monastic campus has a limiting spatial and physical consequence. The monastic spatial layout was designed to limit interaction with the wider community and create a scholar community apart. This intentionally limits knowledge spillover and engagement with the commercial realities of cities. The limitations of monasticism in the context of the knowledge-intensive economy are accentuated when compared with the advantages of organic knowledge exchange and networking occurring within an urban CBD type environment. During the course of the relatively more labour and machine intensive 19th and 20th centuries, it seemed that universities were seen as not being central but secondary in the urban structure. Into the 21st century, with a greater reliance on knowledge intensity, the role of the university, spatially, needs to be more front and centre.

In the modern knowledge-intensive economy, advantages of diverse specialist activity and networks within the largest possible agglomeration ecosystem are increasingly important. As a key deliverer of new knowledge and innovation, universities have to reassess their spatial relationship with the wider metropolitan city. For universities, the consideration of their spatial future should focus on their capability of contributing to (and being engaged in) the most effective knowledge (economic and social) urban ecosystem. With urban scale, density and higher levels of interaction and accessibility (required for knowledge spillover), the isolated campus model has arguably outlived its purpose. Effectively, greater levels of scale, connectivity, diversity and a more intimate physical scale make spillover and networking more efficient and likely, and this is not what campuses deliver.

To deliver knowledge-intensive urban centres with sufficient density, scale and connectivity to the broader metropolitan area requires a different approach to urban transport. **Part E** will address these issues and the transport requirements for a knowledge-intensive economic city.

Part E: The role of public transport in developing Knowledge Economy centres: spatial intensification of urban transport

Part E addresses the appropriate urban transport strategy for knowledge-intense cities. Urban transport modes are considered, as to how they facilitate or hinder more intensive concentrations of human capital and knowledge economic activity. Part E then seeks to answer the second part of the primary question, as to what are the appropriate urban transport strategies for a knowledge-intense Perth based on the preferred urban structure for Perth, as determined by Part D of this thesis.

Research is undertaken on understanding the relationship between knowledge intensification and urban transport systems in Perth. The secondary question is answered, based on the premise that, in a post-industrial knowledge-intense city, the transport task is more about transporting human knowledge capital than human labour. A 'knowledge rail' system is proposed, to facilitate Perth becoming a more knowledge-intense city.

"Traffic congestion is caused by vehicles, not by people in themselves."

- Jane Jacobs, *The Death and Life of Great American Cities*, 1961

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"It is impossible to spend any time on the study of the future of traffic in towns without at once being appalled by the magnitude of the emergency that is coming upon us. We are nourishing at immense cost a monster of great potential destructiveness, and yet we love him dearly"

- Colin Buchanan, *Traffic in Towns*, 1963

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"For carrying passengers quickly, cheaply, and in large numbers, electric railways, either wholly underground or partly underground and partly elevated are undoubtedly far in advance of any means of rapid transit"

- John Job Crew Bradfield, *Proposed electric railways for the City of Sydney*, 1916

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Chapter 12 Literature review – urban transport systems for a modern knowledge-intensive city

12.1 Cities, urban transport and knowledge intensification

The hypothesis of this Part is twofold; firstly, transport modes and how they impact on (through their spatial characteristics) the knowledge intensification of cities, and secondly,

the knowledge intensification in Perth (as previously identified) and how that impacts on the intensification in commuting transport (as has already been seen with Perth's urban density). Arising from this hypothesis is a proposal for a knowledge rail system as a means of increasing knowledge intensification of Perth's urban structure and ultimately its economy.

As previously discussed, planning policy and practice in Australia in recent decades has largely failed to consider the role of knowledge within the modern economy. There has been a further lack of consideration given to the possible interrelationship between transport and the knowledge economy. While the inextricable relationship between transport and urban form has long been recognised, (Buchanan 1964, Newman & Kenworthy 1999, Bertaud 2002, Marshall 2004, Curtis 2005, Eddington 2006, Daniels & Mulley 2011, SGS 2012a) the role that transport should perform for a modern post-industrial city is not necessarily settled.

The focus of urban transport in cities is often on the major, unresolved issues of the pollution and congestion it generates (Newman & Kenworthy 1999, Bertaud 2002, Curtis 2005, Dodson 2008, Duany et al. 2010, Mees 2010, SGS 2012a). Mees (2010) for example, strongly argued that car use was a problem for cities because of environmental and social costs, arguing for alternatives to the private vehicle because of climate change and insecure oil supply. 'Smart Growth' thinking, in terms of more compact urban development (Duany et al. 2010) and 'land use transport integration' (LUTI) are planning strategies which have achieved sustainable travel outcomes (Curtis 2005). With respect to Perth, at the heart of the Network City metropolitan plan was a spatial framework designed to realise land use and transport integration (LUTI) (Curtis 2005), with Perth *Directions 2031* and *Perth and Peel @ 3.5 Million* maintaining the sustainable transport agenda (WAPC 2010a, WAPC 2015).

Arguably, environmental reasons are not the key reasons for land-use planning policies pursuing LUTI. Bertaud (2002) and Dodson (2008) have both specifically argued there are dangers in ignoring land and housing markets, when considering environmental drivers for public transport planning. Dodson (2008) argued that attempts to re-structure Australian cities to achieve reductions in transport emissions and oil dependence are likely to fail because they misinterpret the housing market patterns and processes underpinning the structure and form of the Australian city. In particular, Dodson (2008) has argued that most middle and outer suburban zones in Australian cities lack significant nodal concentration and that consolidation policies will have little effect on residential densities in these areas. This is because the prices generated in these land markets would be insufficient to attract private investment into higher levels of density. Dodson (2008) concluded that the urgency of climate mitigation was too great to rely on medium and long run housing market cycles to generate the level of urban change that was sufficient to produce significant emissions

reduction through public transport.⁷⁹ Supporting this argument Forster (2006) argued that there were better policies for tackling climate change such as encouraging smaller, cleaner and more fuel-efficient vehicles which could deal directly with vehicle emissions, rather than simply hoping that consolidation and centres would make the problem go away. Even with the imperative of climate change, it can be argued that the seriousness of climate change cannot wait for cities to transform based on environmental drivers. City structures, because they are more susceptible to economic forces than environmental policy drivers, are likely to respond too slowly, if at all. As will be examined later in this Part, a transformation is underway, which is addressing high emission transport through (transport) technological changes (i.e. with more efficient internal combustion engines (ICE), lighter vehicles, low and zero carbon fuels, adoption of EVs, traffic management systems, autonomous vehicles).

The alternative way to consider LUTI and the planning of cities, beyond environmental and social issues, is for cities to be planned around their economic roles, including ensuring equitable access to economic opportunities. Jacobs (1961), Feeney (1997) and Zeibots (2007) have all argued that the primary reasons for cities are economic. Effectively, people build and live in cities to reduce travel and time across space when making economic exchanges (Feeney 1997, Zeibots 2007, SGS 2012a). Prud'homme & Lee (1999) have shown that in countries as diverse as Korea and France, a city's economic productivity is robustly linked to the effective labour market size. This, in turn, is linked to the capacity of its transport system to make employment accessible to the largest population (see also Moretti 2012, Hensher et al. 2012, SGS 2012a, Kelly & Donegan 2014, Legaspi et al. 2015). The effective labour market can be seen as *"a function of the geography of the area that is relative location of jobs and homes, in short its sprawl and the efficiency of the transport sector, the speed at which trips are made"* (Prud'homme & Lee 1999, p. 7).

Effectively, the larger the effective labour market, the more productive the city, which suggests that metropolitan planning and transport policies that are either over focused on self-containment of activity and transport movement or allow sprawl (increasing travel time and distance) are *both* limiting economic efficiency of the city. Economic exchanges in an increasingly knowledge-intensive economy are more than the exchanges of goods and commercially contracted services. Efficient operations of large and broad knowledge labour and service markets are fundamental to the functioning of a modern knowledge economy. Further, informal, tacit-knowledge exchange (i.e. knowledge spillover) from increased mobility is also important. This highlights an increasingly important link between the knowledge economy and urban transport; that the transport requirements of knowledge-intensive cities are increasingly about transporting and intensifying human capital. The

⁷⁹ Glazebrook (2009) contended in Sydney that it would take 30 years to change land use patterns and to install a world class public transport system.

increased role of human capital in larger cities with higher agglomeration values for knowledge-intensive industries is linked to higher urban density, which obviously influences the transport equation (Graham 2005, Daniels & Mulley 2011, Hensher et al. 2012, SGS 2012a, Legaspi et al. 2015). As noted in Part C, the links between urban density and the benefits of agglomeration are well recognised (if not well understood) worldwide and in Australia (Knudsen et al. 2008, Rosenthal & Strange 2008, Trubka 2009, World Bank 2009, Rawnsley & Szafraneic 2010, Glaeser and Resseger 2010, Abel, Dey and Gabe 2012, Hensher et al. 2012, SGS 2012a, Kelly et al. 2014). A number of US cities and all major Australian cities have had notable declining growth in VKT, since the 1970s, and then, in the 2000s, eventual peaking of VKT (Newman & Kenworthy 2011, 2015). This, Newman & Kenworthy (2011) contended, was possibly linked to a number of factors including increasing urban density and the growing size of cities. City growth, it was seen, was ultimately constrained by the impact of the Marchetti principle, where people have an average time-budget of only one hour travel per day (Marchetti 1994). The impact of the Marchetti principle is consistent with Prud'homme & Lee's (1999), and SGS's (2012a) research as to the negative impacts of sprawl in cities. This would likely be stronger in knowledge-intensive cities with higher agglomerated, central concentrations of population and employment density, which results in monocentric commuting patterns.

Increases in urban density with knowledge-intensive employment density will require a rethinking of urban mobility. Urban transport modes therefore will need to be considered as to how they facilitate or hinder more intensive concentrations of human capital and knowledge economic activity. Kenworthy and Laube (2001) found that urban form factors of urban density, job density and proportion of jobs in the CBD of cities had the clearest and strongest relationships to urban transport patterns of all factors in their study. Notably, the results were strongest and clearest in more developed cities (notably also those cities with the higher levels of human knowledge capital), than in developing cities. SGS (2012a) similarly found that effective employment density (which factors in commuting times) and labour productivity is higher in the larger Australian cities, particularly in areas closer to the CBDs. If it is accepted that the primary purpose of cities is economic exchange, and that transport is a key part of making economic exchange happen, then the logic is for cities to be planned around the most effective way of maximising the efficiency of the exchanges. With the efficiency of economic exchange being the rational for cities, it is arguably more logical, as Prud'homme (1995), Bertaud (2002) and Arnott (2011) have all contended, that metropolitan planning should be about the harnessing or re-channelling of market forces rather than opposing them.

The need to deliver large and broad knowledge and service markets raises questions as to some current urban planning thinking. The economic focus of 'smart growth' thinking has

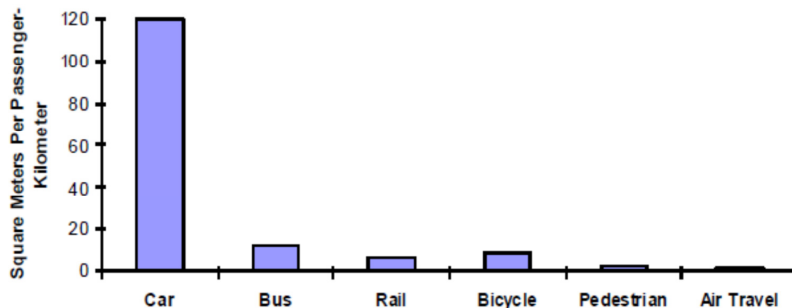
been on increasing the level of self-containment, particularly as it relates to the meeting population needs for goods and services. This is achieved when communities satisfy these needs nearby within self-sufficient local economies delivering a range of economic and sustainability benefits (Duany et al. 2010). However, much of the knowledge and tradable economy requires and involves greater levels of mobility across and out of metropolitan areas. While much of the argument on 'smart growth' has been on the promotion of self-containment, there is also recognition that mixed-use neighbourhoods have to be organised around logical movements between suburbs and cities (Duany et al. 2010). Maximising self-containment of population servicing provides an indirect benefit to the knowledge economy in that it frees up transport capacity and therefore mobility for those parts of the economy that operate across wider and broader labour and service markets. This suggests a complementary adaptation of 'smart growth' thinking is required to fit with knowledge-intense economic urban planning.

12.2 Spatial characteristics of transport modes

Fundamental to understanding the impact of transport modes on knowledge intensification is their land use space requirements, particularly relating to larger and denser urban areas. Effectively, the spatial intensity of the various transport modes is essential to understanding the knowledge intensity capacity of any given transport mode. Analysis of land requirements for transport modes indicates that cars are the most land consumptive (Bannister and Button 1993, Litman 1995, Renner 1998, Beamguard 1999, Kenworthy & Laube 2001, Mees 2010, Department of Transport & Main Roads QLD (DTMR) 2011). Bannister and Button (1993), as per **Figure 39**, determined that cars have an extremely high land requirement (120 metres per passenger) compared to other modes, for example, rail and walking are well below 20 metres per passenger.⁸⁰

⁸⁰ The classical traffic model (in terms of linear metres) states that, above a critical density k_c (approximately 50 veh/km), the traffic state begins to enter in a congestion phase, where vehicles are closer to each other and moving slower, until traffic comes to a full stop, at a jam density k_j , at about 150 veh/km (Fernandez and Nunes 2012). This suggests that, at three linear metres per vehicle, 55 per cent of the linear lane space is empty but no movement is occurring.

Figure 39 Land space required by transport mode



Source: Bannister and Button (1993)

Similarly, Renner (1998) found walking cities typically devoted less than 10 per cent of land to transport, while motor vehicle oriented cities devoted 30-50 per cent of land to roads and off-street parking. Motor vehicle spatial requirements are inherently linked to their method of use. Homburger, Kell and Perkins (1992) have noted that a motor vehicle's road space requirements increase with its size and speed. Cars are also generally private passenger vehicles and therefore presently requiring parking at destination and origin⁸¹. In the USA, as of 2009, there was a vehicle for every licensed driver and 1.87 vehicles per household, with the average car occupancy for all trips being only 1.55 persons (Davis, Diegel & Boundy 2011). In Australia, 60.2 per cent of commuters are drivers (as the sole transport method), with only 5.3 per cent of commuters getting to work as motor vehicle passengers (ABS 2011). The high level of private use in the USA means cars spend 95 per cent of the time immobile, which has resulted in a high demand for parking (Ben-Joseph 2012). In some US cities, with 80-90 per cent of US parking provided by surface parking, it is estimated that parking spaces cover more than a third of the land area (Ben-Joseph 2012).

Litman (1995) has argued that the land requirement of the car would not be a problem if land could be assumed to have no significant value. The high value of land is particularly so in the larger Australian cities where urban densification has seen increasing demand and price value for CBD-centric real estate (O'Connor & Rapson 2003, Forster 2006, Dodson 2008, Kulish, Richards & Gillitzer 2011, SGS 2012a). Related to this real estate centrality is the increased value of real estate with high accessibility to public transport connected to CBDs (McIntosh, Newman, Crane & Mouritz 2011, SGS 2012a, McIntosh 2013). Paradoxically, congestion of road space often leads to calls for consumption of more valuable urban space for further road construction (Duranton and Turner 2009, Curtis & Scheurer 2012).

⁸¹ In 2012, 71 per cent of Australians aged 18 years and over travelled to work or full time study primarily by passenger vehicle either as a passenger or a driver (ABS 2013c). In Australia, in 2014, there were 13,297,260 passenger vehicles making up 75.4 per cent of all cars (ABS 2014a).

The spatial inefficiency of motor vehicle commuting contrasts with spatial efficiency of public and active transport shared space. Mees (2010) noted that public transport uses urban space (and other environmental resources) more effectively than cars because of public transport's shared use of space. This spatial intensity of public transport, compared to cars, is demonstrated clearly in Sydney where cars and taxis dominate the commuting space on the street during peak times (8.00am to 9.00am) with 87 per cent of traffic movements through city intersections while only carrying 35 per cent of people (Department of Transport NSW 2013). In contrast, buses move 62 per cent of people with only 8 per cent of intersection movements during the peak. During the morning peak, when looking at all modes including rail, cars only carry 14 per cent of all people commuting into Sydney. Public transport, active, and motorcycles or scooters can therefore be considered, based on their limited use of land, to perform their transport task as *spatially intense* forms of commuting transport.

The next sections will review the major transport modes (walking, cars and public transport) as to their impact on knowledge intensification. Modes will be considered, particularly in respect to commuting but also to movement of people within and between centres and places of employment and education, as well as their capacity to provide flexibility and deliver scale and density. Innovation in transport technology will also be considered as to how technological changes could impact on knowledge intensification. The key mobility functions of urban transport in a knowledge-intense urban economy are set out as follows:

- *Accessibility*: providing commuting access or reach into a limited number of dense centres and also to disperse knowledge employment, both to enable large and broad labour and service markets for any given metropolitan catchment. Also to provide accessibility between a knowledge-intense centre and other employment locations
- *Capacity*: for delivering sufficient scale and density within knowledge-intense centres to provide required levels of agglomeration (i.e. spatially intense and large scaled labour and service markets) for knowledge industries
- *Circulation*: providing circulation and movement within centres to enable people to interact face-to-face (i.e. providing both efficient knowledge spillover, and knowledge labour and service markets)
- *Flexibility*: for diverse and timely movement to provide the greatest level of diversity of activity (i.e. providing maximum choice to a wide range of workers to make diverse transport choices to suit their work and personal needs)

Chapter 13 Walking and knowledge intensity

13.1 Walking and active transport

Walking is, according to Fruin (1987), the most vital mode of transportation upon which all societal activities depend, with walking interwoven into all aspects of human development. Walking has the narrowest range for accessibility (in terms of commuting distances) of any of the modes of transport. This is because there are practical physical limits for walking, though the limits of human walking distances are more situation-related than energy related (Fruin 1987). This also limits walking to deliver capacity (i.e. large numbers of people) into cities.⁸² Newman and Kenworthy (2009) found that cities based on walking are restricted in size, generally 5-8km wide before it becomes dysfunctional to expand further. Most walking in London, for example, is within 0.96km (Desyllas, Duxbury, Ward & Smith 2003). In terms of commuting modes in Australia's major urban centres, walking and cycling, while spatially intense, have relatively low mode share (with walking at 3.2 per cent and cycling at 1.1 per cent of commuters, ABS 2011). This means, active transport (by itself) is limited in its carrying capacity and accessibility, which limits its likely potential to deliver scale and density in larger low-density cities.

Walking's importance is because of its ability to integrate with other modes of transport. Fruin (1987) found that walking was a unique mode in that it was a versatile linkage between other transportation modes. Walking's support for public transport use is critical because of public transport's heavy reliance on walkable catchments at origin and/or destination (Newman & Kenworthy 2006, Cervero & Guerra 2011). This is consistent with Kenworthy and Laube's (2001) findings that high-public-transport-use-environments also tended to be non-motorised mode environments, particularly for walking. The extent of walking and public transport integration can also be seen from London, UK data that had approximately 73 per cent of rail trips, 79 per cent of trips to the London underground and 50 per cent of all bus trips involving at least one walk of 50m or more (Desyllas et al. 2003). In this sense, walking increases the flexibility of other modes of transport, particularly public transport.

The main role of walking as a mode of transport with respect to knowledge intensification, in addition to facilitating other modes of transport for accessibility, is for mobility and circulation of people within denser urban centres. In the context of the importance of 'face-to-face' contact for knowledge spillover and the efficient operation of labour and service markets,

⁸² Historically larger cities such as London developed alternative modes in the early to mid-19th century to deal with the lack of accessibility and capacity provided by walking (and horse drawn cabs) with the adoption of horse drawn omnibuses and then ultimately rail with the development of London Underground (see Woolmar 2004)

walking is a key link between knowledge intensification and agglomeration. Walking comes into its own as the superior mode of transport for the distribution or circulation of employees and services providers within a centre. That is, walking provides for knowledge intensification of centres through its capacity to deliver sufficiently high levels of face-to-face interactivity amongst people, providing for knowledge spillover, and labour and service market efficiency. This is best demonstrated by the spatial size of major city CBDs remaining within walkable catchments and, in lieu of spatial horizontal expansion, increasing in density. It could be even said that walkability is the principal characteristic of knowledge-intense centres and underpins their capacity to provide high levels of agglomeration. In major centres, such as CBDs, walking is the dominant form of intra-centre means of circulation (Fruin 1997). Notably in the Sydney CBD, 90 per cent of internal trips are walking (Department of Transport NSW 2013).

Walking can therefore be considered a basic building block in urban system design (Fruin 1987). Initially, Australian cities centred on their CBDs, which meant they developed a compact walkable urban form (Curtis 2005). The CBDs provided the focus for a range of services, businesses and governances with many daily activities conducted locally. Cities and CBDs were originally developed at a more human scale; land uses were mixed and addressed the street, providing comfortable pedestrian accessibility (Curtis 2005). However, much of the fine grid street based urbanism has been lost in Australian cities with the dominance of the motor vehicle, from the mid 20th century onwards (Seddon and Ravine 1986, Gehl 1994, McNeill 2011). The re-establishing of more walkable CBDs and centres has, from the turn of the 21st century, occurred for varied reasons including the need to provide streets and urban environments that facilitate higher levels of liveability, civic life, economic productivity and employment density (McNeill 2011, Department of Transport NSW 2013). Effectively, walking, as demonstrated by the mode share of 90 per cent of internal Sydney CBD trips, is an essential mode of transport for the economic performance of Australia's major CBDs.

Walkability has also been associated with strong economic growth in US urban centres. Leinberger and Lynch (2014), in a survey of US metropolitan areas, identified walkability as a driver of economic growth with its importance being likely to increase. Leinberger and Lynch (2014) broadly categorised USA metropolitan land use into two economic functions; *regionally significant* or *local serving*. *Regionally significant* centres typically had civic centres, institutions of higher education, major medical centres, regionally significant retail and one of a kind cultural, entertainment or sporting facilities⁸³. *Local serving* provides for residential and complementary commercial, retail and civic services including education

⁸³ The *regional significant centres* can be seen to cover the three categories of urban centres identified by Levy and Gilchrist (2012) (commercial downtowns, anchor institution districts, and office and research parks)

such as primary and secondary school. The *regionally significant* areas were generally found to be where cities and people created wealth. Leinberger and Lynch (2014) noted that, while regionally significant areas could be walkable urban places, they could also be edge cities (see also Glaeser and Kahn 2001) However Leinberger and Lynch (2014) argued that increasingly walkable urban places were dominating in wealth creating urban development.

Walking, as a means of creating density and a means of knowledge spillover, should also be viewed in the context of (people) scale of urban activity. Public spaces, urban design and walkability all relate to the 'human dimension' (Gehl 1971, 1994, 2009). This type of walkable urban design is also important in that it needs to facilitate diversity, scale and density of activity within centres for efficient face-to-face knowledge spillover. A key urban design element is city streets as they provide the access and connections between functions and activities. Streets are also a key part of the public spaces that function as meeting places, marketplaces and connection spaces (Jacobs 1961, Gehl 2007, WAPC 2009b). Jacobs (1961) saw the streets and their sidewalks as the main public spaces of a city, similarly other urbanists (Duany et al. 2000, Carmona et al. 2006, Montgomery 1998, 2008) have seen pedestrian movement through public space being important in generating street life and activity. Streets, as distinct from more spatially open public or civic spaces, direct people into particular pathways, rather than dispersing them. This helps create interaction and therefore efficiencies in labour and service markets as well as opportunities for knowledge spillover. The promotion of a 'finer grain' urbanism and reinvigoration of civic spaces oriented towards pedestrians goes beyond the street to also include intra-block laneways, often enlivened by commercial activity such as small bars and cafes (City of Melbourne and Gehl Architects 2004, McNeill 2011). Placemaking, in this sense, also goes beyond favouring streets over roads and can include; better pedestrian networks, gathering spaces, livelier and more active streetscapes, and people being engaged over wide a range of hours (Montgomery 1998, City of Melbourne and Gehl Architects 2004, 2008) as well as the quality of society (including but not limited to public safety) that occupies the place (Lynch 1981).

A walkable location or space does not therefore necessarily indicate a positive influence on knowledge intensification. For walkability to positively influence knowledge spillover, a number of supporting factors need to be present. Walking, as a mode of transport to intensify knowledge, should be considered within the context of a diverse series of social, commercial, structural, physical, and regulatory factors. The walkable mono-use, self-contained, low density centres therefore (despite their human scale or their urban design), are not as conducive to high levels of knowledge spillover or agglomeration. Walkability, in itself, is insufficient where there is a lack of scale, density or diversity of activity and people. Monastic-style campus-style developments, while walkable, are arguably not as conducive

as an organic street grid, full of diverse activity for knowledge economic activity or spillover (see Jacobs 1961 and Montgomery 2008 for benefits of diverse activity within street grids). A key reason for failure of campus developments to facilitate agglomerated spillover is the lack of 'streets' and therefore 'street addressing' in campus style development. The campus model has propensities for supporting massive single uses, which form borders and vacuums of activity (Jacobs 1961). This effectively limits interaction and accessibility of outsiders and hence knowledge spillover.

Efficiencies for commercial activity and labour and service markets are also aided by streets not being anonymous, random places but subject to being well ordered through street addressing. This creates accessibility and interaction for both insiders and visitors. Street addressing can be defined as making *"it possible to identify the location of a plot or dwelling on the ground, that is, to "assign an address" using a system of maps and signs that give the numbers or names of streets and buildings"* (Vitkovic, Godin, Leroux, Verdet, and Chavez 2005 p. 2). Street addressing has a range of public, civic, and administrative purposes and generally makes the city more "user-friendly".⁸⁴ Beyond providing for the basic functioning of cities, Vitkovic et al. (2005) have argued that street addressing creates a common ground for diverse community exchange in modern cities:

"A city is, first and foremost, a means for coexistence, exchange, communication, and integration. Street addressing is just one of the many requirements that will help a city achieve social integration."

Notably, prior to street addressing, wayfinding was based on local knowledge with complexity known only to insiders, while outsiders were disadvantaged (Vitkovic et al. 2005). Modern professional wayfinding practices were developed due to the over complexity of modern urban spaces such as with universities campuses, large buildings, and stadiums, for example, which are difficult to circulate through for non-local outsiders (Gibson 2009). 'Streets' are one of the key types of wayfinding strategies (others being 'connectors', 'districts', 'landmarks'). These four foundations of wayfinding are modelled after traditional urban environmental cues that have helped people with the mental maps to reduce complexity and help people navigate urban environments (Gibson 2009). Street addressing and numbering is well adapted to a regular and traditional street layout and is more difficult to implement where the layout is less uniform (Vitkovic et al. 2005). A key element for walkability is that streets and places are accessible and approachable. This makes urban walking efficient. This urban street efficiency assists in enabling larger labour and service

⁸⁴ More user friendly by:

- Improving the system of street coordinates to enable people to get around the city more easily,
- Facilitating the delivery of emergency health, fire, and police services, and
- Locating urban facilities (Vitkovic et al. 2005).

markets within dense centres operate efficiently. Having an address is essential for exchange to occur, and street addressing facilitates the interfacing and exchange, in particular with those people from outside traditional networks. An efficient system of streets and street addressing is therefore a key for the exchange between people in modern cities to ensure people are not anonymous entities, unreachable, without identity in the urban environment (Vitkovic et al. 2005). Hence, both medieval cities and 20th century monastic campuses lack the inherent wayfinding necessary for a modern, diverse, externally focused, connected, scaled and dense knowledge city.

13.2 Streets and roads - their impact on walkability in activity centres

A key issue with knowledge-intense walkable urban design is the treatment of transport space, particularly relating to car transport. Mobility or circulation has been the backbone of settlements, and the 'street' performed this role in centres. However, in many mid to late 20th century cities, the road network was set up to provide for a vehicle function rather than an urban design function, even within urban areas (Marshall 2004). Marshall (2004) argued that it was not necessarily ideal for urban areas to be structured around roads which maximised traffic circulation. This contrasted with traditional streets with mix-use activity. The role of the street was more multi-functional than that of a road. The street has traditionally had three combined roles; providing mobility, providing public space and providing built frontage (Marshall 2004, see also WAPC 2009b). Marshall (2004) has distinguished a street from a road, in that a street had an urban character or acted as an urban space that also served as a right of way. Roads, on the other hand, functioned largely solely for circulation, and this meant that the buildings (and their addresses) were divorced from the street (Marshall 2004).

In respect to centres, it is therefore essential to understand how vehicle transport infrastructure impacts on urban design and the creation of better or worse places. Much of modern transport infrastructure has had a destructive impact on the walkable urban fabric (Jacobs 1961, Buchanan 1964, Marshall 2004, WAPC 2009b). Implicit in this is distinguishing the different roles that 'streets' and 'roads' play in urban design and transport. Simply, streets provide for a multi-functional purpose including the movement of pedestrians and cars, whereas roads have a singular purpose and are engineered to favour traffic in the form of the vehicle over the pedestrian and to give effect to speed (Buchanan 1964, Marshall 2004, Richardson 2010). Streets and roads also need to be seen within their own 'systems'. Street grids, including the more irregular street patterns, operate as systems of local streets as distinct from road systems, which are more part of a wider road and freeway network. The street grid or pattern (as being a series of streets with their three functions), creates a

walkable place, location or centre as distinguished from a road network that provides for a series of vehicle tributaries or pathways between places, centres and locations. Hillier (1996) argued that urban street grids have logic (wherever you go you can see where you have come from and where your next point is) and that this allows for natural and normal walkable movement, even in the back areas. In this sense, the structure of the street grid itself becomes the main influence on the pattern of walkability and movement within urban centres (Hillier 1996). This means that cities and their centres are places for generating contacts, which will see some locations, depending on the effectiveness and structure of their grids, having higher densities of development. This has a multiplier effect, attracting more people and buildings, and creating a feedback loop (Hillier 1996). The multiplier effect is, Hillier (1996) argues, what gives cities their 'urban buzz.' Effectively the co-incidence, in particular locations, of a large number of different activities involving people walking and going about their business in different ways originates from the structure of the urban grid itself (Hillier 1996). A key aspect of this argument is the diversity of activity. This means the street grid system creates walkability and a diversity of economic and social activity that underpins knowledge-intensive centres.

13.3 Technology and personal mobility - extending walkability

The nature of localised personal mobility is evolving with technology and the increasing need for non-vehicle mobility in urban areas. This has seen the increasing development of personal mobility devices⁸⁵ (PMDs), which are essentially small-scale electric transport devices that assist with or provide mobility, generally using footpaths or bikeways. They could also be considered to include electric assisted bicycles. Examples of new electric personal mobility devices are numerous⁸⁶ with new technology proliferating and transport regulations adapting to their development (Litman & Blair 2010 and see QLD DTMR regulatory advice on using personal mobility devices –DTMR 2015 and City of Ryde 2013 study). Litman and Blair (2010) have noted that PMDs have diverse features and uses and are difficult to categorise. Effectively, a continuum of active transport is emerging.

The key benefit of PMDs is their extension of the ped-shed to further afield without requiring a road-based motor vehicle.⁸⁷ Effectively, the ped-shed that is linked to pedestrian

⁸⁵ Personal Mobility Devices (PMDs) have been defined as motor-assisted, low-speed, lightweight devices with one, two, three or four wheels. They are designed to transport one person on footpaths, shared use paths, cycleways and trails (Ryde Council 2013).

⁸⁶ Some of the examples include the Segway www.segway.com, Yike bike www.yikebike.com, Air wheel www.airwheel.net, Winglet www.toyota.com.hk/innovation/personal_mobility/winglet.aspx, Kicktrike www.greenpack.de

⁸⁷ The ped-shed being the theoretical walkable catchment within a 5 minute walking distance, generally being 400 metres, for daily activities; and the 10 minute walking catchment, generally being 800 metres, for a major public transport stop or town centre (WAPC 2009b)

movement is changed to a wider-access shed. For people immediately outside the ped-shed, who have difficulty accessing public transport or activity centres, this additional distance is referred to as the 'last' or 'first' mile (Mineta Transportation Institute (MTI) 2009, Los Angeles County Metropolitan Transportation Authority – Metro (LA Metro), Southern California Association of Governments (SCAG), 2013). Strategies to encourage PMDs, as part of wider accessibility strategies, are driven by the need to increase accessibility to public transport beyond walking limited ped-sheds (LA Metro/SCAG 2013). It has been identified that 80 per cent of 7.8 million Los Angeles County residents will be 4.8km or less from the proposed LA metro rail system stations (LA Metro/SCAG 2013). Support for active (cycling and skate based) and (a variety of) electrical assisted personal mobility devices allows for an “aggregate increase in average personal mobility speeds (which) can dramatically increase regional access sheds” (LA Metro/SCAG 2013, p. 14). Bertaud (2002) has contended that transport should adapt to urban structures; this is arguably what is occurring with PMDs, which can be seen as a response to demand for increased flexibility, accessibility and mobility not presently provided by other existing active or vehicle transport modes whether alone or in combination.

Chapter 14 Cars and knowledge intensification

14.1 Cars negatives and benefits

The car has both positive and negative characteristics in relation to a modern urban knowledge-intense economy. The largely unique benefit of the car within an urban road network to the knowledge economy is that it provides for flexibility and a range of movement for accessibility to diverse locations. This enables human face-to-face networking (in terms of range, timing and choice of movement) to a degree greater than any form of other transport (particularly outside of peak commuting times). The motor vehicle and road system has, for many people, a 'go anywhere, anytime' flexibility (Clarke and Hawkins 2005, Mees 2010, Kent 2014). Kent (2014), in a Sydney based study of people identified as being able to use alternative transport to get to work in the same time it took them to drive, found that the motor vehicle appealed because of its flexibility and autonomy. Additionally, there was considered a sensory experience provided by the cocoon of the car. Flexibility of the motor vehicle was particularly desirable with the increased time pressures and chained trip making (linking work trips to children activities, food shopping and other social and education activities).

In the USA, it was notably women who undertook the most chained trip making, with 70 per cent of commuting households having had two or more workers (Hemily 2004). This increased the complexity of organising residential activities and locations around work locations. Australia has similarities to the USA with the increase in female paid workforce participation rates over the last few decades, resulting in women having a relatively higher reliance on the motor vehicle to juggle paid work and domestic work duties (Dowling & Gollner 1997, Battellino & Raimond 2005). As women are increasingly in knowledge-intense employment (Esposito 2010, Esposito & Abbott 2011) the importance of flexibility in transport for the knowledge economy for parents with family responsibilities would also be expected to increase.

While the motor vehicle and road system has had a 'go anywhere, anytime' flexibility (Mees 2010, Kent 2014), the sense of freedom is increasingly becoming a myth in modern cities (Gratz & Mintz 1998, Mees 2010). The benefits and limitations of the motor vehicle become clearer when considering commuting and accessibility to give effect to creating large labour markets. In Australia, the motor vehicle is the dominant transport mode for travel to work or to full time study with 71 per cent of people aged 18 years and over travelling as a driver or passenger (ABS 2014b). Only 16 per cent of Australians used public transport, while 4 per cent walked and 2 per cent cycled. Since 1976, when census data was first collected on

travel to work, public transport's share declined in Perth from 13.5 per cent to 9 per cent in 1996. Evident from 2006, with an increase to 10.4 per cent, there was a recovery in public transport use, which coincided with a peak in VKT (Newman & Kenworthy 2011). Newman and Kenworthy (2011, 2015) and Stanley and Barrett (2010) have noted that Perth and Australia is not alone in seeing a peaking of VKT, with the US (Puentes and Toner 2009, Sivak 2013a, 2013b) having reached peak car use (in terms of VKT) in the 2000s.

The decline in car use is most noticeable with the Perth CBD. In 1999, access to the central city was strongly car-oriented with the morning peak commute seeing about 65 per cent of city centre workers arriving by car and about 35 per cent using public transport, walking or cycling (Brown, McKellar, Johnstone & Igglesden 1999). During the peak period, 90 per cent of the motor vehicles entering the city carried only the driver. Following a series of Western Australian State Government policy initiatives (i.e. Perth Parking Management Act 1999) and public transport investment (ie Perth to Joondalup Rail Line 1991 and the Perth to Mandurah Rail line in 2007), there was, by 2010, a notable reversal in commuting access to the Perth CBD. In 2010, 35 per cent of commuters entered the CBD by motor vehicle and 65 per cent by public transport (Richardson 2010). Similarly, the Sydney and Melbourne CBDs have both seen, in recent decades, substantial shifts away from single occupant motor vehicle commuting (Hamer, Currie & Young 2009, Department of Transport NSW 2012).

Hanson (1992) noted that the motor vehicle, for personal travel, is necessarily the dominant mode for serving highly dispersed trip origins and destinations. Sachs (1999) has argued that the advantage of motor vehicle speed has led to greater distances travelled. In this sense, cars have, on face value, increased accessibility. The greater distance advantage has led to more sprawling and less intensity of employment with Glazebrook (2011) noting that the widespread use of cars has led to a polycentric urban form, as employment has followed population to the suburbs. With the knowledge-intense economy increasingly dependent on high levels of urban density and spatial centrality in activity, there is a conflict with transport modes and systems that encourage sprawl and weaken agglomeration (though some have argued against a 'hyper concentration' into an overly high centrality because of congestion and pollution impacts, particularly from cars i.e. see Burke, Dodson & Gleeson 2010). Sprawl is, however, not only an economic accessibility issue (i.e. weakening labour market efficiency as per Prud'homme & Lee 1999) but also an economic and social equity issue. Dispersed cities, including effectively all of Australia major cities, with high levels of automobile dependency have fringe households with impaired transport mobility reinforcing acute socioeconomic vulnerability and disadvantage (Currie, Richardson, Smyth, Vella-Brodrick, Hine, Lucas, Stanley, Morris, Kinnear & Stanley 2009, Hensher & Chen 2010, Dodson, Burke, Evans, Gleeson & Sipe 2010, Daniels and Mulley 2011). In contrast, for example, in Melbourne, people living closer to the CBD (in higher-density inner and

middle suburban areas of the city with higher levels of accessibility to employment and services) saw reductions in their VKT, regardless of socio economic status (Currie et al. 2009).

The limitations with motor vehicle flexibility and mobility is impacted by density and scales of urban areas where constraints (mainly relating to time constraints and costs with congestion and parking) are increasingly limiting motor vehicle effectiveness.⁸⁸ Guillianio and Dargay (2006) found, in comparing the UK and the USA, that metropolitan size affected motor vehicle travel only in the largest metropolitan areas of the USA. Daily travel distance was found to be inversely related to local population density, but the effect was much stronger in the US than the UK (see also Guillianio and Narayan 2003). This was because the higher transport costs in the UK (such as higher petrol taxes) promoted economising behaviour leading to more localised consumption of goods and services and higher use of alternative transport modes. Similarly, Duranton and Turner (2011) found, in their analysis of VKT and highway infrastructure between 1983 and 2003, that people in larger US cities drove much less per capita than people in smaller cities. Changing agglomeration values could also mean that some industries had taken advantage of lower transport costs in the US and dispersed to a greater degree than other industries that may have clustered for higher agglomeration values.

It also follows that the modal type of infrastructure built attracts or repels particular industries. This therefore raises questions on the limitations of cars (and associated road infrastructure) in providing accessibility to higher density specialist knowledge-intense centres and its capacity for creating density and therefore scale. Road networks are spatially constrained where there is high mobility demand into centres (Department of Transport NSW 2012, Doyle 2014)⁸⁹. As previously noted, cars are spatially inefficient on a space use per person; this is particularly with single person per vehicle usage. Single person car occupant is a dominant form of motor vehicle commuting in both the USA and Australia with Australian single occupant car commuting increasing to 55 per cent of all commuters in the 2011 Census, up from 53.5 per cent in 2006 (ABS 2011). In the USA, the average occupancy level for private commuting vehicles was 1.13, down from 1.3 in 1977 (Santos et al. 2011). This relatively much lower use of cars for passenger commuting is possibly due to the requirement for driving commuters to have a relatively higher degree of locational matching both at origin and destination with increased dispersement of employment, otherwise there is a lessening of personal mobility (i.e. in terms of time and fuel costs for

⁸⁸ Though the US National Household Travel Survey, in 2009, found the average speed of commuting declined slightly in all metro areas, regardless of size, and, since 1990, the middle sized metro areas have seen the greatest decline (and the highest increase in public transport use) (Santos et al 2011).

⁸⁹ For example in Melbourne, 50 per cent of traffic volume is concentrated on only 3 per cent of the road network during morning and afternoon peak periods (Doyle 2014).

multiple origin and destination points). This possibly reflects the increasing complexity of people's daily commuting patterns, particularly with increased female workplace participation.

Urban density is a notable factor in car use and ownership. In the USA, the more densely populated areas had significantly lower levels of car ownership (Brownstone and Golob 2009, Santos, McGuckin, Nakamoto, Gray & Liss 2011)⁹⁰. The relationship between motor vehicle use and urban density is however not as straightforward as between density and lower vehicle ownership. Badoe and Miller (2000) noted a number of studies that indicated land use and urban densities decreased (though not always strongly) motor vehicle ownership and use while increasing public transport. These earlier studies were supported by Ewing, Bartholomew, Winkelman, and Walters and Anderson (2009), who examined 85 urbanised areas in the USA from 1982 to 2005 and found compact development reduced driving by 20-40 per cent. Looking at Baltimore, Chao & Qing (2011) found the effect of land-use characteristics was an indirect effect with accessibility to public transport or freeways having a greater effect than density, design and diversity. Giuliano & Narayan (2003) similarly found that there is a complexity to motor vehicle usage patterns, noting that per capita income was a major driver of car ownership and use (see also Santos et al. 2011). This suggested that knowledge workers, as better paid workers with university qualifications (see Moretti 2012, Ryan & Siebens 2012), would be more likely to have higher motor vehicle use. The US 2009 National Housing Transport Study (NHTS) indicated that employment, increased income, and having a Bachelor qualification and education were all positively linked with increased VKT (Akar & Guldman 2012). Notably, in the USA, the rates of cars ownership and use are peaking. Sivak (2013a, 2013b) has noted that with respect to light vehicles, rates of cars in the USA per person, and licensed drivers per households reached their historic peak in around 2006 and were now declining. Notably, the peaks occurred prior to the onset of the global finance crisis, and it was likely the declines reflected societal changes that influenced the need for vehicles. The US National Household Travel Survey found that households without vehicles had increased in the period from 2001 to 2009 while households with two or more vehicles had declined, reversing longer term trends towards increasing vehicle ownership among households (Santos et al. 2011). Notably, increased public transport use in the US was noted by Sivak (2012) as a potential driver of declining motor vehicle use.

⁹⁰ US cities with 10,000 people per square mile had 28.44 per cent of households having no vehicles and 39.89 per cent of households had only one motor vehicle (compared to areas with densities of less than 2,000 people per square mile with just 4.38 per cent of households having no vehicles and 26.78 per cent with one vehicle) (Santos et al. 2011).

A key aspect of the overall VKT reductions was a notable trend in the declining interest with younger people in cars. The average age of motor vehicle drivers was increasing (Sivak and Schoettle, 2012a) and similarly, the shift in the peak probability of purchasing a vehicle per licensed driver shifted from those 35 to 44 years of age to those 55 to 64 years of age (Sivak, 2013b). Santos et al. (2011) specifically found in the US National Household Travel Survey that younger drivers (16-34 years of age) drove significantly fewer miles per capita in 2009 than in 1995 or 2001 compared to drivers 35 and older. In rural areas, the decrease was significant for drivers 25–35 years but not for the 16-25 age group. Notably, in the USA, younger people and those living in denser urban areas were more likely to have a graduate degree or higher (Ryan and Siebens 2012, Moretti 2012).⁹¹ This is consistent with a conclusion that the lessening of motor vehicle use among younger workers in the USA is associated with an increased urbanisation of knowledge workers and their working in knowledge-intensive industries within higher density urban areas.

As Australian cities continued to grow in population and land area (see Weller 2010 for an exploration of Perth's continued suburban growth), the efficiency of both urban structure and transport become increasingly intertwined. The Sydney Household Travel Survey⁹², which looks at all household trips, found that tertiary education trips from home and travel to work had the highest trip lengths (Daniels and Mulley 2011). Public transport trips for work and tertiary education were notably longer than vehicle use trips for similar purposes, (Daniels and Mulley 2011). This additional trip time suggested the public transport system was somewhat less effective for trips to non CBD dense employment or education centres. Further, tertiary education trips were longer than TAFE (technical college) trips regardless of mode, which was likely the result of fewer university locations compared to the more numerous TAFE locations being more locally accessible. Notably, with full time work, looking at all modes, trip lengths increased at the higher 75 per cent income quartile. This suggested that for higher quartile workers there is an increase in trip lengths (possibly to a smaller number of distant centrally located dense employment centres as well as dispersed distant trips within a larger size labour market). This is consistent with findings from the BITRE (2015) for Sydney, Melbourne and Brisbane, where commuters travelled further for professional, knowledge-intensive employment in inner city locations.

These findings are not dissimilar to the USA where higher income and Bachelor qualifications were also linked with higher VKT (Daniels and Mulley 2011, Akar and Goldman 2012). This suggested that in major Australian cities, higher income workers use

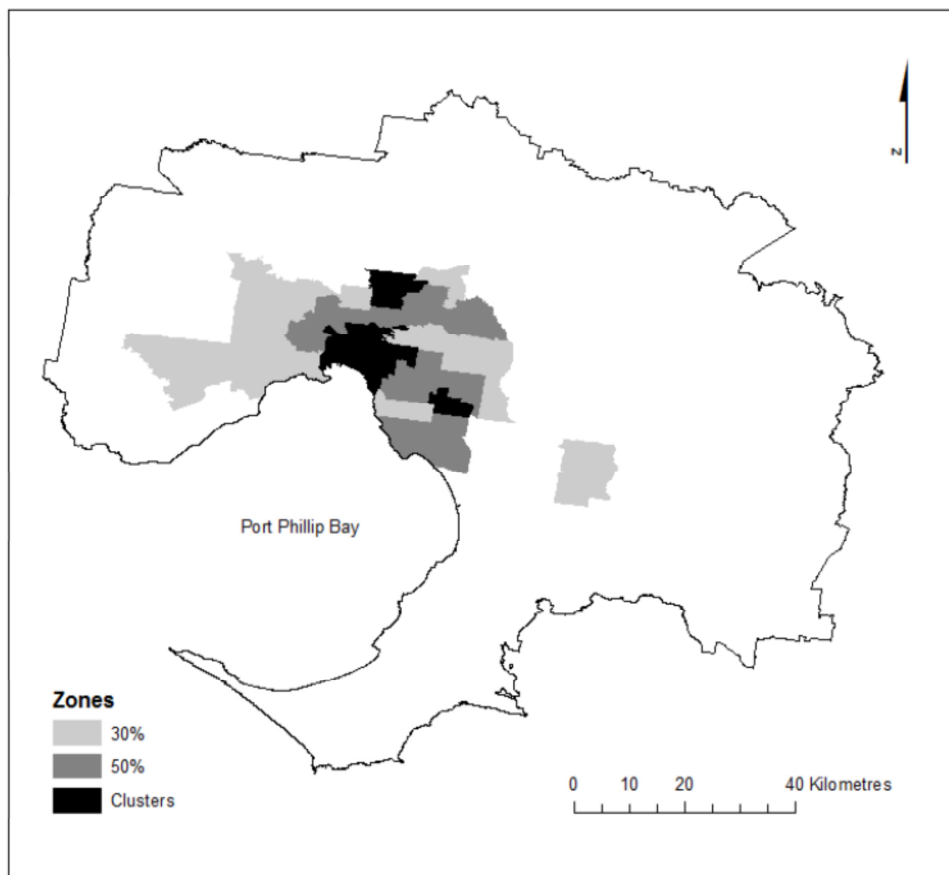
⁹¹ A similar trend is evident in Germany with car use declining in the 18-25 age group between 1996 and 2000 with a corresponding increase in public transport and cycling (Knie 2014)

⁹² The Sydney Household Travel Survey is the largest and most comprehensive source of personal travel data for the Sydney Greater Metropolitan area and is considered best practice in travel surveys in Australia and around the world (Daniel and Mulley 2011)

public transport to access their centralised employment or additionally work in more distant and more dispersed car dependent centres or locations requiring longer vehicle trips. The BITRE (2010, 2011) analysis on labour market commuting in Perth and Sydney also indicated that knowledge centres had the largest metropolitan catchments. At first glance, there appears an inconsistency, in that knowledge-intensive workers are both commuting into denser centralised centres and commuting to more distanced dispersed locations. This however supports the conclusion that knowledge workers work across larger scale labour markets – scale being achieved either through density in a few centres or accessibility across the largest spatial labour market across a metropolitan area. Supporting this is that lower income workers in local population servicing employment have shorter trips (Daniels and Mulley 2011) (presumably because their labour market catchments are smaller with less specialised employment). Daniels and Mulley (2011) also noted that weekend workers had the shortest trips, possibly reflecting local retail and hospitality employment. The Sydney Household Travel Survey is consistent with Johnson's (2010) findings that knowledge workers in Melbourne have different commuting patterns in employment and residential location to the wider labour force. Their employment locations are concentrated generally in and around the CBD and or across a number of other knowledge-intensive centres or (for about one third of knowledge workers) at dispersed locations (including working at home) (Johnson 2010). Generally, Melbourne, and other Australian cities, are characterised as having groups of several 'sub regional' economies within which commuting occurs (Johnson 2010⁹³). This is demonstrated by **Figure 40** and the agglomeration of knowledge workers around employment clusters.

⁹³ See also Hensher and Chen (2010) where using the Sydney Household Travel Survey 1997-2008 it was found travel times were generally similar across Sydney metropolitan area, which suggests that where people lived and worked were linked.

Figure 40 Knowledge economy commuter zones for Melbourne (Johnson 2010)



All knowledge economy employment clusters are shaded in black. The grey areas represent the place of residence of 80 per cent of the knowledge economy workforce for these clusters. For all the clusters, the darker grey represents areas where higher absolute numbers of commuters live (totalling 50 per cent of the Knowledge Economy workforce). The lighter grey accounts for the next 30 per cent of workers. Data Source: ABS, Census 2006

The constraints placed on commuting car use by increased urban intensity are compounded by temporal intensification. That is, the accessibility limitations of the motor vehicle for commuters largely arise out of peak time demand for road space. Cars, as a form of mass transport at peak times (in terms of accessibility into and out of centres, or for circulation around denser urban areas), is characterised by high levels of congestion (Kenworthy & Laube 2001, BITRE 2010, BITRE 2012, Department of Transport NSW 2013, Doyle 2014). This is because of the spatial in-efficiencies of vehicles and the required road network. Kenworthy and Laube (2001) found that as congestion increased, there was less car use,

more motor cycle use, more public transport use, more use of non-motorised modes and more taxi use – effectively a shifting to more use of spatially intense modes of transport. This is clearly the case with Sydney CBD. At the spatially intensive peak times, motor vehicle movements in and out of the Sydney CBD are only 14 per cent of people movements (and are not high compared to the general movement by motor vehicle around the metropolitan area) (Department of Transport NSW 2013).

Networking or accessibility between centres via cars is however more spatially efficient without private use of private vehicles. Kenworthy and Laube (2001) noted that taxi use increased with increasing public transport services and public transport use, suggesting that less private car use for commuting saw work trips during the day being taken by taxi. This is true in respect to Sydney CBD, where people movements throughout the day in and out of the CBD using public transport are 60 per cent, while movements using cars are only 25 per cent (Department of Transport NSW 2013). Not surprisingly, Sydney CBD is the biggest demand generator of trips for taxis (NSW Taxi Council 2013). In general, Kenworthy and Laube (2001) found that for a door-to-door 'private transport' type of trip, a taxi is probably a more economical and spatially efficient way of providing motor vehicle transport (compared to the ownership, storage and operation of one extra car within the urban system). Notably, because taxis are a shared vehicle they do not require high levels of fixed parking within centres, they are particularly less spatially intensive than private cars in denser centres.

The 'go anywhere, anytime' flexibility and mobility benefits are particularly important when recognising the complexity and diversity of activity that is characteristic of a modern knowledge-intense urban economy. The importance of scale and size for knowledge-intense labour markets means that, other than scale through density, dispersed labour markets create scale through size of population and area (see Prud'homme & Lee 1999). This suggests that cars retain an importance for creating larger and more populous catchments and therefore more productive labour market. This would apply beyond the minority of dispersed university qualified knowledge economy workers to skilled technical and other specialist workers. If it is accepted that the car is an essential requirement for the dispersed segments of the knowledge economy (and for other parts of the economy i.e. freight and logistics), then logically, reducing unnecessary commuting and other road travel (i.e. through higher levels of self-containment of population servicing) should be of benefit to the wider economy.⁹⁴ This highlights the need to provide better regional public transport for workers in potentially knowledge-intense and spatially dense centres as well as local public transport or non-motor vehicle transport options for workers in local population servicing. Kenworthy and

⁹⁴ This is not to say that this would alleviate congestion but it would provide capacity for additional road users in the low agglomeration economy – effectively the road system could increase its economic intensity.

Laube (2001) have argued that road congestion is not necessarily totally negative, as congestion acts to promote alternatives to private car use, be that a better public transport system or better land use or walking and cycling. Arguably, if there are better alternatives to cars in terms of delivering capacity and accessibility for knowledge-intense centres then agglomeration benefits will arise. This raises the issue as to what are, economically, the most appropriate investments into transport infrastructure modes.

Notably, Duranton and Turner (2011), looking at the USA Metropolitan Statistical Areas (MSAs) between 1983 and 2003, confirmed Downs (1992) 'Fundamental Law of Congestion'; that traffic congestion increases because of increased road use (i.e. increased VKT) by drivers taking 'advantage' of the increased supply of road network. Duranton and Turner (2009) found that with interstate highways and other important roads in the densest metropolitan areas, VKT increased in exact proportion to the additional supply of highway space (as well as for interstate highways in other less dense locations). Effectively, adding highway and major road capacity does not help to reduce congestion on those roads.⁹⁵ Duranton and Turner (2009) however argue that public interest benefit may be served by adding additional highway or public transport capacity, but this benefit is not likely to be in travel time improvements. Sachs (1999; p. 193) has noted that, with not only new transport but also other forms of new technology:

"time saved has been turned into more distance, more output, more appointments, more activities.... And, after a while, the expansion of activities generates new pressure for time-saving devices - starting the cycle all over again. Time gains offer only temporary relief, because they encourage further growth of all kind; acceleration is therefore the surest way to the next congestion."

Clarke and Hawkins (2005) have similarly argued that the favouring of (road) supply strategies to address congestion is unsound and costly to the broader public interest. The only effective way of avoiding the fundamental law of congestion is to charge for the external costs imposed sufficiently to restrict travel demand. The best solution for this, Clarke and Hawkins (2005) argue, would be comprehensive road pricing coupled with marginal cost pricing of all public transport. This would separate people into their economically preferable mode of transport.

14.2 Parking

An important additional factor impacting car use, particularly as a commuting mode choice, is parking. Shoup (2005) has contended that, in the USA, parking may be the highest

⁹⁵ Duranton and Turner (2009) also found increasing public transport capacity did not relieve road congestion. This suggests that public transport is largely serving a different (spatially located) part of the economy.

external cost for cars.⁹⁶ The negative aspects of having high levels and availability of parking results in urban sprawl, reduces effective density (including wasting land available otherwise for higher uses) (Shoup 2005, Kelly & Pekol 2013), increases the cost of development (Forinash, Millard-Ball, Dougherty & Tumlin 2003, Shoup 2005, McKibbin 2011), while providing poorer urban design, and reduced urban amenity (Shoup 2005, Carmona, Tiesdell, Heath & Oc 2010). All of which are likely to weaken knowledge spillover and limit higher agglomeration values. The availability and expectation of parking spaces at destinations such as in city centres results in both higher congestion and motor vehicle dependency, while increasing the cost and scale of infrastructure (Shoup 1997, 2005, McKibbin 2011, Kelly & Pekol 2013).

The availability of parking and parking policy impacts mode choice. For denser areas of cities and key employment locations, support for alternatives to private vehicles (such as public transport) with regulatory restrictions can reduce parking needs (Richardson 2010, McKibbin 2011, Guo & Ren 2012, Kelly & Pekol 2013) and ultimately, reduce VKT. Kelly & Pekol (2013) found, in Brisbane, that demand for parking reduced substantially in developments with good accessibility to public transport. McKibbin (2011) similarly established in Sydney that parking demand was in part dependent on destination accessibility (i.e. access to the CBD). In Portland, USA, Hess (2001) concluded that that access to free parking was a major factor in encouraging commuting by car. Kenworthy and Laube (2001) noted that CBDs and centres have less need for parking when large numbers of people can access a confined location by a high-capacity public transport system. Issues with excessive parking are recognised by some governments with parking pricing schemes operating in many cities (Hamer et al. 2009). However, as Richardson (2010) noted in his summary of the Perth Parking Policy, the 'conventional wisdom' (at least up to the late 1990s in Perth) was that restricting parking would be a restriction on access that would limit business and economic activity. Therefore, by developing parking policies that do not specify minimum parking requirements in new developments, by working with complementary policies such as strict parking maxima, and by having on-street parking controls and parking taxes, an efficient parking market that reduces excessive parking can form (Shoup 1997, 2005, Guo & Ren 2012).

The Perth Parking Management Act 1999 (WA) (PPM Act) provides a good example of parking policy creating or assisting mode switching. Perth CBD has been subject to the PPM Act since 1979. The PPM Act identifies a Perth Parking Management Area (PPMA) in which Perth Parking Policy (PPP), as a parking management and land use strategy, is applied

⁹⁶ Shoup (2005) has estimated that in the USA, vehicles searching for free parking contribute to over 8 per cent of total traffic, and that off-street parking consumes an area roughly the size of Connecticut.

(Brown et al. 1999, Richardson 2010). The Policy seeks to manage parking in the Perth CBD to support balanced transport outcomes. The PPM Act requires non-residential property with parking bays in the PPM Act to pay a licence fee, with the funds used to operate a free Central Area Transit bus system for circulation within the Perth CBD and immediate surrounding areas. By 2010, following the implementation of the PPM Act, public transport trips into the CBD went from 35 per cent to over 50 per cent, with motor vehicle use doing the reverse (Richardson 2010). Notably, there was a reduction in traffic volumes by between 3 per cent and 20 per cent on streets leading into Perth CBD in the three years after the PPM Act, with further declines since (Richardson 2010).⁹⁷ While the PPM Act's role in this transport transformation was not able to be quantified (due to the influence of other factors such as increased public transport investment) the PPM Act was found to have played a strong supporting role in restraining motor vehicle use in the Perth CBD (Richardson 2010). Reducing the use of cars in the CBD, by restricting parking and their spatial consumptiveness, has also enabled urban planning strategies from the City of Perth. These strategies were designed to grow the CBDs diverse economic activities with increased amenity at street level, supported by a 'people first, public transport second and cars last approach' (Richardson 2010, City of Perth 2010b). Such strategies included a return to the original grid two-way street approach,⁹⁸ which resulted in reduced peak time VKT (due to reduced circulation patterns) and reduced overall vehicle speeds in the CBD (Richardson 2010). The growth in the Perth CBD and inner city economic activity, particularly knowledge-intense industries in the period following the PPM Act (Department of Planning et al. 2009, BITRE 2010, Martinez-Fernandez 2010, Richardson 2010) clearly suggested the 'conventional wisdom' against restricting parking within the CBD was anything but wise.

14.3 The technological revolution in road transport

More than any other transport mode the motor vehicle is seeing the most fundamental technological and business model changes. This is, and will continue to be, largely being driven by major changes in transport and energy technology (Internal Energy Agency (IEA) 2013, Seba 2014, Institution of Engineering & Technology (IET) & Intelligent Transport Systems UK (ITSUK) 2014, Shaw 2014, Nykvist & Nilsson 2015, and Committee on Overcoming Barriers to Electric-Vehicle Deployment et al. 2015, Department for Transport UK 2015) and the business models delivering the potential energy transformation (Girardet 2011). This energy and technology transformation is occurring across a number of

⁹⁷ Similarly the numbers of people accessing the Sydney CBD at the morning peak through public transport increased (in the decade to 2012 from 105,000 to 145,000) the number doing so via cars plateaued at 25,000 (NSW Department of Transport 2013).

⁹⁸ The original two way CBD street system was replaced in the 1970s by the one way system so as to increase capacity for cars (Richardson 2010)

technologies and business model areas including passenger vehicles, particularly electric vehicles (EVs) (IEA 2013, Gartner 2014, Seba 2014, Shaw 2014, Nykvist & Nilsson 2015), car share (Martin, Shaheen & Lidicker 2010, SGS 2012b, Gartner 2014, Shaw 2014), autonomous or semi-autonomous vehicles (PWC 2013, Seba 2014, Shaw 2014, Department of Transport UK 2015), and traffic infrastructure management information systems (Shaw 2014, IET and ITSUK 2014). How this technological transformation impacts on knowledge economy intensification of cities is unclear and seemingly contradictory. It is however important to consider, in some detail, the potential impacts of the technological change, particularly before any assumptions can be made as to the future role of the motor vehicle in knowledge-intensive cities.

14.3.1 Electric vehicles (EVs)

While EVs account for only 1 per cent of the USA passenger annual sales market (IEA 2013, Gartner 2014, Committee on Overcoming Barriers to Electric-Vehicle Deployment et al. 2015) and 0.02 per cent of the worldwide vehicle stock (IEA 2013), there are number of indicators for increased uptake of EVs. One key driver will be the pressure for increased emission and efficiency improvements (Pasaoglu, Honselaar & Thiel 2012, IEA 2013, Gartner 2014, Committee on Overcoming Barriers to Electric-Vehicle Deployment et al. 2015). Gartner (2014) has argued that emission and efficiency improvements cannot come from improving the combustion process alone and realistically, they will require electric motor technology to be a key part of the solution. IEA (2013), Nykvist and Nilsson (2015) and the Committee on Overcoming Barriers to Electric-Vehicle Deployment (2015) each noted that, along with government policy (particularly support for EV public vehicle charging Overcoming Barriers to Electric-Vehicle Deployment 2015), consistently falling battery costs are likely to be a major supply-side driver for EVs in the next decade.

Nykvist and Nilsson (2015) reviewed over 80 different cost estimates from 2007–2014 of Lithium-ion battery packs for EV manufacturers. Industry-wide cost estimates declined by approximately 14 per cent annually and were continuing to decline with the costs among market leaders much lower than previously reported. Nykvist and Nilsson (2015) concluded that future energy and transport modelling should factor in ongoing battery price reductions. Overall, car sales are maturing and close to peaking, making future sales of EVs in this market difficult to predict (Gartner 2014). Seba (2014) has bullishly argued that the electric vehicle will be the overwhelming dominant new sale vehicle by 2030. While long-term predictions on EVs are difficult, strong claims are made as to the overall benefit of EVs over ICEs and ultimately a significant shift across to EVs is seen as a matter of time (Pasaoglu et al. 2012, IEA 2013, Gartner 2014).

How would a significant uptake in EVs impact on knowledge-intensive cities? The impact of EVs can be considered by examining two interrelated factors that could significantly influence mode share:

- The rebound-effect theory and how potential increases in energy efficiency impact on prices and consumer behaviour, and
- How price changes (or public transport elasticities) impact on mode choice between personal vehicles and public transport use.

The shift from ICEs to EVs represents a significant increase in energy efficiency (Went, Newman & James 2008, IEA 2013, Seba 2014, Shaw 2014). Energy economics suggests that energy efficiency innovation, while leading to a reduction in cost per unit, leads to consumers using some of the savings in further energy consumption. That is where a product price falls because of an improvement in efficiency. It becomes cheaper to use and more consumption is induced. This is the 'rebound effect', where the efficiency savings, in part get, lost to or absorbed into increased use or the take up of more or larger products. Herring and Roy (2006) define the 'rebound effect' (or take-back effect) as being the effect that the lower cost of energy, due to increased energy efficiency, has on consumer behaviour at the individual or national level.

The rebound effect occurs across a range of energy uses, though its extent can vary (Greening, Greene & Difiglio 2000). In a mature market, Gottron (2001) has noted that, the rebound effect is generally considered to be limited. The actual rebounds are complex and dependent on a range of variables including the type of device (Gillingham, Kotchen, Rapson & Wagner 2013). Hertwich (2005), considering the rebound-effect energy economic theory in terms of a wider industrial ecology approach, notes that the rebound effect has to be seen in a wider context than just an energy use response. Cleaner product solutions often have secondary effects, which can have substantial impacts. These secondary effects, Hertwich (2005) argues, are less well defined, let alone investigated, with policy considerations often not factoring in behavioural and technological spillover effects or transformational effects. This can be in both positive and negative ways.

The rebound effect was said to be higher where there may be fuel poverty or latent unmet demand for the energy product. That is, the cost of the fuel was limiting greater use of the product or device. Interestingly, fuel economy and automobiles have been subject to a

number of past studies and the rebound effect has been reasonably significant (Gottron 2001, Knittel 2012). Knittel (2012) found that from 1980 to 2006 there was a 60 per cent increase in the fuel efficiency holding weight, horsepower and torque constant. In practice, the fuel efficiency gain was only slightly more than 15 per cent, meaning that much of the rebound effect saw consumers selecting larger and more powerful vehicles. The rebound for vehicles therefore was not realised in increased vehicle kilometres travelled but vehicle 'amenity' (in the form of power and size). BITRE (2014b) reported a similar scenario in Australia prior to 2008, with efficiency gains being taken up in vehicle size, greater power, 4WD capacity or accessories. However, since 2008, with the further development of fuel-efficient vehicles, it was found that there had been an uptake of smaller vehicles leading to a decrease in fuel consumption per new vehicle sold.

The energy rebound effect is therefore not readily or easily translated to predicting the impact of EVs on congestion and spatial planning. Whitehead, Franklin and Washington (2015) found evidence of a significant rebound effect of 1.5 per cent to 12.2 per cent, with increased driving of EV owners in Stockholm, but in part, this could be attributed to a congestion tax exemption policy for EV drivers. A key difficulty is the relatively small uptake in electric vehicles at this point. Haan, Peters and Scholz (2006) undertook a relatively small study of 367 Toyota Prius purchasers in Switzerland and found no rebound effect in terms of usage or size of vehicle compared to other similar purchased ICE vehicles (although the energy efficiency differences between vehicles was not relatively significant). The USA 2009 National Household Travel Survey found hybrid vehicles had higher vehicle kilometres travelled (VKT) than other light passenger vehicles (along with SUVs) (Akar & Goldman 2012). However, whether this higher VKT was due to users with pre-existing higher VKT selecting hybrids or whether the hybrids created an increased VKT is unknown. Where plug-in full EVs may have a more significant energy rebound effect is where there is a significant transport energy saving. This scenario could be where on-going transport energy costs effectively fall to zero. This is plausible where EVs are coupled with decentralised solar – either at home or particularly at workplaces⁹⁹ – due to the significant operational cost reductions (see also Went et al. 2008, IEA 2013, Seba 2013).

The price impact that results in the energy rebound effect can also be considered through an examination of public transport elasticities. Price changes affect public transport use as do other factors such as time and (dis)comfort (Litman 2015). Kenworthy and Laube (2001) found that higher costs of private transport had a significant dampening effect on automobile

⁹⁹ For example, the US Office of Energy Efficiency and Renewable Energy (2014) is promoting a workplace EV charging initiative, seeking a tenfold increase in the number of USA employers offering workplace charging by 2018).

dependence; however, the reverse is also true. Price sensitivities are generally measured using the concept of elasticities, being the percentage change in consumption resulting from a percentage change in price. A key consideration is to recognise that some commuters are public transport dependent and therefore less price sensitive, however, discretionary riders are more price sensitive or elastic (Litman 2015). Elasticities are higher for people with cars and, not surprisingly, increasing fuel prices increases public transport ridership (though more so in the short run than the long run as some consumers elect to purchase more fuel-efficient vehicles) (Litman 2015). The energy cost difference between EV and public transport travel is dependent, in part, on the input cost of electricity. Other technological changes, such as the combined electricity generation for dwellings and personal transport through dwelling-level solar photovoltaic cells (possibly as sunk capital cost) could increase the price difference in favour of EVs. If the relative operating costs of an EV declines markedly in comparison to ICE vehicles, then it is likely there will be even greater price signals driving greater commuter private vehicle use.

Longer-term capital decisions (like purchasing a second car and/or dwelling-level solar photovoltaic cell panels to fuel a household and an EV) could also have a significant effect. This is because longer-term elasticities increase over time (up to two or three times short-term elasticities), as consumers take price changes into account with longer-term decisions (Litman 2015). It is worth noting that where households are induced by a major impact to purchase a second car, the move to private vehicle use may be somewhat irreversible, since once they become accustomed to driving, they often continue (Litman 2015). A scenario in these terms could be recognition by consumers of the fundamental shift with lower capital or operating costs of EVs or price or tax incentives to purchase EVs.

The context for considering potential elasticities between EVs and public transport mode share in Australia can be assisted by consideration of historical trends on urban passenger transport. In Australia, from 1980 until 2004, urban public transport grew at the same rate as light vehicle travel – a quarter of a century of equilibrium in mode share (Cosgrove, Gargett & Mitchell 2009). Since 2004, the equilibrium between public transport and light motor vehicle use has been broken, with public transport use increasing relative to vehicle use (Cosgrove et al. 2009, Gargett 2009; Newman, Glazebrook & Kenworthy 2013). A number of factors have played a part in this, including higher petrol prices, increased CBD employment, higher interest rates, and investment in public transport infrastructure. The trend in the long run, of higher energy prices, renewed economic growth (and presumably concentrated CBD employment), and the growing demands of climate change, is likely to see a public transport mode shift over private vehicle use (Cosgrove et al. 2009). EVs potentially remove some factors from this equation, notably higher petrol prices and climate change. Other factors

driving public transport use remain, particularly increased concentrated employment density. Effectively, urban structure will be a factor heavily influencing elasticities.

The discretion to drive or take public transport is influenced by the size of the city and related factors such as congestion, parking costs and levels of public transport service. Commuter urban public transport plays an important role in alleviating congestion (Cosgrove et al. 2009). In larger cities, with congestion and ineffective or high cost public transport, the introduction of EVs could create greater congestion. Other cost factors other than fuel are also important to note. Parking fees or toll roads cause car use to decline, with the use shifting to public transport (Litman 2015). Parking and tolls often tend to have a greater impact than other vehicle costs such as fuel (Litman 2015). Further service elasticities indicate that improved public transport service levels in terms of availability, convenience, speed, comfort, frequency and priority make a difference in terms of public transport ridership. Again, similar to price sensitivities, service elasticities tend to increase over time. Cross elasticities for vehicle to rail and bus use, consistently across countries, indicates that consumers prefer mode switching to rail over bus (Litman 2015).

This means strategic long-term commitment to quality and value improvements in public transport is important for a city. Litman (2007) cautions that the research on public transport elasticities is somewhat dated, with there now being greater numbers of discretionary public transport riders, and that long-run elasticities are more appropriate for strategic planning. Clearly, it would suggest that (where parking, tolls and urban structure factors are neutral), if EVs reduce the operational costs of private vehicle transport, public transport use will decrease and private car use (and congestion) will increase. What this means in terms of the potential impact of EVs is that the number of people who can switch between public transport and private vehicles will be higher where there is a larger and more price-sensitive commuting market. Government policy initiatives may be influential in this price equation. Government support for EVs, (i.e. an extensive public and workplace charging network, reduced or free tolls, parking or traffic priority and preferences or government subsidies for work-provided EVs – see Mock and Yang 2014¹⁰⁰), could strongly encourage EV commuting, potentially at the expense of more economically sensible modes. Instead of charging for the external costs of commuting, the EV commuting policies could do the reverse, by subsidising the negative impact of EVs.

A consideration of both rebound-effect theory and public transport elasticities suggests that the transition to EVs will be accompanied by possibly strong price signals that will encourage

¹⁰⁰ Also in the USA, the Office of Energy Efficiency and Renewable Energy (2014) promotes EV workplace charging through their EV Everywhere Workplace Charging Challenge <http://energy.gov/eere/vehicles/ev-everywhere-workplace-charging-challenge>

greater private vehicle use. A clear conclusion as to the future mass adoption of EVs on knowledge-intensive cities is difficult to forecast; however, in the absence of appropriate urban and transport policy settings, there is potential for a rebound effect and a notable negative shift in public transport elasticities, which if they were to occur, would likely see an increase in:

- vehicle use, i.e. kilometres travelled, and
- the number of cars owned and used.

These two factors would negatively impact traffic congestion and increase the demand for parking, leading to spatial inefficiencies. This, in turn, would negatively impact on knowledge-intensive centres through limiting accessibility, mobility, and capacity. In this scenario, EV use, in the absence of any strategic government policy interventions, could see the trend to public transport in cities negatively impacted. The potential impacts of EVs also need to be considered in the context of other technological and business innovations.

14.3.2 Car share and ride sharing

Car share and ride sharing also have the potential to transform motor vehicle use. Car share is a membership-based business model providing members with access to a network of vehicles from unstaffed and distributed neighbourhood locations, with minimal effort to check in and out. Car sharing can be defined as the provision of short-term hire of passenger and light commercial vehicles for personal and business uses (SGS 2012b)¹⁰¹. Car sharing provides an increasingly popular alternative to car ownership in a number of cities, while transferring the costs and troubles of purchasing and maintaining a private vehicle to the car sharing provider (Martin, Shaheen & Lidicker 2010, Shaheen & Cohen 2013, Gartner 2014)¹⁰². The fixed costs of private vehicle ownership are replaced by a slightly higher variable cost of becoming a member of a car share scheme. This more expensive variable cost (i.e. incurring hourly and sometimes mileage charges) acts as an increased disincentive to motor vehicle travel, therefore reducing the number of trips, fewer VKT, and increased public and active transport use (Martin et al. 2010, SGS 2012b).

'Peer to Peer' ride-sharing platforms or transportation network companies (TNCs) such as Uber and Lyft rely on social networking to connect independent drivers to passengers who

¹⁰¹ Shaheen and Cohen (2007), in an international survey, found that 'neighbourhood residential' was the predominant car sharing use in the majority of countries. This was followed by 'business', though a small number of countries had business as their largest market. University-based demand for car sharing services has also been growing internationally (Zheng et al. 2009).

¹⁰² By 2012, worldwide, there were an estimated 1.788 million car-sharing members in 27 countries (Shaheen and Cohen 2013). Car-sharing has grown considerably in North American cities during the past decade (Martin et al. 2010, Gartner 2014).

'share' a lift for a fee (Belk 2014, Cici, Markopoulou, Frias-Martinez, & Laoutaris 2014, Cohen & Kietzmann 2014). Ride 'sharing', it has been argued by Pick and Dreher (2015), is not 'sharing' as the drivers are providing a commercial service. Ride sharing has experienced rapid growth and the TNCs have achieved high corporate valuation, which indicates strong market acceptance and customer satisfaction (Cohen & Kietzmann 2014). Ride sharing benefits are claimed to include reductions in traffic congestion and pollution, lower vehicle ownership in cities, reduced urban travel costs, as well as creating parking and drive-time efficiencies (Belk 2014, Cici et al. 2014, Shmueli, Mazeh, Radaelli, Pentland, & Altshuler 2015).

The key characteristic of car share and ride sharing are that they both offer urban residents mobility, via cars, without the necessity of vehicle ownership. Research on car sharing is relatively extensive. Possibly, being a membership based system, assists in the facilitation of research. Survey research of car sharing throughout North America has indicated that members reduce their vehicle holdings to a significant level (Martin et al. 2010). The average number of vehicles per household in this survey reduced from 0.47 to 0.24. Most of this reduction was with one-car households becoming carless. Other research indicates that car share members in North America made fewer trips by cars and their total mileage driven decreased after joining a car-sharing program (Martin & Shaheen 2011).¹⁰³ SGS's (2012b) City of Sydney survey of Go Get members found similar benefits, including car-share members in 2011 reporting a 67 per cent deferred car purchase. Respondents reported that they were walking and cycling more and, significantly, public transport was used more frequently. Further, it was estimated that, on average, one additional car-share space would result in 22 additional car-share members. This increase in membership was therefore estimated to see a net reduction in 12 private vehicles owned. The car-share exemplar project has been the AutoLib program in and around Paris, with the electric Bolloré BlueCar model (Gartner 2014)¹⁰⁴. The Paris car-sharing model has been to saturate the city and its nearby suburbs to provide great flexibility for drivers who primarily walk, cycle or rely on public transportation, but occasionally need access to a car (Gartner 2014).

SGS (2012b), in reviewing opportunities for car share for the City of Sydney, argued that car sharing could play an important role in providing a seamless, integrated transportation service for people that needed to or wanted to reduce or remove their car ownership. Car sharing provided an alternative means of transport, thereby providing more transport options to residents and businesses of a serviced area (SGS 2012b). Car sharing also minimised

¹⁰³ Research in Toronto, Canada by Costain et al. (2012), on the behaviour of car-share members, found that car sharing was most often used for off-peak travel or on weekends, i.e. when public transport services were poor and traffic congestion low.

¹⁰⁴ The Paris program, Gartner (2014) noted, has had high growth since its inception in December 2011, averaging 62,000 rentals per week and was expected to expand to 3,000 cars by the end of 2014.

the need for public and private car parking space, providing the potential for more land to be used for higher order activities (Shaheen, Rodier, Murray, Cohen & Martin 2010). In this sense, car sharing enables intensification of urban transport space. Further, while car sharing and ride sharing does not necessarily increase accessibility at peak hours, it does increase day time and later evening accessibility and mobility, both in terms of flexibility and networking between centres. Indirectly, if there is less demand for parking, this increases opportunities for better urban design and increased walkability. This, therefore, is likely to increase circulation and mobility within activity centres.

14.3.3 ITS (Intelligent Transport Systems) and ICT for Road Infrastructure) and Autonomous Vehicles (AVs)

Intelligent (road) transport (management) systems (ITS) and ICT are presently technically capable of being widely applied to increased road system efficiency (PWC 2013, IET & ITSUK 2014, Shaw 2014). ITS and ICT allow for the monitoring of activity on the road network, as well as predicting what may happen. This provides the means to manage transport proactively on an area-wide basis (IET & ITSUK 2014), as well as assist motor vehicle autonomous driving and vehicle-to-vehicle communication (Anderson, Kalra, Stanley, Sorensen, Samaras & Oluwatola 2014, Shaw 2014). ITS and ICT are seen as a means to increase road capacity without necessarily further investing in the physical road space – effectively, the opportunity exists to intensify the use of the road network for much lower costs (IET & ITSUK 2014). Much of the focus of ITS in Australia has been on improving the efficient network operation of major freeways and key roads rather than vehicles (Doyle 2014, Main Roads WA 2014). Notably, in Australia, there has not been full utilisation or effective use of IT systems in traffic management (see Doyle 2014 in respect to metropolitan Melbourne and the Main Roads WA 2014 ITS strategy which dates from 2005).

Perhaps the most revolutionary ICT and ITS opportunity, though still in its infancy in terms of its application, is semi-autonomous and autonomous vehicles¹⁰⁵ (PWC 2013, Anderson et al. 2014, Shaw 2014). ICT is now effectively sufficiently advanced that ITS and vehicles with semi or fully autonomous driving capability can be expected to start to provide a far higher level of efficiency in road transport network (Anderson et al. 2014, Shaw 2014). The industry research estimations on the broad availability of autonomous vehicles (AVs) is that they will be widely available by 2020 (Navigant Research 2014) or 2025 (ABI Research 2013), though significant regulatory and liability hurdles are yet to be resolved (Anderson et al. 2014, Navigant Research 2014). Navigant Research (2014) forecast that autonomous

¹⁰⁵ Autonomous vehicles ultimately are where the motor vehicle can drive itself without a human driver, freeing up the human to safely engage in other activities (Anderson et al. 2014).

vehicles will gradually gain market traction, and by 2035, 75 per cent of all light duty vehicles will be of autonomous.

Potentially, the largest impact of AV (coupled with car share) is a large reduction in private ownership of vehicles; possibly as high as a 99 per cent reduction according to the bolder predictions (see PWC 2013). The impacts of AVs are however likely to be contradictory, in that while some impacts should drive reductions in road congestion, other impacts will likely induce greater demand. Anderson et al. (2014) predicts that an obvious impact will be that congestion should improve due to the reduction in human-caused road accidents and the increased efficiency of autonomous driving. That is, AVs will have the ability to constantly monitor surrounding traffic and respond with finely tuned braking and acceleration adjustments to enable AVs to travel safely at higher speeds with reduced headway (space) between each vehicle. Ultimately, a group or platoon of closely spaced individual AVs could move, stop or slow down as a single unit. This has been referred to as 'platooning'. Platooning is the proposed act of cars autonomously and cooperatively following their leaders to form a road train (Fernandes & Nunes 2012, Jonsson, Kunert & Bohm 2013, Segata, Lo Cigna & Dressler 2013). Fernandes and Nunes (2012) have noted that the key driver for platooning is that road space demand tends to always surpass supply. While the mobility of urban inhabitants and goods is a requirement of cities, more road network construction is not always viable and might not be economically or socially beneficial.

The problem for cars is the need to improve existing road capacity (effectively intensifying road space) through reducing both travel time and traffic congestion. Platooning has huge potential to increase spatial efficiency, while reducing energy consumption, improving traffic flow efficiency and driving experience on freeways, and most importantly, improving road traffic safety (Jonsson et al. 2013, Segata et al. 2013, Segata, Bloess, Joerer, Sommer, Gerla, Lo Cigno & Dressler 2014). Fernandez and Nunes (2012, p. 94) have theorised that optimal platooning is eight vehicles in a chain – to increase lane capacity from an ideal present-day scenario of around 2,500 vehicles an hour to 9,443 vehicles per hour. This would increase the density of vehicles from 50 to 131 vehicles per kilometre of road space. This is, however, a relatively limited intensification compared to existing rail capacities (see **Figure 41 Operating capacities and speeds of different urban transit modes**). Logically, platooning could also occur with multi-people vans or buses or other new vehicle types. This would further intensify road-based public transport. This, arguably, is more akin to a form of public transport. However, a limitation to be addressed would be the multiple origins and destinations. This could be addressed through clustering locations with vehicle technology adapting to that requirement.

Platooning is seen as the most visionary end result of autonomous vehicles, though it is likely to be extremely challenging (Segata et al. 2014). These challenges are numerous and solutions will need to encompass control theory, vehicle dynamics, transportation engineering, traffic modelling, communications, energy, computer science and wireless networking (Fernandes & Nunes 2012, Segata et al. 2013). Fernandes and Nunes (2012) noted, for example, that one second in reaction time delay leads to a lack of string stability in the vehicle platoon. This means there would need to be fully autonomous systems. Fernandes and Nunes (2012) also see platooning optimally occurring, with vehicles evolving onto dedicated tracks and operating on a nonstop basis from origin to destination, eliminating the stop-and-go problem of common car and transit systems. Potentially, AVs and platooning could also be applied to car-sharing vehicles with automated parking, managing and assisting in redistributing vehicles and reducing parking space requirements in centres (Marouf, Pollard & Nashashibi 2014). Intensification through platooning would however be greatly assisted by a change in the size of motor vehicles. The standard Australian large sedan car is five metres¹⁰⁶ in length, though Fernandes and Nunes (2012) relied on only three metres in length for the vehicle architecture in their modelling.

Another impact AVs could have, is in respect to driverless car services, which could reduce trips during congested periods and improve spatial density by reducing parking requirements in centres. Effectively, AVs would enable car sharing to evolve to a driverless taxi system that, over time, replaces traditional taxi services, car-sharing, TNCs like Uber and Lyft, and possibly even transit lines (Anderson et al. 2014, Fagnant, Kockelman & Bansal 2015). This new AV business model has been referred to as 'shared autonomous vehicles' (SAV) (Fagnant et al. 2015). Fagnant et al. (2015) expect that SAVs are likely to be a significant cost-saving factor over taxi services. Burns, Jordan and Scarborough (2013) estimated, using a low (marginal) cost of just \$2,500 for self-driving automation capabilities, that SAVs, compared to taxis would reduce costs in Manhattan from \$7.80 to \$1. This was mainly due to the driver automation removing the human labour cost. Even with higher automation costs, Fagnant and Kockelman's (2014) concluded that SAV costs could cut taxi fares by around a third. Additionally, SAVs are also likely to operate under more optimal operating systems than TNCs like Uber and Lyft. Fagnant et al. (2015) argued that TNCs are more similar to SAVs (than to taxis) due to their more centrally managed framework, although similar to taxi, there is a degree of operation decision-making left to the drivers. SAVs would have the advantage of being 100 per cent centrally controlled with operational automation,

¹⁰⁶ Car length for a large sedan in Australia can be obtained from *Australian Standard for Parking Facilities AS 2890.1-2004*. A large car (called the 'B85') is classified as being the 2004 Falcon measuring 4.91 x 1.87 metres in length x width. Eighty-five per cent of vehicles are equal to or smaller than this. The largest cars are 4WD vehicles, with the Toyota 100 series Land Cruiser at 5.2 x 1.94 metres being used as the standard largest car (B99) with 99 per cent of cars being equal to or smaller.

which would provide a higher level of service at lower costs. There are also spatial advantages with SAVs in metropolitan areas as a result of increased density and a decreased need for home and proximate parking.¹⁰⁷ Another consideration is that SAVs and decreased rates of car ownership would mean fewer parking spaces are needed, thus permitting greater density. Another key benefit for commuters (particularly knowledge-intensive workers) will be the increased capacity to undertake work-related activities while in the moving vehicle rather than undertaking driving activities (Anderson et al. 2014).

Fagnant et al. (2015) have simulated SAVs at a low level of market penetration (1.3 per cent of regional trips) for trip patterns in the central metropolitan area (19.2km x 32km) of Austin, Texas. The simulation showed that each SAV would be able to replace around nine conventional vehicles; however, it would create an additional 8 per cent increase in VKT, due to SAVs travelling unoccupied to the next trip, or relocating to a more favourable position in anticipation of demand. This simulation relied on existing demand patterns and did not consider induced VKT demand from previously mobility-constrained persons. Arguably, the door-to-door convenience of SAVs would be higher as there would be no parking cost (in terms of monetary or time), which might lead to increased demand and tend to promote additional VKT (Anderson et al. 2014). Increased VKT from AVs and SAVs would also likely come from increased trips by previous non-drivers (e.g. elderly, disabled, and those under driving age) (Anderson et al. 2014). Further increased demand for SAVs is also likely from existing public transport users, if the forecasted cost reductions are achieved. This is because lower costs of SAVs are likely to impact on public transport mode share, based on understanding how public transport elasticities work. That being, there is likely to be an increased demand and price-driven shifting across to SAVs from price-sensitive public transport users. This would suggest that the VKT increases could be underestimated.

AVs and SAVs therefore could lead to an increase in total VKT, which could lead to more congestion, particularly on roads where platooning is not suited. There could also be longer commuting and personal trips, with some households choosing to live in remoter or more distance areas, where housing is more affordable or amenity higher. This would also mean population dispersment further from the urban core and could lead to low-density patterns of land use surrounding metropolitan regions. This would have potential negative impacts for agglomeration if it limited the development of larger denser knowledge-intensive centres. However, there are potential benefits to knowledge intensification with road infrastructure information management systems plausibly leading to increased intensity of road use, providing a greater level of road-based economic output. However, this may not necessarily

¹⁰⁷ Assuming that after dropping off passengers, the SAVs drive away to satellite parking areas or undertaking other driving jobs.

address congestion as it may induce increased traffic volumes and VKT. Car sharing and AVs are likely to have positive impacts on knowledge intensification because of the potential for reduced private motor vehicle use; however, AVs/SAVs could, along with EVs, lead to increased VKT and more dispersed development. Therefore, the overall effect of AV technology on congestion, Anderson et al. (2014) has argued, is uncertain, though possibly significant and fundamental. As with EVs, if the advent of AVs and SAVs is not subject to strategic policy decision-making, the outcomes could be negative for the knowledge intensity of cities. Anderson et al. (2014) has proposed that careful policymaking will be necessary to maximise the benefits of AVs while minimising the negatives, though they note policymakers in the USA are only beginning to consider the impacts of this technology.

The potential overall impact from the technological transformation of road-based transport on the knowledge economy intensification of cities is therefore not clear and potentially the impacts could be contradictory. The complexity of new technology and the potential impact on road transport systems requires a fundamental understanding of the key economic functions of a city's metropolitan area and how the city's transport system supports or otherwise impacts on its economy. Such an understanding will be important to avoid a narrow judgement of a city's future economic function based on past practices based on a road-dominated economy.

If AVs and EVs are adopted by consumers relatively quickly (within one to two decades) without an appropriate policy setting, a range of negative consequences could occur, which may be difficult to reverse. Arguably, this suggests a fundamental need for strategic, consistent policy making on the introduction of AVs/EVs as the key opportunity to establish the cultural and elasticity settings for the AVs/EVs on their introduction. The potential distortion of public transport elasticities and negative energy rebound impacts of AVs/EVs could be tempered by a range of policy factors underpinning public transport mode share. A mature market, as a means of minimising impacts of the public transport elasticities and/or the energy rebound effect, could occur where urban and transport policy settings seek to ensure transport price mechanisms alone are not the key driver of commuter behaviour. Such policy settings may need to include support for:

- Public transport and active transport support and infrastructure investment,
- Employment densities in key centres, i.e. density at journey destinations
- Increased support and adoption of car share and ride sharing
- Parking limitations in terms of accessibility through regulations and pricing, particularly in knowledge-intense centres,

- Congestion charging or tolls on key commuting radial roads
- Quality higher residential density at journey origin
- Support for improved 'access sheds' around key public transport hubs and employment centres.

The above factors are inherent in supporting mode share for public transport and, once established, would provide a strong framework for tempering the negative and enabling the positive impacts of road-based technological change.

If forward-thinking regulatory and policy support is delivered, there is potential for the knowledge intensification of the road system. There will need to be on-going research to understand these potential opportunities for road intensification relative to rail and other forms of public transport. As is already apparent, there is likely to be integration and merging of transport modes. The greatest limitation on road intensification is likely to be spatial constraints on associated road infrastructure capacity (notably freeway off and on ramps and street circulation at destination both potentially impacting walkability). The ideal future outcome may be a system of high-capacity fixed rail providing accessibility into dense knowledge-intense centres, supported by SAV ride sharing services through providing accessibility to public transport stations (i.e. providing 'last mile/first mile' services) and more general non-peak mobility and accessibility.

Chapter 15 Public transport and knowledge intensification

15.1 Public transport modes

Public transport (or in the USA 'transit'), according to the US Transportation Research Board (TRB) (2003), is a multifaceted concept that deals with the movement of people and vehicles and depends on the size of the transit vehicles, how often they operate, and the interaction between passenger traffic and vehicle flow. Public transport is generally considered to cover fixed-route and scheduled urban passenger transport, covering modes such as bus, bus rapid transport, light rail, heavy rail and commuter rail (TRB 2003, Vuchic 2005). Differences between public transport modes (i.e. between heavy and commuter rail, and between heavy and light rail/trams) are not always clear. For the purposes of this thesis, the TRB (2003) categories are used, with the Australian suburban rail services on wholly separated lines being referred to as 'heavy rail'¹⁰⁸ or 'rail' (as distinct from 'light rail'¹⁰⁹). 'Heavy rail' would include Perth's and Sydney's metropolitan rail systems, while Sydney's longer distance inter-urban rail services would be classed as 'commuter rail'.

Arguably, the key transport tasks for knowledge-intense centres relates to accessibility and capacity – that is, providing commuting access, reach and scale to concentrate sufficient number of employees and service providers from wide and large metropolitan areas into a relatively few numbers of (generally central) agglomerated centres. This means high-volume, high-frequency spatially intense transport is required to create a density of knowledge workers and activity. It has been recognised by the NSW and WA state governments that public transport is essential for the continued expansion of (effectively knowledge) economic activity in major capital city CBDs (Richardson 2010, Department of Transport NSW 2013). In the Sydney Centre Access Strategy (Department of Transport NSW 2013), it was concluded that future strong growth in Sydney's CBD working population would have to be met mainly by public transport, meaning the transport for a centre such as Sydney CBD had to be considered completely differently to the rest of the metropolitan area. Richardson (2010) noted that it was in the 1990s that the WA State Government recognised that commuting patterns for the CBD had to radically shift from low-capacity, congested car-based transport to public transport to avoid limiting accessibility and restricting capacity.

¹⁰⁸ Heavy rail is characterised by fully grade-separated rights-of-way, high-level platforms, and high-speed, electric multiple-unit cars. The expeditious handling of passengers is enabled through the use of long trains of up to 11 cars running frequently. Loading and unloading of passengers at stations is rapid due to level access and multiple double-stream doors (TRB 2003).

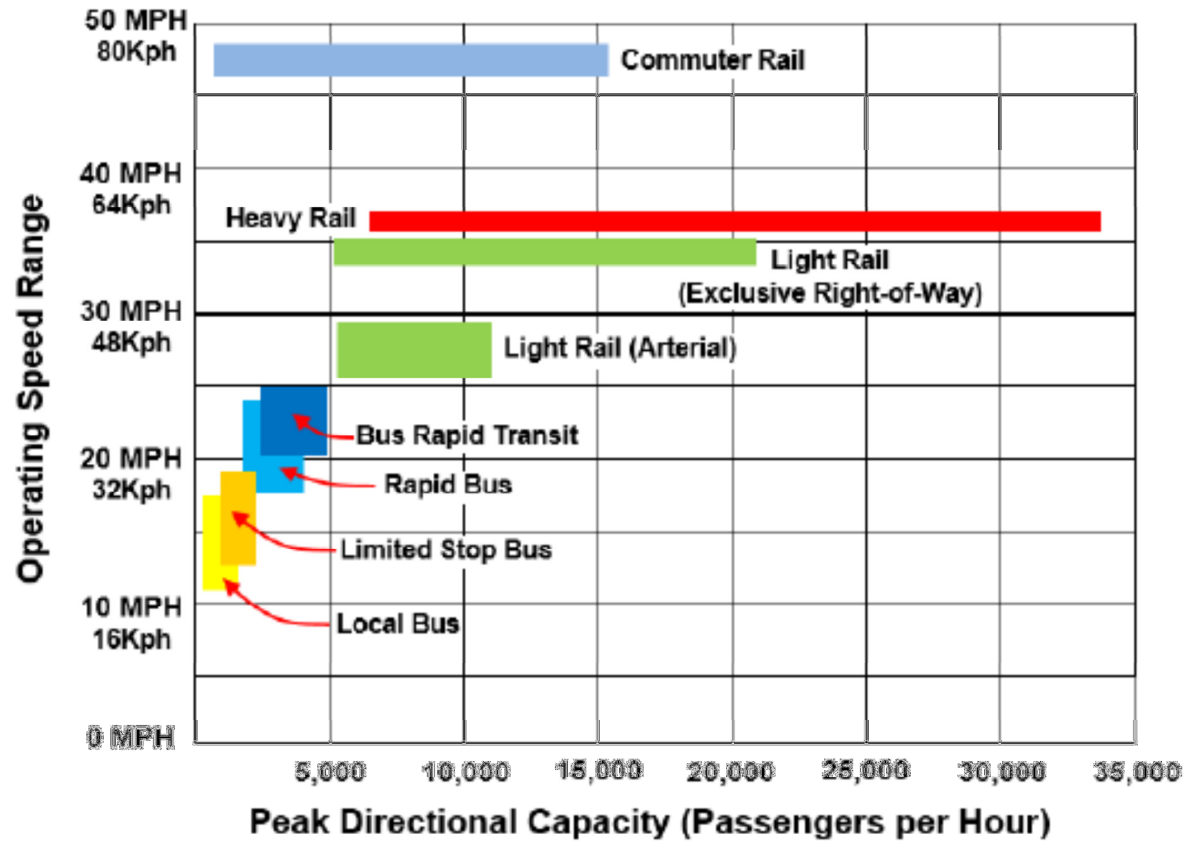
¹⁰⁹ Light Rail Transit (LRT) is usually used to describe modern low-floor trams operating in a right-of-way separate from other vehicle traffic. Trams are generally considered to be older vehicles, often with steps to access, with services running on-street as 'streetcars' but can have some degree of segregated right of way (Currie & Burke 2013).

15.2 Public transport – accessibility and capacity

In considering public transport, in terms of both accessibility and capacity into knowledge-intensive centres, it is necessary to regard its effectiveness versus commuting car use (the car being the main competitor in terms of accessibility and capacity). As noted previously, price and other factors such as time and (dis)comfort affect public transport use (Litman 2007, 2015, McIntosh et al. 2013). The competitiveness of public transport against private motor vehicle commuting can be converted to 'generalised costs' of either mode – i.e. generalised costs being travel time, financial and opportunity costs (see Hensher & Chen 2010, McIntosh et al. 2013, Legaspi et al. 2015). The 'generalised costs' impact on the mode-choices people make (effectively the 'elasticities' between the two choices). In this sense, the accessibility and capacity of a public transport system is not simply a matter of the physical characteristics of a transport network or a city, but is also heavily influenced by government or operator policy and pricing (Mees 2010, McIntosh et al. 2013).

Public transport modes also need to be considered in terms of their capacity to deliver sufficient agglomerative density and scales. Figure 41 illustrates the capacity of the various public transport modes, in terms of operating capacity and speeds.

Figure 41 Operating capacities and speeds of different urban transit modes



Source: McIntosh et al. 2014 adopted from the *TRB (2003) Transit Capacity and Quality Service Manual*

The TRB (2003) has concluded that public transport in the USA is essential for accessibility and mobility into the CBDs and other concentrated employment centres in a number of major cities.¹¹⁰ Different modes of public transport have different capabilities in terms of providing accessibility and capacity. According to Queensland Department of Transport and Main Roads' analysis, fixed and separated rail outperforms all other public transport modes, with a single rail service of six train carriages or a subway carrying the equivalent number of people carried by 625 to 833 cars, compared to 208 for light rail and 40 for buses (DTMR 2011, p. 28). Public transport trips can be both time and cost competitive to private motor vehicle use, particularly where there is exclusive right-of-way operation. TRB (2003) identified the key characteristics of the differing public transport modes. Fixed reserved route systems (particularly with fixed rail), along with a greater service provision and more public transport investment are associated with greater public transport usage, particularly for dense employment and population centres (Kenworthy & Laube 2001, TRB 2003, BITRE 2012b). This is largely due to separated, reserved routes avoiding stop signs and conflict with cars, effectively increasing speed and usage. Further, McIntosh, Trubka, Kenworthy and Newman (2014) found that the quality of rail services was most strikingly linked (over other forms of public transport) to reduction in car VKT per capita.

Heavy rail's advantage over buses (and often light rail), in terms of accessibility and capacity, is its increased speed arising from its use of fully separated and reserved transit space, higher standard platforms and its larger train multiple car carriage carrying capacity. This advantage makes it the most efficient at moving large volumes of passengers in densely populated areas (TRB 2003, BITRE 2012b)¹¹¹. As in Australia, the largest metropolitan areas in the USA are dependent on heavy rail transit for the existence and economic operation of their CBDs as their densest urban areas (BITRE 2012b)¹¹². Notably, TRB (2003) found that the newer USA rail systems tended to place a higher value on operating speed with greater spacing distance. This value on speed was especially so in suburban areas. In terms of accessibility at origin stations, often in suburban locations, lesser network coverage and greater distances between stations meant that accessibility to stations and services was generally lower for heavy rail than it was for other public transport services.

¹¹⁰ Public transport carries a majority of all peak-hour travellers to the CBD, particularly in the older major North American cities. This is more than two-thirds to or from the New York, Chicago, and Toronto downtown areas, and more than one-third for most other CBDs of other major North American cities. In the densely occupied core of lower Manhattan in New York City, 84 per cent of morning commuters arrive by public transportation (TRB 2003).

¹¹¹ Bradfield's (1916) research on the pedestrian movements in high capacity of electric railway system in early 20th century Europe and USA is still pertinent today.

¹¹² In 1995, 51.9 per cent of business day travel into Lower Manhattan was by heavy rail transit. During the 7:00 to 10:00 a.m. time period, this share increased to 62.2 per cent. Rail transit plays a vital role in five metropolitan areas, carrying over 50 per cent of all work trips and, in three regions, over 70 per cent of all downtown-oriented work trips (TRB 2003).

Perth's heavy rail system is the highest capacity part of the Perth public transport system, which delivers 60 per cent of peak-hour commuters into the CBD, with rail increasing its patronage share significantly since 1990 (Richardson 2010, BITRE 2012b). Rail's overall patronage went from 7 million in 1992 to 59 million in 2010–2011. This has been driven by a number of factors, but particularly with network expansions with the opening of the Joondalup/Clarkson and Mandurah lines (BITRE 2012b, McIntosh et al. 2013). BITRE (2012b) found the Transperth rail system, with its frequent services, good reliability standards and high average speeds over much of the network, as arguably, Australia's highest-standard urban rail system. McIntosh et al. (2013) have contended that the newest line, the Mandurah line, with speeds of up to 137 km/hr and average speed of almost 90km/hr, acts more like a new high-speed rail than a typical Australian suburban rail system. Suburban rail typically averages only around 40km/hr for all-stops services (McIntosh et al. 2013). Perth's rail system is particularly noted for its longer distances between stations. This suggests limitations on station accessibility. However, once station access is achieved, destination access is enhanced by the higher train speeds and higher frequency services (provided by the greater stations distances and lesser station dwelling times) (Martinovich 2008, BITRE 2012b, McIntosh et al. 2013). Fixed rail, particularly in lower density cities, requires station accessibility strategies such as park-n-ride and/or integrated rail-bus networks (Mees 2010, McIntosh et al. 2013) or other non-road means of enlarging the ped-shed to a higher reach access shed (LA Metro/SCAG 2013). This means accessibility to origin stations on Perth's existing radial services is crucial in respect to overall accessibility of the system.

In Australian urban public transport, trip mode split is evenly split between buses and heavy rail, with heavy rail increasing its patronage, notably in later part of the 20th century (Cosgrove 2011).¹¹³ Heavy rail however dominates all other public transport modes in terms of kilometres traveled per person (Cosgrove 2011). For all types of road-based modes of transport, buses are the most spatially intensive. While buses account for a relatively small proportion of the vehicles in a traffic stream, they can carry a sizable part of the total person flow (TRB 2003, Department of Transport NSW 2013, Devney 2014). TRB (2003) noted that there are effectively two types of bus systems – bus rapid transit (BRT) and mixed traffic bus systems.¹¹⁴ Bus systems can also be classified by their network attributes depending on their stopping pattern, whether they focus on commuting to the CBD, whether they service the CBD or not, and their service levels (Devney 2014).

¹¹³ Buses, as at 2000, prior to the rail revival, were the most commonly used form of public transport in North America (TRB 2003).

¹¹⁴ Devney (2014) has noted that bus systems can also be classified by their network attributes depending on their stopping pattern, whether they focus on commuting to the CBD, whether they service the CBD or not, and their service levels. This diversity reflects the flexible nature of bus systems.

BRT typically uses a two-way roadway in a segregated right-of-way designated for the exclusive use of frequent bus services with maximum operating speeds of 70 to 80 km/h range accommodated by providing passing lanes at stations (NTB 2003, see also McBrayer 2003, Bus Industry Confederation 2014). BRT stations often resemble light rail stations in scale with BRT also providing high accessibility for commuting services. BRT is most successful (Hendrigan and Newman 2013) where it:

- has few stops (1km apart at minimum),
- operates along a very recognisable transit corridor,
- operates on a separated road,
- has very little or no diverging corridors,
- has strong origins and destinations (including employment or business destinations), and
- has signal priority.

BRT provides superior quality of service and/or capacity benefits over mixed-traffic bus operations and is capable of providing capacity to light rail levels (McBrayer 2003). Arguably, light rail has additional customer attractions even with equivalent frequencies, such as increased comfort and customer preference for rail (WA Department of Transport 2011). The differences between BRT and light rail will likely diminish with technological change. Electric buses deliver an improved smoothness in the ride, compared to the internal combustion engine buses because of electric traction and regenerative braking systems (Kuhne 2010, Wang, Fu & Liang 2010).

Operating buses in general traffic lanes results in both buses and general traffic being subject to delays, with buses impacted by traffic congestion and general traffic slowed as buses stop to serve passengers (NTB 2003). As urban densities have increased, frequent mixed-bus services in Australia have become slower and more unreliable (Devney 2014)¹¹⁵. Devney (2014) has argued that bus systems in Australia are capable of increasing accessibility and capacity with better system design, with the need to focus on simpler routes, faster more dependable services with greater bus priority and better connectivity. Consistent with this argument is WA's Department of Transport's (2011) transport plan that foresees most of Perth's outer-suburban new-growth corridors being served by road-based services, though with these services having substantial priority over general traffic.

Light rail also provides for potential conflicts with vehicles and other road users (TRB 2003, Currie & Smith 2007, Currie & Burke 2013). This is more so with older tram streetcar

¹¹⁵ Mixed-traffic bus operations in the USA are the predominant system with over 99 percent of total bus route distances (NTB 2003).

systems such as Melbourne with its much lower levels of road separation (ranging from a low of 7 per cent to 22.9 per cent within routes) than with much higher separations on the Adelaide–Glenelg route (89 per cent) and Sydney light (79 per cent) (Currie & Burke 2013). With the new Gold Coast light rail operating in two key commercial centres, the route reverts to streetcar operations with mixed traffic (Currie & Burke 2013).

Australia's tram and light rail systems are generally radial in nature, with only two tram routes in Melbourne not being radial in nature (Currie & Burke 2013). Light rail radial services are mainly from inner and middle metropolitan areas, with overall average route length of tram services in Australia being only 9.3km (Currie & Burke 2013). Light rail and tram networks however, have much fewer passengers per hour travelling capacity than heavy rail (TRB 2003). In recent years, public transport accessibility and capacity has been increasingly provided by light rail in a number of Australian cities, though from a low base. The volume of tram travel to work has grown at a higher rate than total work travel by public transport in all cities with light rail (Currie & Burke 2013). However, Adelaide and Sydney growth rate performances have been highest. The strong growth in light rail use has resulted from increased services and added routes, with additional system capacity linked to the increasing inner urban residential populations and strong employment and commercial growth in Australian city CBDs (Currie & Burke 2013).

Inherent in older tram streetcar systems such as Melbourne, where there is potential conflict with vehicles, are tram stops that present safety, accessibility and transport efficiency challenges (Currie & Smith 2007, Currie & Burke 2013). The Melbourne streetcar based system, the largest light rail network in the world, has some of the slowest light rail speeds in the world (with average speeds of 15km/hour¹¹⁶), being increasingly impacted by traffic congestion (Currie & Cliche 2008, Currie & Burke 2013). Average speeds on Australia's tram services are lower than the average services in Europe (32 per cent lower) and North America (5 per cent lower) (Currie & Burke 2013). Newer light rail systems in Australia have higher average speeds (with much greater level of route segregation) than Melbourne, with Sydney averaging 34.6km per hour and Adelaide averaging 33.1km/hour (Currie & Burke 2013). These speeds are however notably slower than the Perth to Mandurah rail line average of almost 90km per hour (McIntosh et al. 2013).

Frequency of stops also impacts on travel times. Stop spacing in light rail and tram systems are notably short in Australia. This is mainly a legacy of the Melbourne Streetcar network with stop removal being a major priority of the Melbourne operator (Cliche & Reid 2009,

¹¹⁶ Yarra Trams report a slightly higher average speed of 16km, though the CBD trams are slower at 11km (Yarra Trams 2015).

Currie & Burke 2013). The proposed Perth–Mirrabooka light rail line provides for station spacing of an average of 1.47km over its 22km route (Currie & Burke 2013), a much narrower spacing compared to the Mandurah line (a station spacing of 6.54km i.e. 11 stations over 72km). The proposed Mirrabooka light rail though is comparable to the Fremantle line on non-peak services (a spacing of 1.24km¹¹⁷). Essentially, the shorter station spacing and potential for road conflict (which are not fully avoided in newer light rail systems in Australia (see Currie & Burke 2013) means that light rail is inherently more competitive than private vehicle road commuting in denser areas when origins and destinations (such as CBDs) are much closer. This is reflected in shorter routes of light rail compared to heavy rail. Impacting also on light rail's accessibility and capacity has been the service levels (frequency and span of hours¹¹⁸), which are particularly low on Australian light rail compared to European and North American systems. This is despite Australian light rail operating in higher residential and commercial activity densities compared to average routes in Europe and North America (Currie & Burke 2013). Notably, this is telling because service frequency has been identified as one of the most influential ridership factors (Currie et al. 2011).

Beyond public transport modes and service levels, there are a range of other factors that impact on public transport accessibility and capacity. These include the form of urban development, infrastructure priorities, and the competitiveness of motor vehicle travel in terms of speed and pricing, which all have a major influence on public transport effectiveness (Newman & Kenworthy 1999, Kenworthy & Laube 2001, Scheurer & Curtis 2008, Glazebrook 2009, Mees 2010, SGS 2012a, McIntosh et al. 2013). Cervero and Guerra (2011) have argued that fairly dense urban development is an essential feature of a successful public transit system. Job and population densities have been found to be important within, as well as across, public transport systems. Cervero and Guerra (2012), in their USA research, found general support for using a 400m catchment area for jobs around transit and an 800m catchment for population (see also Mathur 2014)¹¹⁹. Heavy rail in the USA, Cervero and Guerra (2011) found, needed 60 person per gross acre (24.3 per person gross ha) to place them in the top one-quarter of cost-effective rail investments. Glazebrook (2009) found that increasing the density of settlement to 60 or more people per hectare increased public transport to work trips, as does a person's residential location being within 20km of a CBD. In Perth, the likelihood of workers using public transport has been

¹¹⁷ Assuming a stopping pattern with all 15 stations over 18.7km.

¹¹⁸ Average peak-direction headways are 8 minutes for Melbourne routes, 10mins for Adelaide, and 12 mins for Sydney. Australia's most frequent tram routes are Melbourne route 19, 55 and 57 with an average effective headway of 5.5mins (Currie & Burke 2013).

¹¹⁹ Mathur (2014) considered a wide international body of literature that quantified the land value impacts resulting from the development of rail transport infrastructure. A common finding was the increase in the value the closer the property was to the public transport stop. This was most commonly differentiated around 400-500 metres, and 800-1,000 metres from the stop.

determined by employment density at destination, with the Perth CBD being overwhelmingly the main destination focus of the public transport system (Martinovich, 2008, McIntosh et al. 2013). In the USA, Barnes (2005) has also found that employment destination is important for increasing public transport use.

This is not to say other factors do not play a role in delivering successful public transport. Brown and Neog's (2012) analysis of USA cities with more than 500,000 people questions the relationship between the strength of the CBD and public transport ridership. Their analysis suggested that frequency of service and lack of car ownership were stronger factors. This is consistent with Kenworthy and Laube's (2001) study using comparative data of a wide range of land use, transport, economic and environmental variables across 100 cities worldwide. This study found that the spatial intensity of public transport services was by far the strongest explanation in the modal share of public transport in cities. A similar conclusion was also reached by McIntosh et al. (2014) when looking at urban form and public transport use from 1960–2000 in car dependent cities across 26 Australian, European and North American cities. McIntosh et al. (2014) found that while location effects were important, public transport service levels and urban density played a significant part in the split between car and public transport use. In particular, rail services had the strongest link to reduced car use. Similarly, Mees (2000 & 2009) questioned the link between urban density and public transport use, asking whether transport policy was more significant than density. McIntosh et al.'s (2013) examination of the Perth to Mandurah rail line supported, in part, this argument. This was particularly in respect to the benefit of having an appropriately designed and managed transport system as well as the irrelevance of density at origin. Overall, the evidence is strong that car ownership, and residential and employment density are all linked. Higher density provides a higher market demand and price for space (and therefore there are limits on commercial and residential motor vehicle parking spaces). This increases the cost of vehicle ownership and therefore reduces ownership levels. In turn, this provides opportunities for more cost-effective alternatives such as public transport.

There is little to dispute that urban employment or residential density in key centres such as CBDs is characterised by high public transport use. As discussed previously, urban density at origin as a factor driving public transport use is less clear in Australia. Martinovich (2008) and McIntosh et al. (2013) have noted that low-density suburbia was not precluded from relatively high public transport patronage. In particular, park-n-ride coupled with effective bus transfer has been found to be very effective in delivering rail patronage in low-density suburban areas of Perth (Martinovich 2008, McIntosh et al. 2013, 2014). Park-n-rides have been criticised by Mees (2010) as wasting valuable land for transit-oriented developments (TODs), being popular for peak-only commuting travel, and potentially increasing peak car trips through taking people off feeder buses. McIntosh et al. (2013) have also noted that the

lower density around Perth to Mandurah rail stations holds a high level of latent value. Arguably, the relevance of origin TODs depends on whether the combined patronage numbers arising from any park-n-ride facility and an effective networked bus transfer system deliver more patronage to the network than a walk from an origin TOD development. This of course can change over time.

TODs are also defined by the concept of the ped-shed. The LA Metro and LA County (2013) have sought to provide means of extending the traditional ped-shed to a wider 8km access shed, i.e. beyond the walk on ped-shed of an origin TOD. These means include; better quality urban realm, cycling and electric assisted devices. It could also be argued that multiple suburban *destination* TODs (centres of local employment or services) are not essential for knowledge economic activity within a metropolitan area.¹²⁰ The key characteristic of high agglomeration knowledge cities is a relatively few number of spatially dense knowledge-intense destination centres (Levy & Gilchrist 2012). The fewer number of destination centres provides for a maximising of the size and scale of economic activity and therefore agglomeration. TODs though arguably play a part in the wider urban efficiency by increasing the overall opportunities for suburban residential urban density within a metropolitan area (Newton, Newman, Glackin & Trubka 2012, Holz & Kane 2015) enabling greater regional agglomeration. Urban density, coupled with an efficient transport system, can help give effect to the largest possible labour market through reducing the overall transport task (Prud'homme & Lee 1999) and hence agglomeration (Knudsen et al. 2008, Rosenthal & Strange 2008, World Bank 2009, Glaeser & Resseger 2010, Abel, Dey & Gabe 2012, Hensher et al. 2012, SGS 2012a). Prud'homme and Lee (1999) found the effective labour market was a function of the geography of the area, the relative location of jobs and homes, and the efficiency of the transport system. The avoidance of sprawl through urban density can therefore enable more efficient transport through higher public transport use.

15.3 Public transport – flexibility and network effect

A key factor for the effectiveness of the public transport system for both flexibility and accessibility is having a network structure. High public transport patronage has been linked to a public transport system having network coverage and service frequencies across modes that offer a viable alternative to the motor vehicle for many travel purposes (Laube 1998). A networked public transport system increases the flexibility of journey choice as well as the accessibility and reach of the public transport system in terms of passenger destination.

¹²⁰ This is not to say that destination TODs (as well as origin TODs) do not have other urban planning and wider policy benefits (i.e. providing accessible local services and good, reducing obesity through reducing motor vehicle use, reducing household costs associated with vehicle ownership and creating land efficiency).

Increased network journey choices in particular increase public transport's accessibility to centres other than CBDs.

Derrible and Kennedy (2009) found, in a study of international subway networks, that good network design and higher patronage is based on higher levels of coverage (accessibility to stations based on number of stations within a given area), directness (based on number of transfers) and connectivity (ability to travel freely with multiple path choices). Generally, the more dispersed origins and destinations, the more difficult the transport task was (Prud'homme & Lee 1999, Derrible & Kennedy 2009). Cervero (2007) argued that when mixed-use TODs were aligned along a linear corridor, like a 'string of pearls', they resulted in efficient bi-directional flows, delivering higher and better passenger patronage and spread. Arguably, radial lines, as the distance from the centre increases, make larger scale development further from the centre difficult. This suggests that rather than a 'string of pearls' approach, a network of clustered centres connected with radial and orbital connections, i.e. a 'cluster of pearls' approach. Notably, Paris, as identified by Burke et al. (2010), has a number of inner suburb sub-centres close to the CBD as does Copenhagen, Singapore and Stockholm (though the last on radial lines) (Cervero 2006). This has resulted in these cities (though relatively short for Paris) having bi-directional public transport. Cervero (2006) found that bi-directional or contraflow public transport increases, often significantly, public transport mode share. Notably, Mees (2010:p147) argued that:

"Public transport uses urban space and environmental resources more efficiently than the car if it can attract people with different trip origins and destinations to travel together."

Mees (2010:p. 8) similarly argued that public transport is most effective when it achieves a 'network effect', imitating the flexibility benefits of the motor vehicle by "*knitting together different routes and modes into a single, multi-nodal network*". A key element of effective networking is the speed of movement. Where a city is geographically spread out, the choice of a higher speed system will ensure a greater level of accessibility (Curtis & Scheurer 2012). Kenworthy and Laube (2001) found that, in particular, greater speed competitiveness (usually through urban rail systems) equated to increased use and greater prominence. This network effect requires making transfers, between routes and services, effective and effortless.¹²¹ Supporting this argument, Kenworthy and Laube (2001) found that the length of actual public transport lines per capita bore no relationship to public transport use and that fewer, better located, better serviced and physically segregated public transport lines were more successful at promoting public transport use.

¹²¹ The network effect benefit for public transport has been identified occasionally but little understood in Australia. Notably, Barry Jones (2007), the former Federal Science Minister, recalled that in the 1970s, as the State Shadow Minister for Transport in the Victorian Parliament, he launched a transport policy promoting a network strategy for public transport called 'Moving People not Cars' which gained interest from no-one including from within his own party.

In dispersed cities, overly diffuse travel patterns do not allow effective single mode/operator services (Mees 2010). Therefore, Mees (2010) argued that a well-organised network system was required to provide better public transport in lower density cities. This meant that, to achieve a network effect, integrated fares and services (with efficient transfers) were required. The network effect often required a multi-modal approach with service transfers. The key to an efficient public transport network was the efficient operation of transfers, whether between rail-to-rail or rail-to-bus services (Vuchic 1999, 2002, Porta & Scheuer 2006, Iseki & Taylor 2007, Mees 2010). Vuchic (2002) found that virtually all major, efficient, well used public transport systems relied heavily on a complementary network combination of trunk rail lines, feeder and distribution rail lines, and street bus services. Further, Vuchic (2002) and Porta and Scheuer (2006) contended that multi-line networks with well-planned superior transfer stations were perceived to be more attractive by passengers than complicated networks of many different lines with poorly-planned station areas, irregular headways, lower reliability, or uncoordinated services. Mees (2010) noted, as an example of the impact of uncoordinated services, that without an integrated bus feeder service, Melbourne's train system had insufficient feed-in connections to support all-day frequencies.

In Australia and the USA, the higher capacity public transport services, particularly heavy commuter and light rail, tend to be radial (TRB 2003, Burke et al. 2010, BITRE 2012a, Currie & Burke 2013). Generally, this means that rail services alone provided a limited network effect. In major Australian cities, where activity centres had more convoluted links with other activity centres, there are disadvantages for higher capacity public transport accessibility compared to more compact cities (Burke et al. 2010, Curtis & Scheurer 2012). Perth's rail system, in particular, has only two effective junctions outside the CBD central station (Claisebrook and Cannington stations), which provide for immediate transfers onto intersecting rail lines. The lack of junction or rail-to-rail interchange stations reduces the network effect and opportunities for 'service intensification' (BITRE 2012b). With Melbourne, Sydney and Perth, buses are relied upon to create the network effect (Devney 2014). These cities have more non-CBD routes, meaning bus services are less focused on the CBD; whereas with the bus services in Brisbane and Adelaide, the routes are heavily focused on radial services into the CBD (Devney 2014).

The Perth rail system has a relatively high level (for Australia) of integration with its bus network (Mees, Sorupia & Stone 2007, Martinovich 2008, Stone 2008, Curtis & Scheurer 2012, BITRE 2012b, McIntosh et al. 2013, Devney 2014, McIntosh et al. 2014). The bus integration helps to compensate for the lack of long-term planning for the line easements on the Mandurah and Joondalup line. Due to an early decision to save travel time and infrastructure costs, the Mandurah line was not routed through some key established activity

centres along the corridor (the Kwinana, Rockingham and Mandurah town centres) (Curtis & Scheurer 2012). This meant these centres are dependent on well-integrated, connected bus routes (Martinovich 2008, Scheurer & Curtis 2008, Curtis & Scheurer 2012). For Perth, the different public transport modes (rail and bus) are organised into a multimodal network with interchange facilities providing for easy transfers, while avoiding parallel mode services along the same corridor (Curtis & Scheurer 2012, McIntosh et al. 2013). Perth's rail system effectiveness, with high service frequencies¹²² in shoulder periods outside peak, is reliant on effective transfers and network integration with bus services (BITRE 2012b). Effectively, the resulting slight increase in transfer requirements is compensated for by additional operational efficiency and network legibility. McIntosh et al. (2013) also noted that the Perth to Mandurah rail line patronage model has increased flexibility between rail and other modes such as integrated bus and motor vehicle park-n-ride, though this flexibility is largely limited into and out of the Perth CBD rather than to or between other destinations.

As a radial system, the Perth rail system is well structured and high performing (Glazebrook 2008, Stone 2008, BITRE 2012b, McIntosh et al. 2013). The opening of the Joondalup line in 1993 and the Mandurah line in 2007 effectively saw Perth complete the 'spokes in the wheel' of its radial rail system. The lack of a rail 'network' however within the broader Perth public transport network is stark, with the rail system being almost completely radial. Analysis of the Mandurah line found it was successful quickly on a range of fronts: in terms of patronage, accessibility, travel times and frequency (Martinovich 2008, Scheurer & Curtis 2008, McIntosh et al. 2013). The linking of the Mandurah and Joondalup lines, however, created a dominant radial rail spine with a greater focus on the CBD and to some extent more reliant on radial movements than in the past (Scheurer & Curtis 2008). This has led to the rail system having an overly strong focus on Perth CBD as the major destination for the system. BITRE (2012b) saw the crucial question for Perth being whether its public transport system's performance could be applied to attract significant levels of non-radial, non-commuting travel.

For centres not on the dominant north–south line, Scheurer and Curtis (2008) found relative accessibility had remained stagnant (or even dropped slightly for activity nodes along the Fremantle line and at Curtin University). Scheurer and Curtis's (2008) network analysis concluded that further infrastructure and services were needed, particularly stronger orbital links. The lack of public transport 'network' coverage of activity centres in Perth was further evidenced by not all the major activity centres (identified from origin and destination data from the Perth Area Regional Travel Survey) being public transport hubs or having significant public transport infrastructure (Curtis & Scheurer 2012). Conversely, some

¹²² Throughout the day and in the post-peak night time there is a maximum of 15 minutes between services (BITRE 2012b).

significant public transport nodes were not identified as major concentrations of origins and destinations¹²³. The notable examples of this mismatch between key activity centres and major public transport infrastructure was identified previously in Chapter 11 (and in **Appendix 6**) with Perth's key Specialised Centres of UWA/QEII and Curtin University. This was despite these knowledge-intense centres being recognised in the Perth 2031 Regional Plan as having metropolitan wide catchments (WAPC 2010a).

In terms of networking of multiple centres, Scheurer and Curtis's (2008) spatial network analysis of the Perth rail system indicated that public transport tended to perform better and attract greater share of trips in parts of the city with greater centrality of activity (see also Porta & Scheurer 2006). A high level of centrality with increased spatial proximity had the benefit of increasing the opportunities for networking between other nearby urban activities. Centres, like regions, benefit from connectivity to each other and centrality of centres improved access. However, centrality ultimately depends on transport infrastructure (Cervero 2006, Ahlfeldt & Feddersen 2010). In Perth, the lack of focus on the non-CBD potential knowledge-intense specialist activity centres as destinations reflects Perth's radial rail system's focus on providing accessibility to the CBD from the outer suburbs. The radial rail service provides CBD accessibility using fast high-to-medium frequent services for a large geographical area out to the urban fringe (Curtis & Scheurer 2012). This focus on periphery, Curtis and Scheurer (2012) found, using a measure of public transport accessibility from each activity centre to all others, meant that Perth, along with Melbourne, had an excessive strategic focus on origin centres in peripheral locations. Sydney's designated centre hierarchy and ease of public transport was found to be the most effective (Curtis & Scheurer 2012). While Perth lacked public transport network accessibility for key knowledge-intense centres, it did, for a low-density Australian city, have relatively good levels of overall origin aggregate network access. Curtis and Scheurer's (2012) analysis of aggregate network coverage in terms of absolute numbers of residents and jobs sited within walking distance of the 20 minute frequency network, and percentage of metropolitan total, found Perth scored 44.5 per cent. This compared to only 26.2 per cent for Brisbane, as the most comparable Australian city in size and urban density.¹²⁴ The lack of focus on destinations other than the CBD has an economic impact. Dispersed numbers of destinations that lack centrality and scale not only make the public transport network less effective; they also lessen the agglomeration benefit for knowledge-intense activities. The importance of scale and the value of agglomeration are often not fully considered when arguing against centrality in urban structure (see the absence of agglomeration arguments in Burke et al. 2010, p. 25).

¹²³ Perth was not alone with Sydney, Melbourne, Adelaide and Brisbane also having planning strategies specifying activity centres that were not on the major public transport network (Curtis & Scheurer 2012).

¹²⁴ Sydney was the highest at 49.8 per cent followed by Melbourne on 47.4 per cent. Adelaide finished below Perth on 40.3 per cent.

The network capability of a public transport system notably provides 'flexibility', in terms of giving people choice and allowing for a diversity of economic transport options. Compared to the motor vehicle and road systems, public transport in Australia has largely, outside of peak times, failed to deliver a 'go anywhere, anytime' principle that would make it more competitive with car travel (Scheurer & Curtis 2008, Mees 2010, Newman & Kenworthy 2015). While the flexibility of the motor vehicle and the road system is decreasing with higher levels of urban density and congestion, there is an increasing demand for mobility. Notably, public transport park-n-rides have been a key part of providing additional flexibility, benefiting people living in remoter areas (Mees 2010) or people who have multiple stops, for example. child care, school pickups, and shopping. Further, it is likely that on-demand car share/ride sharing and AVs will provide a greater level of flexibility and accessibility (outside of peak commuting times or outside of dense centres for 'last mile' transport needs) than public transport. Car share/ride sharing with AVs, if it becomes sufficiently standardised and cost effective, will provide a challenge and alternative to non-peak public transport services, particularly road-based bus services.

15.4 Public transport – circulation

While active transport (i.e. mainly walking) has been previously noted as being the key mode of transport for circulation, public transport, mainly in the form of buses, has played a supporting role. A notably successful example of bus transport providing circulation is the free-to-ride CAT (Central Area Transit) system in the Perth CBD (Richardson 2010, McIntosh et al. 2013). Notably the CAT-funded buses play a role in circulating and distributing people from major rail or bus hubs across the Perth CBD and inner city areas (and in particular, to those CBD areas distant from the public transport hubs). The free CAT service, integrated with the rail services into the Perth CBD, has provided a greater level of attractiveness to rail users by reducing generalised costs (i.e. improving travel time, and financial and opportunity costs) (McIntosh et al. 2013). The success of the Perth Parking Policy and its parking levy hypothecated to bus CBD circulation routes, including the CAT liveried buses, has led to the development of other activity centre circulation free bus services in other strategic metropolitan centres in Perth, such as with Fremantle and Joondalup (Richardson 2010).

Light rail can also be seen as circulation and connector of CBDs with inner city areas and associated centres (such as universities and hospitals). Light rail radial services, with their much tighter stop spacing than commuter rail, also provides for increased circulation within CBDs and inner city areas (Currie & Burke 2013). Currie and Burke (2013) have noted

varying justifications provided by governments in Australian cities planning for light rail including:

- Clearance of busy central business district from bus congestion
- Provide higher capacity for commuters
- Provide the basis for urban residential and commercial land use re/development
- Link key educational and health facilities
- Enable last-kilometre city centre distribution of passengers.

For example, the Gold Coast light rail focuses on circulation along a dense coastal corridor dominated by high-rise tourist accommodation, including commercial and retail centres (Currie & Burke 2013) with the terminal being at the Gold Coast's largest university campus and hospital. The first stage of the light rail system stops short of connecting with the wider South East rail network.

Chapter 16 Part E research into knowledge intensification of transport

16.1 Research methodologies

The research proposition is to determine the extent, if any, that commuting transport modes reflect the change in knowledge intensification (that was demonstrated in **Chapter 6**) of Perth metropolitan area's labour market. This will enable the second part of the primary question of this thesis to be addressed: determining the most appropriate complementary transport strategies for post-industrial cities with their urban structure planned around knowledge intensification.

To determine the change in the knowledge intensification of transport modes (used by Perth's commuting workforce) the census responses from the 2006 question 'W20 Method of Travel to Work by Occupation' (W20) and the 2011 question 'W21 Method of Travel to Work by Occupation' (W21) were assessed and compared. The 2006 census was the first where the method of travel to work by occupation question was asked. One difficulty in comparing the occupational commuting patterns over these two census periods was that the 2011 Census W21 considered the Perth metropolitan area to be 'Greater Perth (5GPER)'. 'Greater Perth' includes the region of Peel (including the local government areas of the City of Mandurah and most of the populated areas of the Shire of Murray, being the main suburbs closer to Mandurah – Barragup, South and North Yunderup, Pinjarra) whereas the 'Perth metropolitan area' for W20 in the 2006 Census was the 'Perth' statistical division (SD), which excluded the City of Mandurah and Shire of Murray. To ensure an appropriate comparison, the commuting data for 2006 were adjusted to include the City of Mandurah and Shire of Murray data. The entire inclusion of Shire of Murray is unlikely to be significantly distorting, as populated suburbs of the Shire of Murray were in the 'Greater Perth' area as per the 2011 Census and the total population of the Shire of Murray was very low – 11,970 – in comparison to the population of the Perth metropolitan area of 1,445,078 (ABS Census 2006). The most spatially challenged spaces in the urban transport system have temporal characteristics. In peak times during the working week, commuters heavily impact on the spatial capacity of key transport modes. Therefore, the focus of this research is on transport modes during commuting. To isolate commuting workers, only workers actually travelling to a place of work outside of their homes were included. Therefore, workers who worked at home, or did not go to work, were excluded.

For occupational groupings, the 2006 and 2011 Census used the 2006 Australian and New Zealand Standard Classification of Occupations (ANZSCO). ANZSCO is skill-based and highly reliant on three factors: education, training and years of experience (Esposito 2008). There are eight broad occupational groupings with broadly descending levels of skill and education: 'Managers', 'Professionals', 'Technician and Trade Workers', 'Community and Personal Service Workers', 'Clerical and Administrative Workers', 'Sales Workers', 'Machinery Operators and Drivers', and 'Labourers'. The largest occupational group in the two censuses analysed was the 'Professionals' (generally meaning holding at least a Bachelor degree). Over the five-year period to November 2013, 'Professionals' had the largest number of new jobs for any occupational grouping in Australia (with more than two out of every five new jobs) (Department of Education 2014).¹²⁵ Professionals were concentrated in particular industries with two-thirds in just three industries 'Education and Training', 'Health Care and Social Assistance', and 'Professional Scientific and Technical Services' (Department of Employment 2014). Projections of future educational qualifications in the Australian labour market assumes a high-skilled future (Access Economics 2009, Shah 2010, Department of Education 2014) with 'Professionals' leading the other occupations with the most likely percentage employment growth to 2025, and with lower-growth predictions for relatively low-skilled occupations (Access Economics 2009).

There are limitations to using ANZSCO. Esposito (2008) has argued that ANZSCO measures are overly broad for the detailed study and analysis of the skill composition of Australian jobs. This means there are limitations in assuming knowledge intensities of ANZSCO occupational groupings.¹²⁶ Esposito and Abbott (2011) found that the knowledge intensity change did not occur either all at once or uniformly across all occupational groups, but slowly and incrementally. However, consistent with the Department of Employment (2014) ANZSCO analysis, Esposito and Abbott (2010) found, using the O*NET occupational classification system, that overall job growth in the Australian labour market was more orientated towards occupations that require high levels of knowledge intensity (Esposito & Abbott 2010, Esposito 2011). The orientation to high knowledge intensity could be interpreted as a process of knowledge-bias towards occupations that require increasing levels of knowledge. It also indicates that, in order to carry out these more knowledge-intensive activities, increasing levels of human capital are needed (Esposito & Abbott 2011). The declines in knowledge intensity were most apparent in occupations relating to physical and manual work activities and may reflect a decline in the relative importance of the

¹²⁵ 'Community and Personal Services Workers' had the highest percentage employment growth (19.5per cent). The relatively lower skilled jobs of Labourers lost jobs, while Machinery Operators and Drivers had low employment growth. The predicted outlook to November 2018 is more of the same, with Professionals expected to account for one in three of new jobs, and Community and Personal Services Workers with lower skilled manual employment likely to have the least employment growth (Department of Employment 2014).

¹²⁶ Knowledge intensity of Australian occupations is arguably better determined using the United States Government's O*NET occupational classification system. O*NET represents an advance on current definitions and measures of skill, and provides a richer set of variables for understanding human capital and the changes occurring in the labour force over time (Esposito 2008, Esposito & Abbott 2011).

manufacturing sector in Australia over the last 35 years (Esposito & Abbott 2011). In this sense, the use of ANZSCO occupational groupings to determine broad levels of knowledge intensity is valid.

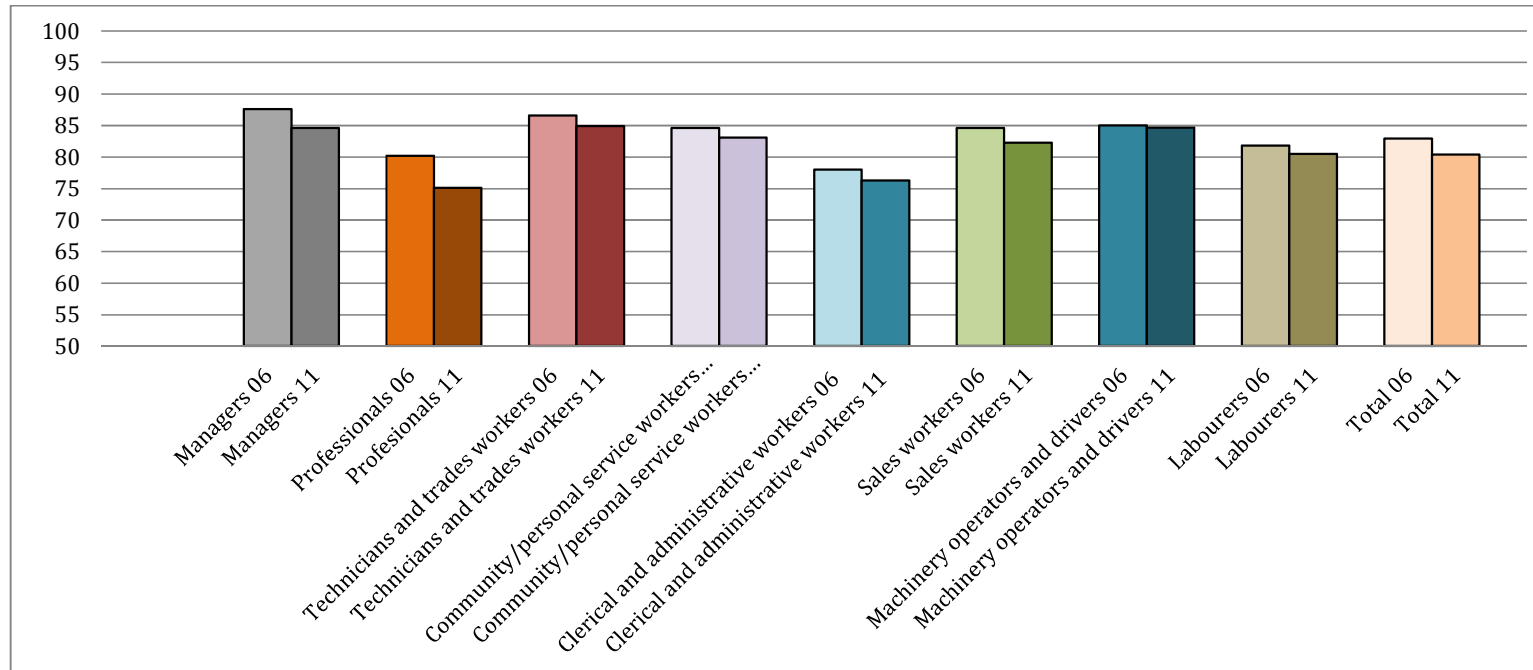
Chapter 16.2 Research into knowledge intensity – Perth’s labour market and spatially intense commuting

The increasing intensification of the knowledge economy in central Perth has been accompanied by a transport reconfiguration over the last three decades. The transformation of the CBD, in particular, has followed a number of state government actions supporting high-capacity rail in the period since the 1980s (Muhammad, Low & Glover 2006, Richardson 2010, BITRE 2012b, McIntosh et al. 2013).¹²⁷

The impact of the above transport strategy and investment can be considered by examining changes in commuting patterns for the census period 2006 to 2011. An examination of commuting transport modes by ANZSCO occupations for Perth demonstrates that, even within a single census period, there has been a notable shift in transport intensification. While car commuting remained the dominant transport mode for all occupations, there was a greater shift away from car use and an increase in more spatially intense forms of transport. This was particularly so for more knowledge-intensive occupations. **Figure 42** demonstrates the dominance, albeit declining use, of cars for commuting in the Perth metropolitan area for 2006 and 2011.

¹²⁷ This included the Fremantle to Perth line reopening in 1983, the establishing of the Perth Parking Policy (limiting parking within the city and subsidising free public transport within the CBD on all buses and trains), the opening of the Joondalup rail line in 1991, and the opening of the Perth to Mandurah rail line in 2007. This facilitated a downgrading of the CBD freeway feeder road network (and the reversal of one-way road systems within the CBD). The return of two-way streets has been accompanied by strategies to increase and support pedestrian movement and activation within the CBD (Gehl 2009, Department of Planning et al. 2009, City of Perth 2010, Richardson 2010).

Figure 42 Perth metropolitan area – Percentage of car commuting (as driver or passenger) as single method of travel by occupation from 2006 to 2011 (Occupations coded to 2006 ANZSCO, ABS Census 2006 and 2011)



Note: Occupations coded to 2006 ANZSCO, Source: ABS Census 2006 and 2011

While for all occupations in Perth the car was the dominant form of commuting,¹²⁸ there were notable changes from 2006 to 2011 as well as differences between occupations. From 2006 to 2011, all occupations declined in car use for commuting (on average by 2.5 per cent, from 82.9 per cent to 80.4 per cent). By far the largest decrease in car commuting between 2006 and 2011 was with 'Professionals' (declining 5.1 per cent from 80.2 per cent to 75.1 per cent). The next two largest declines were for 'Managers' (declining 3 per cent from 87.6 per cent to 84.6 per cent) and 'Sales Workers' (declining 2.3 per cent from 84.6 per cent to 82.3 per cent). It was notable that the two most knowledge-intensive occupations had the largest decline in car commuting.

'Managers' had, in 2006, the highest level of commuting by car (87.6 per cent) but by 2011 (84.6 per cent) had been overtaken by both 'Technician and Trades Workers' (84.9 per cent) and 'Machinery Operators and Drivers' (84.7 per cent)¹²⁹. The occupation least likely to commute in a car in 2011 was 'Professional' followed by 'Clerical and Administrative Workers' (75.1 per cent and 76.3 per cent respectively) – although in 2006, 'Clerical and Administrative Workers' (78 per cent) were less car dependent than 'Professionals' (80.2 per cent). This again reflected a trend towards the increasing knowledge intensification of Perth's commuting transport system.¹³⁰ The cause of this, based on the relative increase in the commuting use of trains, was likely due to the relative higher employment density of office employment in the knowledge-intensive CBD and its greater levels of public transport accessibility. Other than the 'Professional' and 'Clerical and Administrative Workers', all other occupational groupings were between 80 per cent and 84.5 per cent. For 'Managers', their relatively high car use likely reflected their greater diversity of industries and employment locations (see Department of Employment 2014). Additionally, greater levels of access to free or reduced-cost parking in denser employment locations may have been a factor. For lower knowledge-intensive occupations such as 'Technicians and Trades Workers', the higher levels of commuting likely reflected the diversity of their worksites or the low density of industrial and manufacturing employment.

The decrease in private car use for commuting is reflected in an increase in other, more spatially intense, modes. For example, all occupational groups overall increased their public transport (rail and bus) commuting by 2 per cent from 2006 to 2011. Notably however, 'Professionals' increased their public transport commuting by 4 per cent. The three less

¹²⁸ As the single method of transport from the residence to the place of work as the driver or as a passenger (though as passenger to a much lesser degree).

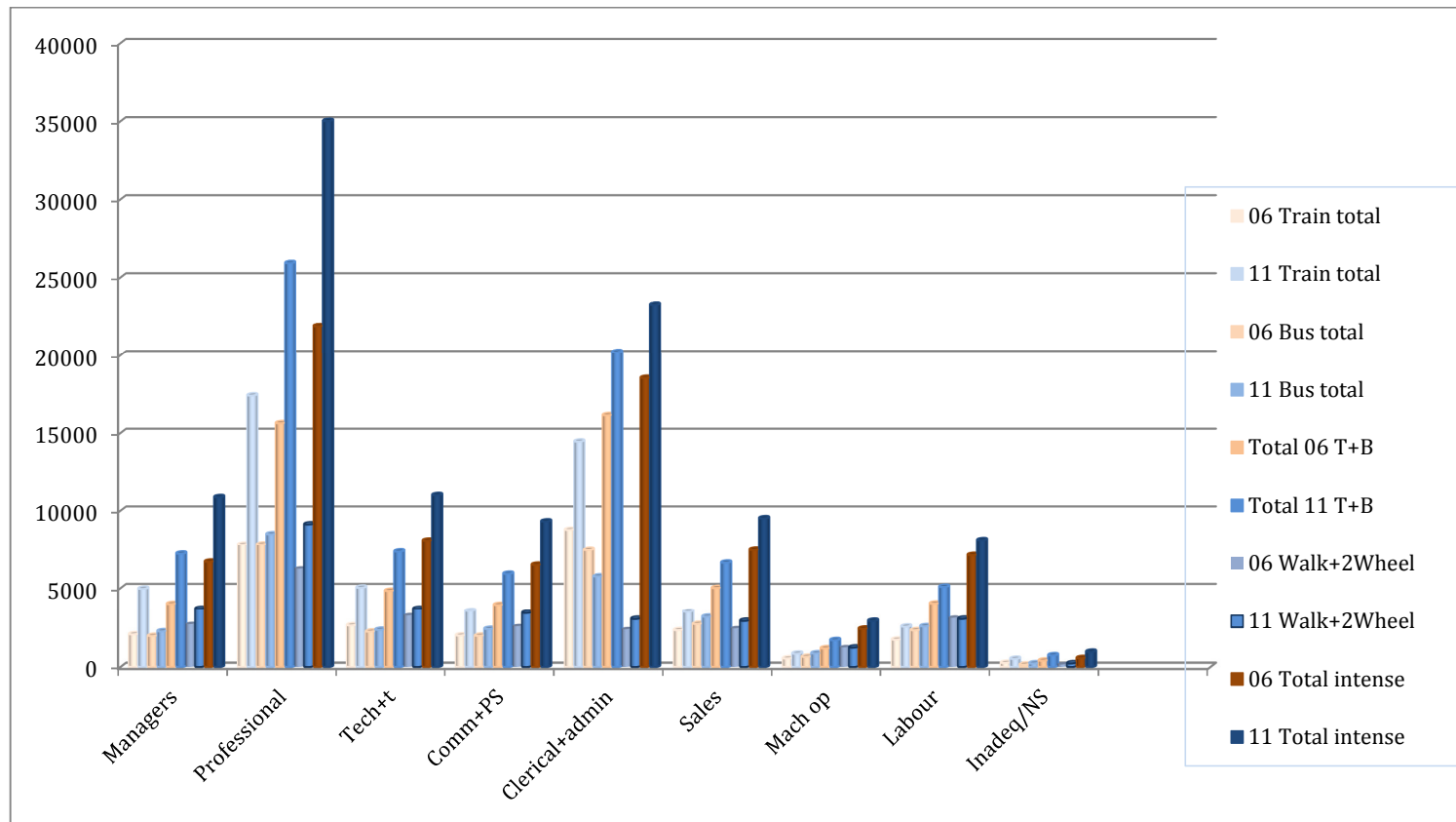
¹²⁹ The more 'blue collar' occupations (Technicians and trades workers', 'Machinery operators and drivers, 'Labourers') also all had notably higher commuting by truck, which could be assumed a requirement of employment rather than a mode choice.

¹³⁰ Though 'Clerical and Administrative Workers' nationally worked in a diverse range of industries and were more likely to have vocational education and training than a Bachelor degree, which contrasts to 'Professional'.

knowledge-intensive occupations ('Sales', 'Machine Operators and Drivers' and 'Labourers') had the lowest public transport use, though they all had a relatively higher use of 'motorbikes and scooters' – another form of spatially intense transport.

An understanding of spatially intense transport modes can be determined by noting the relatively different land space requirements of different transport modes (Bannister & Button 1993). Spatially intense modes of transport, it is proposed, can be considered to include public transport (rail more so than bus), walking and two-wheel transport (cycling and spatially intense motor cycles and scooters). Motorcycles and scooters can be considered as intense modes of transport; while road-based private transport, they use little road space compared to cars. These spatially intense modes of transport are all capable, to different capacity levels, of facilitating higher levels of density and enabling walkable centres. **Figure 43** sets out the number of commuters for intense transport modes for Perth for 2006 and 2011.

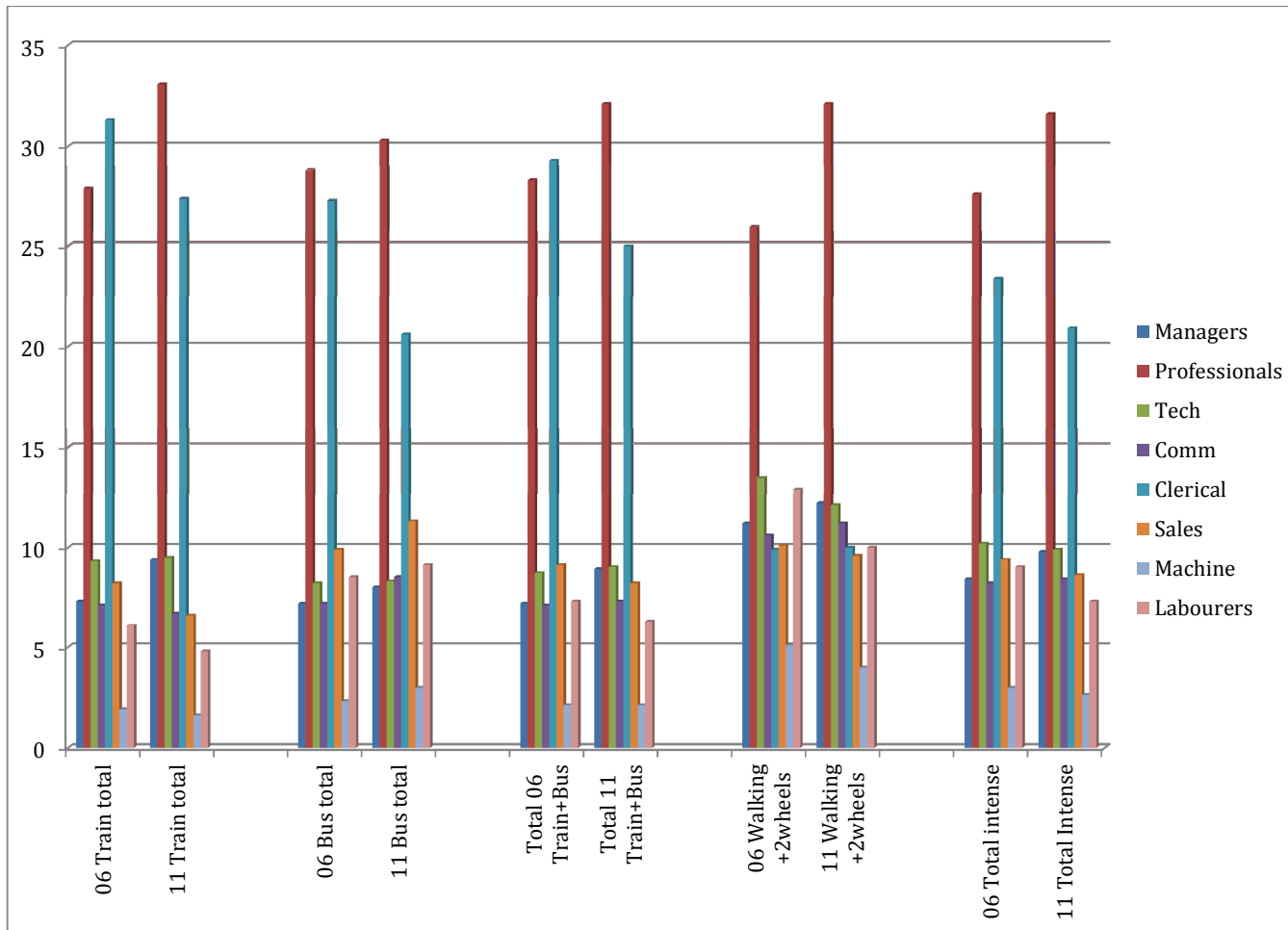
Figure 43 Total number of commuters by occupation using spatially intense commuting modes for Perth metropolitan area 2006 and 2011 (ABS 2006 and ABS 2011)



The accumulative totals in **Figure 43** reflect the overall increase in commuter numbers from 536,123 in 2006 to 639,186 in 2011, as well as the change in the occupational workforce composition, i.e. 'Professionals' increased from 117,744 (22 per cent) to 149,651 (23.4 per cent). In addition to increasing their numbers within a growing labour market the 'Professional' occupation are increasingly driving demand for more spatially intense types of transport, with significantly higher use of rail, bus and active transport. Even within the public transport modes, 'Professionals' are increasingly using rail, with a notable shift from 2006 to 2011 (presumably in part resulting from the opening of the Perth to Mandurah rail line in 2007).

The dominance of 'Professionals' using spatially intense forms of transport for commuting, including their shift to rail from buses, is demonstrated in **Figure 44**.

Figure 44 Percentage of commuters by occupation and spatially intense transport mode (ABS 2006 and 2011)



Public transport commuting use by occupational groupings for Perth from 2006 to 2011 showed that 'Professionals' and 'Clerical and Administrative Workers' are the two most likely occupational groups to use public transport. In some respects, this is not surprising, as 'Professionals' are the largest occupational group (22 per cent of commuters in 2006 and 23.4 per cent in 2011). Their share of public transport use and their overall spatially intense commuting, however, was notably higher than their share of the commuting labour market overall.

In 2006, 'Clerical and Administrative Workers' had the highest percentage of commuting train trips but by 2011 'Professionals' had the highest with 33.1 per cent of commuting rail trips (with 'Clerical and Administrative Workers' slipping to 27.4 per cent). The percentage of bus trips taken by 'Professionals' increased at a lesser rate compared to rail, increasing from 28.8 per cent in 2006 of all commuting bus trips to 30.5 per cent in 2011. However when other spatially intense modes such as walking, cycling and motor bikes/scooters were factored in, 'Professionals', of all occupations, had the highest use of spatially intense modes of transport.¹³¹ In 2011, 'Professionals' made 31.6 per cent of spatially intense commuting trips, up from 27.6 per cent of trips in 2006. This was an increase of 4 per cent in spatially intense modes of commuting while their increase in total number of commuters was only 1.4 per cent.

The increasing spatial intensification of knowledge-intense 'Professionals' use of spatially intense modes of commuting is strongly suggestive of a link between knowledge intensification in the labour market and the economy with intensification of transport modes. Key to public transport use, based on occupation, in Perth appears to be the destination of employment (its density and public transport service levels) as research elsewhere consistently shows in terms of the link between rail investment, urban density and knowledge intensification in labour markets and economy generally. Ultimately, these factors play out into higher levels of agglomeration and economic productivity.

16.3 Knowledge intensification and transport

The conclusion of this research is relatively clear; spatially intense transport infrastructure and modes are increasingly attracting knowledge-intense commuters. The conclusions as to increased 'Professionals' use of spatially intense transport, identifiable onward from 2006, is

¹³¹ Similarly, the 2011 Census national travel to work data (ABS 2011a) indicates that 'Professionals' are just behind 'Clerical and Administrative Workers' in terms of public transport use. However, when other spatially intense modes such as walking, cycling and motor bikes/scooters (i.e. modes that use the least physical space) are factored in 'Professionals', of all occupations nationally, have the highest use nationally of spatially intense modes of transport.

consistent with (and a possible explanation for) peak car-use findings in Australia and in the USA (Newman & Kenworthy 2011, 2015, Sivak & Schoettle 2011a, 2011b, BITRE 2012b, Newman et al. 2013, Sivak 2013a, 2013b). It can be concluded, based on the evidence of increasing urban agglomeration and knowledge urban intensification of human capital, that increasing the use of spatially intense modes of transport will deliver greater levels of economic productivity (Knudsen et al. 2008, Abel 2012, Hensher et al. 2012, SGS 2012a, Legaspi et al. 2015). The logical extension of this research suggests that increasing investment in public transport, particularly rail (rather than urban road infrastructure) into and around knowledge-intense centres will deliver higher urban density and knowledge economic productivity benefits.

The use of rail transport investment to drive spatial intensity of the urban transport system and economic development is the model adopted by Singapore. Cervero (2006), in looking at Singapore (with its far higher urban density¹³² than Perth), found that sub-centre new towns were interconnected with fast rail, but were also interconnected economically with new towns having differing specialist functions and services. In this sense, a regional interconnected agglomeration has been achieved using rail as a key economic transport link. Public transport is a means of intensifying human knowledge and knowledge economic activity within centres. While modern ICT, with the shift from copper to optic fibre, intensifies codified and virtual tacit knowledge, public transport intensifies human carried knowledge through displacing low-volume private vehicle travel with high capacity public transport. Public transport has traditionally been planned in response to urban growth, to connect areas of sprawl to the city centre. However, it is argued in this thesis that public transport needs to also be seen as a catalyst for knowledge-intense economic agglomeration, including potentially knowledge-intense centres outside CBDs.

16.3.1 Implications of knowledge intensification on transport planning

Transport modes in a modern urban knowledge economy therefore have to be considered in terms of their capacity to contribute to effective knowledge exchange (both economic and social) within an urbanised agglomeration ecosystem. Scale and density, delivered by high levels of mobility and accessibility into a concentrated commercial urban ecosystem, are required to give effect to higher levels of the face-to-face interaction required for knowledge exchange and spillover. Whereas previous transport thinking understood rail's main benefit of delivering higher capacity, there now needs to be a recognition of the '*brains on trains*' economic impact of increasing the intensity of knowledge-intense workers in key knowledge-intense activity centres.

¹³² 7,736 people per sq km as of 2014 - see World Bank <http://data.worldbank.org/indicator/EN.POP.DNST>

For road infrastructure planning, there are also a number of logical extensions of this research. Radial road infrastructure, which seeks to increase traffic volumes into knowledge-intense centres, can be seen counter-productive for economic productivity. The spatial demands of knowledge-intense centres and urban areas require transport modes that increase urban density and knowledge intensity on the labour market. This suggests a need to rethink urban transport planning. Where urban road infrastructure is likely to be more appropriate, orbital road infrastructure (rather than radial or orbital roads in denser inner city areas) in outer suburbs (of cities) can facilitate lower density lower agglomeration industries. Furthermore, adaption of new car business models and technologies, such as car share, ride sharing and autonomous vehicles, present opportunities to integrate transport modes to enable greater mobility and flexibility for future knowledge-intense workers. This mobility will be essential to enable efficient transfer and movement between spatially intense forms of transport such as rail to dispersed forms such as car-based transport (i.e. for moving between higher and lower density areas). This would effectively provide the combined benefits of rail, in terms of accessibility and capacity, with the flexibility benefits provided, in an unrivalled sense, by the car.

Australia's major capital city CBDs, being the beneficial destination of the overwhelming number of higher capacity and high frequency radial public transport routes and services, are provided with an overwhelming knowledge-intensity advantage. This high quality public transport exclusivity effectively creates Australian CBDs as the key metropolitan hubs with the greatest and widest level of accessibility from across the metropolitan area. This advantage provides capacity not only for higher levels of urban density, but for the diversity and size of workforce required to take advantage of the agglomeration opportunities. This means the CBDs have the largest and most effective labour market for knowledge-intense workers and services. The centrality of density in the Australian urban agglomeration is therefore heavily oriented in and around Australia's CBDs, with relatively poor provision of rail services to other metropolitan-scale, potentially knowledge-intense centres (i.e. Specialist Centres). This strong CBD centrality is effectively driving a monocentric urban structure for the knowledge economy (with monocentric cities eventually becoming inefficient (Berliant & Wang 2006)).

Arguably, there is a lack of coherence in the purpose and planning of public transport in an increasingly knowledge-intense urban Australia. Glazebrook (2009) contended that, despite having the largest public transport system (in size and patronage) in Australia, Sydney, as Australia's 'global city', has an inefficient and unsustainable transport system. For Australia's premier knowledge city to be identified as such indicates Australia has a wider problem with its cities being structurally unsuited to Australia's knowledge-intense economic challenges. To give effect to other potentially knowledge-intense centres, transport-planning strategies

need to provide greater and wider levels of public transport accessibility and capacity to the non-CBD knowledge-intensive centres. However, the selection of potential non-CBD knowledge-intensive centres for urban and transport investment needs to reflect the need for a high level of urban 'centrality' (accessibility to the CBD) in order to provide higher levels of combined agglomeration through scale and density. An overall lack of population scale within Australia – and, in particular, with more isolated cities such as Perth – means there is a need to maximise the centrality to realise knowledge-intensive agglomeration. Effectively, the urban structure required is a form of polycentricism but within the context of an agglomerative clustered centrality.

To create a 'knowledge-intensive' post-industrial city, an appropriate integrated urban structure and transport strategy is proposed in **Figure 45**. This proposed urban structure for a knowledge-intensive post-industrial city is adapted with overlays for centre catchment, agglomeration values, knowledge education development and transport infrastructure.

Figure 45 Proposed new urban network for post-industrial cities - with transport/education/economic contexts added (Green being tradable economy and blue being population/consumption economy)

Network	Catchment	Agglomeration values	Knowledge development	Key transport modes	
CBD/City centre	International, national, state, and regional	High, knowledge-intense	Tertiary, Secondary, Pre-primary	Multi-line rail, bus hub, car share/car hiring, air/airports	
Global metro centres (previous Specialist Centres)	International, national, state, and regional	High, knowledge-intense	Tertiary, Secondary, Pre-primary	Multi-line rail, bus hub, car share/car, air/airports	
Global metro infrastructure/ industrial Port/ airport/key tradable industrial areas	International, national, state, and regional	Mid-level dependent on industry, with elements of knowledge-intense workers	Training focused, Tertiary (TAFE)	Road/rail freight vehicles, private car, sea freight, and air freight	
Strategic Regional Centre	Regional and sub-regional	Mid-level sub regional retail agglomeration	Tertiary, Secondary, Pre-primary	Rail line, bus interchange, car share/car hiring, private car	
District/local centres	Sub-regional and local	Low, with elements of population/community service knowledge-intense workers	Secondary, Primary, Pre-primary	Private car, bus, car share/car hiring	
Dispersed employment	Local and sub-regional	Low, with elements of knowledge-intense workers	Secondary, Primary, Pre-primary	Private car, bus	

The key transport characteristics of the proposed urban network for post-industrial cities identified in **Figure 45** are that:

- Tradable economies are focused on exchange and are dependent on mobility with trade in services becoming increasingly knowledge-intense within denser parts of cities (knowledge-intense centres in and around the urban core) and therefore needing increasingly spatially-intense and flexible transport
- The key transport mode for exchange in a knowledge service based economy is walking as it is the mode that facilitates the most efficient means of face-to-face in denser areas
- Centres with scale and density in the urban core that operate with the greatest reach (global) and labour market catchment (metropolitan wide) should have spatially intense, high-capacity, high-frequency public transport (rail) and operate as hubs with multiple lines (rail ideally) or close accessibility to multiple lines
- Major industrial and transport infrastructure such as airports and ports operating in the global economy require a diversity of high-capacity transport infrastructure and modes
- Centres in the population/consumption economy with limited reach and catchments (sub-regional or local) ideally will have (origin) rail stations and local bus networks, with continued high demand for car transport,
- Areas of dispersed employment, such as industrial areas, will continue to be car and vehicle reliant, and
- Road transport infrastructure should be oriented to orbital road systems in the middle and outer suburban areas. Transport infrastructure, both radial and orbital, in denser urban core and surrounding knowledge centres should be focused on public transport as to facilitate increased connectivity, density and scale.

This model is premised on the need to support the increasing demand for mobility and economic exchange, inherent in a growing and globalising knowledge-intense economy. It is also premised on aligning knowledge intensity with spatially intense transport modes. This is not to dismiss the need for reduced carbon emissions from transport and land use; however, emission reductions can be better and more quickly achieved by new vehicle technology and the effective pricing of carbon.

Part F: Conclusion

"For the importance of knowledge for life ought to appear as great as possible."

"The press, the machine, the railway, the telegraph are premises whose thousand-year conclusion no one has yet dared to draw."

– Friedrich Nietzsche, *Human, All Too human: A book for Free Spirits*, 1878

Chapter 17 Conclusion

17.1 The knowledge intensification of cities

This thesis argues that post-industrial cities are driven, and increasingly so, by an intensification of knowledge across multiple layers. This multi-layered theory of intensification of knowledge proposes that, in metropolitan cities, an increase in human knowledge capital and improved economic exchange or connectivity, relative to a fixed population and metropolitan spatial size, will result in an increase in knowledge economic activity. Therefore, economic agglomeration outputs are increased not necessarily by increasing population density or population scale alone.

The knowledge-intense cities are identified by a number of layers of intensification:

1. intensification or agglomeration of knowledge economic activity,
2. intensification of knowledge within human capital knowledge, i.e. increasing levels of knowledge within individual workers and their jobs and where those workers work and reside, and
3. intensification of the means of knowledge exchange, i.e. both within ICT and transport devices, systems and infrastructure (technological intensification), and with the spatial urban concentration or intensification of ICT and transport infrastructure and usage.

The multi-layered knowledge intensification theory is used to address a number of questions as to how post-industrial cities should be planned. The primary question of this thesis was as follows:

If the nature of the post-industrial economy has changed (and continues to change) towards knowledge-intense activities, what are the appropriate urban and transport structures for post-industrial cities such as Perth, Western Australia?

The importance of this thesis question is that if the national productivity is increasingly linked to knowledge intensification, then knowledge-intense cities will be fundamental to economic success. At the Federal level of government in Australia, the understanding of the importance of cities for the economy has been somewhat intermittent, with recent leadership changes seeing the economic importance of cities again being recognised¹³³. Strategic metropolitan planning, however, has traditionally been a state government responsibility and the focus on metropolitan areas has been on managing growing city populations, sustainability and achieving desirable planning outcomes such as polycentric urban structures. Knowledge intensification as a key influence in metropolitan urban planning has only been identified in Plan Melbourne (2014).

Increasingly, modern post-industrial economies are experiencing a shift from natural resource production to increased urbanised knowledge-intense production. Knowledge, rather than labour, is now the key driver for economic growth. A key part of the modern knowledge production process is the increase in intellectual/immaterial activities, which are amenable to extremely fine and highly efficient divisions of labour that require a diversity of specialisation across firms. Complex and unfamiliar coordination of innovative activities requires high levels of specialist skills, communication, trust and closeness. This specialisation and the increasingly fine division of labour therefore require an intensification of knowledge both in a spatial and non-spatial immaterial sense.

Agglomeration theory provides for advantages arising out of clustering around geographic locations, i.e. cities or regions. Three advantages are provided: access to a relatively large skilled labour pool; economies of scale in terms of access to and availability of resources, materials and inputs including services; and the intensity of knowledge exchange between people, firms and institutions within close geographic proximity. At the national scale, the increasing and ongoing levels of population primacy of all of Australia's major cities for their state regions is consistent with a greater level of agglomeration at the national scale. Due to Australia's relative low population size, urban concentration and agglomeration in just a few cities is a key economic characteristic of Australia (with a 'core-periphery' national urban system with Sydney and Melbourne at the core). The more knowledge-intense activity and labour markets in Australia's are in the combined urban 'core' of Sydney and Melbourne. In the more peripheral cities, such as Perth, there is a strong regional primacy and a high level of monocentricity in knowledge-intense activity in the metropolitan area.

¹³³ With September 2015 seeing Australia having a new Prime Minister and the creation of a new Minister for Cities and Built Environment (PIA 2015)

This urban population and economic concentration means understanding agglomeration at the urban and activity centre level is essential. In addition to providing labour market scale and efficiency, cities also provide urban spaces and places that intensify human experience essential for knowledge transfer. Urban life fundamentally intensifies the individual human experiences (through an intensification of stimulation) and therefore changes the way individuals think and act. Importantly, tacit knowledge exchange is reliant on place and personal focus. It is 'sticky' at the geographical urban scale – that is, urban places support the building of relationships and trust between people and organisations within a defined space. A key to understanding knowledge intensification is the recognition that knowledge, being increasingly critical in economic activity, is embedded in human beings (as 'human capital') and that knowledge spillover (particularly of tacit knowledge) is heavily reliant on close physical contact. The value of tacit knowledge transfer is often in the conversion to new codified and commoditised knowledge. The exchange or spillover of knowledge is one of the key elements in the theory of agglomeration economics.

In an ICT-enabled, efficiency-focused economy – where large amounts of complex data and codified knowledge are transferred quickly – tacit knowledge is critical, because practical, brain-held, tacit new knowledge is the originator, primary process of creating new knowledge. In a commercial and fast moving economy, the newest knowledge provides competitive advantage. This helps explain why ICT, including ICT enabled business activities and social media, are subject to distance decay. ICT infrastructure, with its strong bias to urban and population scale, reflects this. This means that ICT supports the still highly critical secondary codifying and dispersement processes in the knowledge economy. ICT, rather than dispersing economic activity, is complementary to face-to-face activity and therefore is spatially concentrated. The theory of knowledge intensification suggests that specialist skills and activities, with the highest levels of ICT use, will accrue to the urban centres, rather than dispersing to low-density regional areas. The long-term evidence of increased primacy and urban concentration in Australia, which occurred with the extensive transport and ICT advances of the 20th century, supports this conclusion. This suggests that, into the 21st century, the NBN and investment into regional major roads and airports, while critical for regional economic development, will not increase regional populations relative to the faster growing metropolitan populations. Arguably instead, ICT and transport investment will drive further urban population growth into the major capital cities. The possible, somewhat counter-intuitive, logic of this is that the more efficient regional communications and transport connections are, the more the capital city-based operations can service or exploit regionally based resources or demand areas. Logistics and management chains can be extended, allowing service delivery and human resources (for example, using 'fly in fly out') to operate from and be concentrated in major urban areas, taking advantage of urban agglomeration.

Agglomeration benefits and modern transport and communication advances are likely to allow regional economic development to be managed most efficiently from capital and other major cities.

In summary, the impact of knowledge intensification is that post-industrial cities are increasingly characterised by scale (of population size and employment density), high levels of human knowledge capital, connectivity and speed of information and knowledge flows, as well as being politically economically liberal (or open) and focused on a small number (generally one to three) of high-profile, central, dense, walkable, urban centres delivering face-to-face economic exchange.

17.2 Is knowledge intensification occurring in Perth? Yes.

This thesis has argued that in post-industrial cities, as demonstrated by Perth, economic outputs are increased, not just by greater population density or population scale, but also through increases in human capital of the given population and their level of interconnectivity through communication and transport. It is argued in this thesis that urban structures of post-industrial metropolitan cities or regions require a small number of larger, interconnected, dense, knowledge urban centres with high levels of human knowledge capital and urban density. This enables higher levels of local and regional agglomeration. Furthermore, when knowledge-intense activity is dispersed or constrained through planning and transport inefficiencies or mobility barriers there will be a weakening of the knowledge intensification of the city. Essentially, urban sprawl and spatially inefficient transport – all other factors (such as human knowledge capital and/or improved connectivity) being unchanged – means lower knowledge intensification.

To assist in answering the primary question, a series of preliminary secondary questions were put forward relating to three elements of knowledge intensification:

1. Is knowledge economic activity intensifying in Perth, both in terms of an increase in knowledge-intense industries and their spatial distribution?
2. Is human knowledge capital intensifying in Perth, both in terms of the labour market knowledge capacity and in terms of the spatial distribution?
3. Is ICT knowledge intensification occurring in Perth, both in terms of the spatial distribution infrastructure and ICT enabled businesses?

In terms of the secondary questions on knowledge intensification in Perth, it can be concluded that there is strong and increasing evidence that knowledge economy activity, human knowledge capital,

and ICT infrastructure and ICT business distribution in Perth are characterised increasingly by urban concentration and intensification. The dispersment of population-driven economic activity in the Perth metropolitan area, driven by the motor vehicle prior to the turn of the 21st century, is being overlaid by an agglomeration of knowledge economic activity in and around the Perth CBD. In this sense, in terms of the knowledge economy and high-quality employment, Perth can be described as largely monocentric. However, outside the central city, there are dispersed 'population-driven' employment patterns, with evidence of economically vulnerable and disconnected outer suburbs. Hence, Perth could be best described as a knowledge economy monocentric city within a consumption-based polycentric sprawling metropolitan area (located within a monocentric state).

The knowledge intensity of human capital is also clearly increasing within the Perth labour market. At some point in around 2010, Perth could arguably have become a 'knowledge economy,' as this was when the labour market began to have more university-qualified workers than workers with no-post school qualifications. This knowledge intensification is happening at both the low and high knowledge end of the Perth labour market, with decreases in workers with no non-school qualifications and an increase in workers with intermediate skills. However, the knowledge intensification of the labour market is not spatially even.

Knowledge intensification is also strongly evident with Perth ICT development. Perth's ICT infrastructure and internet-reliant firms, consistent with research elsewhere, have been shown not to be removed from the advantages of proximity or economic agglomeration, nor from the traditional economic, social and political practices. The spatial concentration of both the multi-national mining industry and the WAIX participants in Perth CBD is further evidence that the Perth knowledge economy is subject to localisation agglomeration. This urban knowledge economy concentration has been facilitated and supported by a number of knowledge intensification factors including early provision and adoption within the Perth CBD of high levels of Internet infrastructure. Increasingly, knowledge workers are living in and around the denser, inner-urban core.

17.3 The appropriate urban structure for a knowledge-intense city

Urban economies have changed and are continuing to change towards knowledge-intense, service-based economies. The answer to the primary question of this thesis is that the appropriate urban structure for metropolitan post-industrial cities is one that facilitates high-value urban knowledge intensification. The proposed urban structure for a knowledge-intense city is developed with regard to agglomeration values, knowledge education development and transport strategy (as per **Figure 45**).

A key challenge for knowledge-intense cities in the 21st century is the valuing of the combination of urban density, ICT, human capital and agglomeration. This will be a greater challenge for Australia's would-be, knowledge-intense cities because of the lack of national scale with respect to Australia's relatively low population. Ultimately, for any city, it will come down to how they plan and develop (and connect) urban centres within their metropolitan areas. Activity centres, with shopping centres as the main focus, are fundamentally about consumption, imported goods, technology adoption (rather than technology development), localised labour markets, low skills and low wages. The corporate shopping centres, both economically and culturally, are bland; though arguably, they are highly evolved and appropriate for population servicing.

While universities might provide the best opportunity for primary activity centres outside of CBDs in a knowledge-intense city, Australian universities (and associated tertiary hospitals), with their tendency for single-use institutional campuses (i.e. the monastic approach), are not without their limitations. The monastic campus has a spatial and physical consequence. The limitations of monasticism in the context of the knowledge-intense economy are accentuated when compared with the advantages of organic knowledge exchange and networking occurring within an urban environment. It is as if, during the course of relatively more labour, machine and then consumption intensive 19th and 20th centuries society saw the appropriate place for universities in the urban structure as being secondary and not integral to the functioning of cities. The conclusion of this thesis is that, regardless of planning policies, the knowledge economy will grow in areas of cities that are capable of agglomeration and of attracting the knowledge intensification of human capital, ICT and economic activity. The urban structure and designs, and the transport infrastructure that facilitates density, and knowledge intensification and spillover, are crucial to the successful development of any potentially knowledge-intense activity centre. For major university campuses, the consideration of their spatial future should include their capability of contributing (and being interconnected) to the most effective knowledge (economic and social) urban ecosystem. With the knowledge-intense economy's increasing need for urban scale, density, accessibility, and commercial knowledge spillover, the isolated campus model has outlived its purpose. This requires a rethinking of existing major university campuses and it is argued that sizable mixed-use urban centres should be developed into or adjacent existing campuses.

17.4 The appropriate transport strategies for a knowledge-intense city

The second part of the primary question relates to appropriate urban transport strategies for a knowledge-intense city. This question was answered based on the premise that, in a post-industrial knowledge-intense city, the transport task is more about transporting human knowledge capital than human labour. Planning and transport policy and practice in Australia in recent decades have largely failed to consider the role of knowledge within the modern economy and there has been a lack of consideration given to the possible interrelationship between transport and the knowledge economy. In the modern knowledge economy, intensity, diversity of activity and networking within the largest possible agglomerative urban ecosystem provide competitive advantage.

National and international competitiveness for knowledge cities is increasingly about providing a larger and thicker market for (more knowledge-intense) specialised labour and intermediate services. Increasingly, accessibility through improved transport infrastructure can have a significant effect on urban and regional economic development. The importance of scale and size for knowledge labour and service markets means transport accessibility and capacity are essential to maximise metropolitan catchment efficiencies. Transport modes in a modern urban knowledge economy therefore, have to be considered in terms of their capacity to contribute to effective knowledge exchange (both economic and social) within an urbanised agglomeration ecosystem. The requirements of knowledge-intense cities are changing, with the transport task becoming increasingly about transporting human capital than human labour. The characteristics of the mode of transport are crucial to this. The scale and density delivered by high levels of mobility and accessibility into a spatially concentrated commercial urban ecosystem are required to give effect to higher levels of face-to-face interaction required for knowledge exchange and spillover.

The intensification link between human capital knowledge, urban structure and transport can be seen with the decreasing dominance in Perth of the car for commuting for the knowledge-intense 'Professionals' occupational group. This thesis demonstrates a link between the spatial intensity of commuting transport and the increasing knowledge intensity of labour market and the urban economy. The 'Professionals', as the largest and fastest growing occupational grouping, were found to be increasingly driving demand for more spatially intense types of commuting transport. Within the public transport modes 'Professionals' are increasingly using rail with a notable shift from 2006 to 2011, with 'Professionals' also relatively high users of other spatially intense two wheel and active transport. This provides an indication of how the economy is changing to more knowledge and spatial intensity, consistent with the proposed theory of knowledge intensification within cities.

The increasing use of spatially intense transport (in all its forms) for commuting by knowledge-intense workers, it is concluded (because the role of the private vehicle, so dominant in Australia and North

America), has limitations as a mover of human knowledge in urban settings, particularly into denser urban centres. The limitations of the capacity of the private vehicle as against public transport (in terms of road space limiting urban amenity and tacit knowledge exchange, parking space requirements and limited carrying capacity) are well understood. Cities in the USA and Australia, which are seeing a decline and reduction in VKT, are also characterised by corresponding increases in public transport use and urban density, particularly around the central, urban cores. These intensification changes in urban structure and transport have occurred while the economy and labour markets have also knowledge intensified. The ongoing intensification of economic activity and urban densification strongly suggests that urban policy transport investment should be about intensifying transport systems, rather than consuming valuable urban space for inefficient transport modes. Transport infrastructure (radial freeways) that leads to urban dispersement will lessen agglomeration and therefore knowledge economic productivity, whilst transport that provides density (i.e. public transport and particularly rail) will ultimately deliver agglomeration and knowledge labour and service market productivity. In this sense, the investment of new transport infrastructure in a knowledge-intense city is not about delivering additional spatial capacity to alleviate congestion, but about intensifying space for even greater levels of spatially intense economic activity. Effectively, the need is to deliver an increased intensification of the transport system, not necessarily to alleviate congestion.

Congestion can be seen as arising from an increasing intensification of human knowledge within limited temporal spatial boundaries – that is people commuting to a limited number of 'attractive' and increasingly dense centres and locations (such as CBDs) within the same peak periods. Higher agglomeration knowledge-intense centres are, by necessity¹³⁴, a rarity and minority of centres. The spatial and temporal intensifying of knowledge-intense labour and service market activity is a positive, in that it provides for knowledge intensification and therefore economic agglomeration. The problem is the over-reliance of entropic, spatially inefficient transport modes (i.e. use of private cars) for commuting into attractive and increasingly dense locations. Higher capacity and spatially intense transport (i.e. public transport supported by other modes of spatially intense transport) is the most effective means of changing the intensity of the commuting process. There is also potential for a greater transport intensification of modes, particularly with road transportation, while not likely to be sufficient to replace the requirement for increased public transport investment. Road intensification, to the extent that it happens, is likely to be provided by transport technological and business model changes (with car sharing). There is likely to be a lessening of the distinctions between transport modes, with a continuum of transport options developing. This will be driven, in part, by increasing demand for urban mobility with increasing worker and firm specialisation within a networked economy. Demand for increased urban mobility within denser and larger cities will require greater efficiency of transport modes with transferability between modes.

¹³⁴ A necessity to maximise agglomeration

However, transport technological change is also a double-edged sword. Electrification of vehicles and the automation of driving both provide opportunities, within an appropriate policy framework, to intensify urban transport. They also present a risk for increased (and unnecessary) private car use, partly because of the potential energy rebound effect and reduced and potentially lower running costs for EVs as against public transport fares. While the intensification of urban transport will provide an economic benefit to cities, it will require not only a rethinking of traditional transport planning, but appropriate policy frameworks through which to guide technological and new business case adoption. Essential to achieving this will be wider policy understanding of the link between knowledge economy intensification, economic growth and the benefits of spatially intense transport.

The need for an intensification of the transport task arises from the importance of scale and size for knowledge labour and service markets. Effectively, transport accessibility into denser urban areas and the need for high capacity to maximise metropolitan catchments are essential to the efficiencies of knowledge-intense cities. Scale and density of human activity in knowledge centres to achieve agglomeration is also dependent on walkability. That is, to obtain the scale and employment density, knowledge-intense centres have to be able to inflate their activity through modes of transport that provide large-scale intensification. This in return, gives effect to high levels of circulation of people and therefore exchange. This means there is a requirement for spatially intense mass public transport to increase intensity and density for high levels of circulation and exchange. Effectively, rail feeds pedestrian numbers. The conclusion that this leads to is that the key and primary transport mode for the final realisation of knowledge intensification is (and has always been) walking. Walking is the mode that delivers the actual face-to-face knowledge exchange. This means that knowledge-intense centres within a wider agglomeration or metropolitan areas need to have high levels of accessibility across their metropolitan areas to achieve scale and density. The self-contained centres – regardless of any vitality in their urban design – are not conducive to knowledge spillover or agglomeration if they lack scale, density, diversity and connectivity to external marketplaces and (increasingly human) resources. This means, the role of key knowledge-intense centres becomes crucial. It could be said that the knowledge intensification of urban transport could be reduced to two slogans: 'brains on trains' for providing the 'feet on streets'.

Public transport is a means of intensifying human knowledge and knowledge economic activity within cities and centres. While modern ICT, with the shift from copper to optic fibre, intensifies codified and virtual tacit knowledge, shifting human commuting transport from private car use to public transport enables knowledge to be spatially intensified. Effectively, displacing low-capacity private vehicle travel with high-capacity public transport into denser employment centres is a means of intensifying human

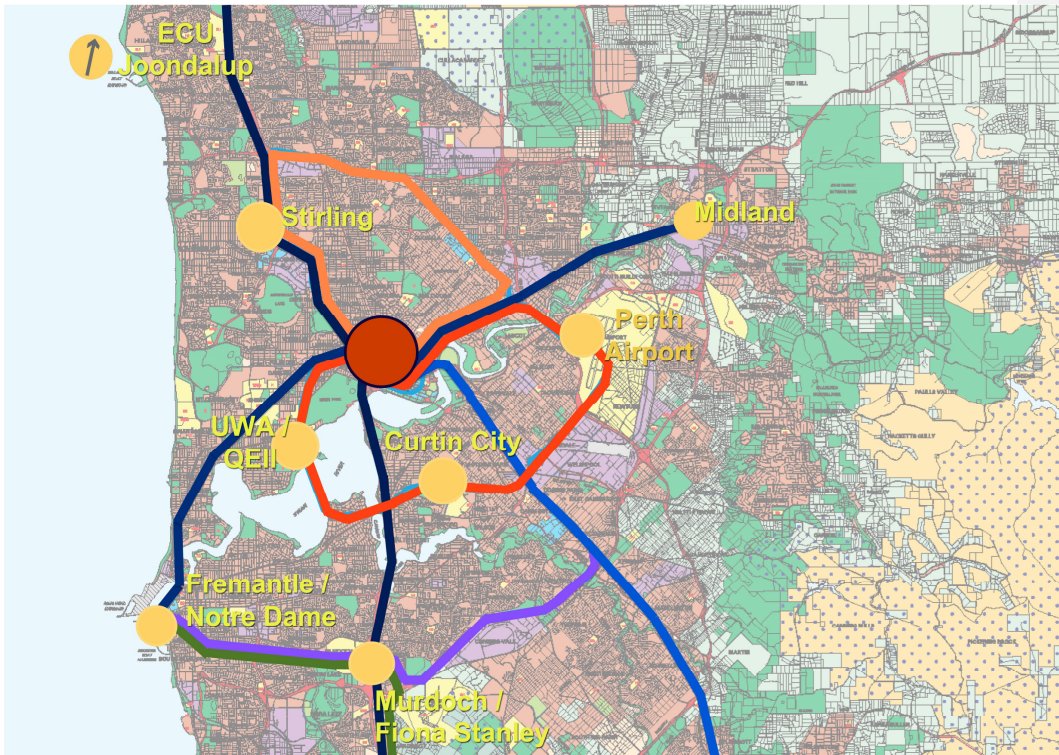
knowledge capital in cities. A key conclusion of this thesis is that transport modes should be considered in terms of their impact on the knowledge intensification of cities. Public transport has traditionally been planned in response to urban growth, to connect areas of sprawl to the city centre. Our existing urban transport strategies are not consistent with a knowledge-intensification approach. Further, an over-reliance in cities on radial road infrastructure and private use of cars for commuting will become increasingly ineffective and there should be a refocusing of road infrastructure investment to orbital road systems.

Australia's major capital cities' CBDs, being the beneficial destination of the overwhelming number of higher capacity and high-frequency radial public transport routes and services, are provided with an overwhelming knowledge-intensity advantage. This spatially intense transport exclusivity creates Australian CBDs as the key metropolitan hubs with the greatest and widest level of accessibility from across the metropolitan areas. This advantage provides capacity, not only for higher levels of urban density, but also for the diversity and size of workforce required to take advantage of the agglomeration opportunities. This means the CBDs have the largest and most effective labour market for knowledge-intense economy driving a return to an ultimately inefficient monocentric urban structure.

The centrality of CBDs also reflects the relatively poor provision of rail services to other metropolitan scale potentially knowledge-intense centres (for example, Specialist Centres around universities and tertiary hospitals). While major universities have a metropolitan wide transport demand, there has been little to no transport planning investment that reflects their need for high order public transport. To realise the potential of non-CBD knowledge-intense centres for new and diverse industries, transport planning strategies need to address the demand for higher levels of public transport accessibility and capacity (i.e. rail based public transport) to these non-CBD knowledge-intense centres. However, the selection of potential non-CBD knowledge-intense centres for urban and transport investment needs to reflect the demand for a high level of urban 'centrality' (closeness to the CBD) so as to provide a higher level of combined agglomeration through scale and density. An overall lack of population scale within Australia, and in particular, within more isolated Australian cities such as Perth, means there is a need to maximise the centrality to realise knowledge-intense agglomeration. Effectively, the urban structure required is a form of polycentricism but within the context of a clustered agglomeration. However, it is argued that public transport needs to also be seen as a catalyst for knowledge-intense economic agglomeration, including potentially knowledge-intense centres of sufficient scale outside of the CBDs.

The urban structure of Australian cities such as Perth requires higher levels of intensification and density within a small number of larger interconnected knowledge urban centres with the intent of driving higher levels of local and regional agglomeration. Applying the key principles from this thesis to Perth, an alternative urban structure for Perth, as a means of supporting growth in the knowledge-intensive economy, could and should be adopted based on the principles set out in **Figure 45**. A 'Knowledge Rail Network' (KRN) is therefore proposed (see **Figure 46 Knowledge Rail Network for Perth** and **Appendix 8 Rail network policy and infrastructure strategies for Perth: the Knowledge Rail Network**), based on the preferred urban structure for Perth (as per **Figure 45**), to facilitate Perth becoming a more knowledge-intensive city.

Figure 46 Knowledge Rail Network for Perth¹³⁵



¹³⁵ The proposed four new lines are as followed:

Line 1 (RED) – Central orbital – (west to east) Perth to Bayswater Station along the Midland line alignment then under to Perth Airport, then along Leach Highway alignment crossing the Armadale line and then under Curtin University, crossing under the Perth to Mandurah line at Canning Bridge Station, continuing under the Swan River to UWA, continuing under the QE11 hospital precinct, connecting onto Fremantle line alignment before Subiaco Station and into Perth Station

Line 2 (ORANGE) - Northern orbital – (west to east) Perth to Bayswater Station along the Midland line alignment, north along Tonkin Highway alignment, under Morley Galleria Strategic Regional Centre and continuing under the Mirrabooka district centre and onto the Reid Highway alignment and then south on the Joondalup to Perth rail alignment just north of Stirling Station and onto a new underground station and line re-alignment at City West (providing a non-CBD Fremantle-Joondalup lines hub station), and then onto the Perth Station.

Line 3 (PURPLE) – Southern orbital – (north to south and then west) Extension of the existing Thornlie line to Jandakot Airport and then under to Murdoch Station, under to Murdoch University and then onto Fremantle Station (and possibly as a Fremantle to Perth service completing the circle).

Line 4 (GREEN) – Fremantle to Mandurah line – (south to north and then west) Mandurah to Cockburn Central on the Mandurah to Perth rail alignment, and then deviating into unused tunnel intended for the Mandurah to Perth via the southern Thornlie alignment and then onto the Southern orbital alignment under to Murdoch Station, under to Murdoch University and then onto Fremantle Station.

Both of these proposals follow the premise that urban economies, labour markets and real estate markets are being subjected to an intensification of knowledge. The proposed urban structure and KRN can be described as following a 'cluster of pearls' approach, as distinct from the radial public transport 'string of pearls'. The KRN reflects not only a transport strategy, but also an alternative approach to developing Perth's key knowledge-intense major 'Specialist Centres'. The KRN provides accessibility and capacity opportunities for the major 'Specialist Centres', effectively creating an agglomeration spillover from the CBD and from other centres within the knowledge-intense 'centrality'.

The rail connectivity, aided by the full range of other modes of spatially intense transports), seeks to address the isolation and absence of metropolitan and local scale within the potentially knowledge-intense 'Specialist Centres'. Effectively, the lack of sufficient local or internal agglomeration needs to be addressed through high-level public transport connectivity to:

- the CBD,
- other potentially knowledge-intense centres, and
- the wider metropolitan area.

The KRN therefore facilitates the maximising of the overall metropolitan urban agglomeration by focusing on the strongest potential knowledge-intense agglomerative locations and, as a result, seeks to maximise Perth's knowledge (and tradable) economic activity.

Ultimately, policy makers need to beware of the driving forces in 21st century urbanism. In this thesis, it is proposed that knowledge intensification is the major driving force. As per the second law of thermodynamics (Davis & Masten 2004), any system or machine that creates an energy outcome, suffers entropy. Similarly, cities seeking to achieve agglomeration benefits from intensification or densification can also experience some levels of dis-agglomeration. These negative energy dis-benefits or dis-agglomerations from intensification – be it road congestion or housing unaffordability (as the real estate markets 'heat up') – means knowledge intensification is about the good management of cities. It raises the question: if we are seeing dis-benefits with density, then do we require a different system of management or infrastructure to lessen the entropy and instead deliver beneficial agglomeration? As Prud'homme and Lee (1999 p. 2) put it:

... not all cities are equally well managed. Tokyo, the largest world city, is probably not too large, because it is reasonably well managed. There are other

cities of the world, cities of 200,000 people which are definitely too large, because they are very poorly managed.

Ultimately, planning and transport policy is, however, more than an issue of good management. Drucker (2003) argued that: “*Management is doing things right; leadership is doing the right things.*” As economies are transformed by the growth of the knowledge economy, this thesis proposed an alternative urban and transport approach that could enable stronger growth of the knowledge-intensive urban economies. To do so will require a change in thinking about post-industrial cities; it will also require innovative and aware leadership.

17.5 Areas of further research

Any thesis seeking to propose a multi-layered theory of knowledge intensification to address broad issues relating to the nature of knowledge economy and its influence on the planning of cities and their transport systems will, raise more questions than it proposes to answer. The theory of knowledge intensification is but an emerging theory and to take the theory to the next level of maturation, it will need to be the subject of further research and application. Knowledge intensification is, in some respects, not a stand-alone theory. At the broad theoretical scale, there is a need for further examination of the theory of knowledge intensification in the context of time intensification, income intensification (or wealth concentration), and endogenous growth theory. It has long been argued by a diverse range of economists that the creation of wealth and subsequent capital accumulation is one of the underpinning (and with over accumulation limiting) elements of the capitalist system (Smith 1776, Marx 1867, Schumpeter 1911, Rosen 1981, Stiglitz 2012). Many notable economists have also argued that a large proportion of growth in developed countries arises from technological change, investment in human capital, knowledge and innovation (Solow 1957, Romer 1986, 1988, Lucas 1988). The theory of knowledge intensification, therefore, could be viewed as a (spatial) subset of endogenous growth theory (in that investment in human capital, innovation and knowledge are significant contributors to economic growth).

The research in this thesis acknowledges that knowledge intensification can become over-concentrated where city structures become monocentric without adequate transport or subsequent sub-centre development. Capital and wealth over-concentration, similar to cities that become spatially over concentrated (i.e. monocentric), has been argued as leading to inefficiencies. There are no doubt links between inefficiencies in knowledge intensification and wealth concentration. Stiglitz

(2012 p. 104) has argued that societies, which become widely unequal, do not function efficiently and their economies are neither stable nor sustainable (see also Rosen 1981).

The relationship between knowledge intensification and time intensification (see Rosa 2013) is an area worthy of further exploration. Efficiency of economic processes and the speed of communication are integral to modern knowledge-intense economic activity. This impact and potential limitations of social and personal time intensification on the changing tempo of modern human existence is worthy of further consideration.

In more practical terms, debates on urban policy and investment application relying on agglomeration theory are in many ways limited in Australia because of the lack of extensive research of urban agglomeration. Further, there is a lack of research on major city commuting patterns based on occupation. Where are professionals commuting to? How long do they travel based on various modes? In many ways, the lack of research and understanding of urban agglomeration is negatively impacting on Australia's metropolitan regional planning. There needs to be a focus on and prioritisation of spatial structural change to our cities that supports agglomerative knowledge production and innovation. This could be undertaken using Census data at the distinctive zone level and GIS to estimate average journey time by occupation. Additionally understanding the impact on modal choice of accessibility of (free) parking, age, and income, for occupations would add greater depth to this analysis.

Another area of research that needs further work is the impact of regional transport and communications infrastructure investment. The evidence strongly suggests that the agglomeration benefits of cities in Australia outweigh the benefits of the combination of dis-agglomeration costs of cities and any low-cost benefits of locating in regional Australia. This is not to say there will not be regional economic development, but that it is not likely to result in relative population growth because the economic development will be managed from the state capital cities. Research into the most appropriate means of achieving regional economic development, in the context of knowledge intensification, is therefore needed.¹³⁶

¹³⁶ Post script:

"The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom."
- Isaac Asimov

"To attain knowledge, add things every day. To attain wisdom, remove things every day."

- Lao Tzu, *Philosopher ~4th - 6th century BC*

The evidence that knowledge intensification as a driving force of knowledge economic activity is overwhelming. However, the author cautions that it should not be assumed that there is a moral superiority to knowledge intensification. Knowledge intensification, while a driver of economic development and wealth in the modern economy, should not be confused with wisdom intensification. Historically, it would appear that the intensification or gaining of knowledge does not appear correlated with the gaining of wisdom. Arguably, the gaining of knowledge and the gaining of wisdom are two different though not mutually exclusive journeys. This

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APPENDIX 1

Economic and Urban Structure Background to Perth, Western Australia

Perth, the capital city of Western Australia, is one of the most isolated cities in the world. Western Australia has a total land area of 2.53 million sq km (Geoscience Australia 2004). Perth's metropolitan area (including the Peel region) had in 2012 grown to contain an estimated population of 1.9 million (over 78 per cent of the state's population) (ABS 2013e). The increasing population has been accommodated largely through residential development on the urban fringe.¹ The next largest city in regional Western Australia is Bunbury with only 33,237 people (ABS 2013e). The Perth metropolitan area is spatially 120km long and up to 40km wide (Weller 2009).

Perth has been described by Weller (2009, p. 29) as being:

...a flatland of freestanding suburban homes and their related infrastructure. In a word 'sprawl'... Perth is now one of the most sprawled (or should we say spacious) cities on earth.

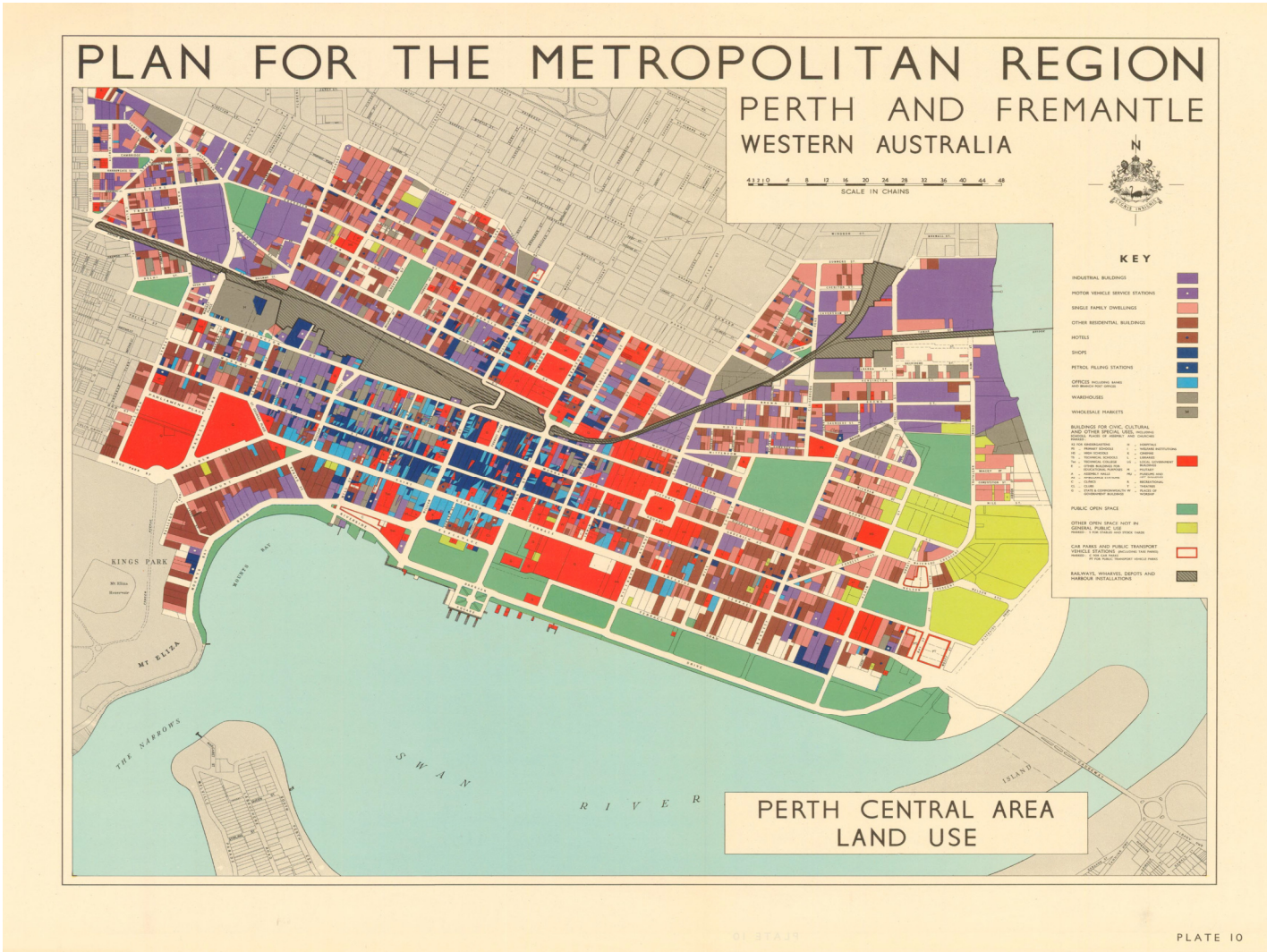
"Urban sprawl" has been said to be an ill-defined term including terms such as 'low density', 'dispersed', 'decentralised', 'suburban', 'polycentric', 'scattered', 'leapfrog development', 'commercial strips' and 'single-use development' (Ewing 1997, Curtis 2006). All of these features are recognisable in the suburbs of Australia's major cities. Weller (2009) and Scannell (2010) contended that Perth is rapidly heading down the path of endless sprawl. Perth's urban density declined with the advent of the motor car in the 1960s and 1970s, similar to other Australian and a number of southern US cities (Newman and Kenworthy 2011). Newman and Kenworthy (2011, p. 7) noted though that Perth, along with many car dominated cities, has seen a peak in the decline of urban density and is now increasing in density, and is one of the cities that is 'coming back in faster than it is expanding'.

The low-density nature of Perth is reflected in its transport systems, and not surprisingly Perth has been one of the most car dependent sprawling cities on the planet (Newman and Kenworthy 1989, Weller 2009). The historical impact of transport infrastructure, particularly road, on the form of urban development and structure of metropolitan Perth is well accepted (Edmonds 1998, Davis & Hartford-Mills 2016). The car has been the dominant transport mode share in Perth for over half a century, and hence, is a major influence on employment spatial distribution within the metropolitan area. The structure of

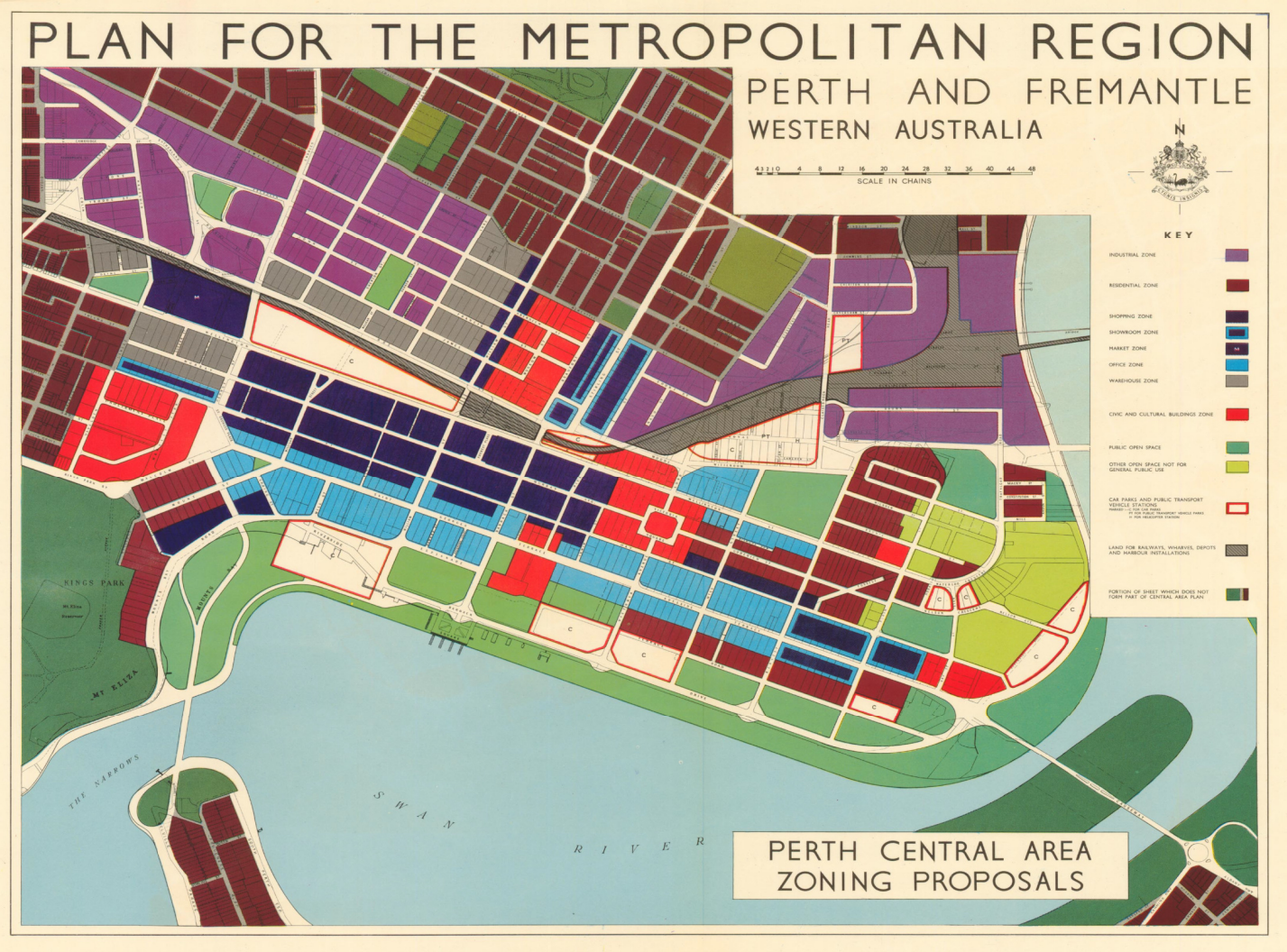
¹ With the City of Wanneroo, on Perth's northern fringe, accounting for 23 per cent of Perth's population increase. In 2006, the outer subregions had 50 per cent of the population, but just 30 per cent of jobs. A lack of jobs, relative to population, is most evident in the South-East and North-West metropolitan subregions.

modern metropolitan Perth, following the Plan for the Metropolitan Region, Perth and Fremantle, 1955 (Hepburn and Stephenson 1955) was that of a road-based city. **Figure 1A** demonstrates the impact of planning for the car on land use within the Perth CBD (Hepburn and Stephenson 1955).

Figure 1A – Plan for the Perth Central Area – Hepburn and Stephenson 1955
 Map A – Perth Central Area Land Use (<http://www.planning.wa.gov.au/5308.asp> Plate 10 of Atlas)



Map B – Perth Central Area Zoning Proposals (<http://www.planning.wa.gov.au/5308.asp> Plate 11 of Atlas)



Map A in **Figure 1A** is pre-metropolitan planning with land uses developing organically – a fine grain mixed use 19th century walking and rail focused grid. **Map B** provides the Stephenson Hepburn zoning proposal plan. This includes the Kwinana Highway dominating the city foreshore, coming across Narrows Bridge with a ring road around the southern, eastern and northern boundaries of the CBD. The impact of the freeway was not just to be on the CBD. The car provided the mechanism for Perth to grow to a large city, area wise, for its population (Edmonds 1998). By 2001, Perth had the third highest number (77.9 per cent) of separate houses in Australian state capital cities after Brisbane and Hobart, with the third lowest amount of highest density housing, also after Brisbane and Hobart (Beeton et al. 2006, p. 9). Perth continued to support its sprawl with major transport infrastructure investment, not only in freeways but also radial rail which has serviced and supported sprawling suburbs (McManus 2005). However from the early 1990s, with the increase in urban density, there has been an increase in public transport use and a decline in car use for commuting, particularly into the CBD where there has been a dramatic turnaround back to public transport use (Richardson 2010).

The major economic drivers influencing Perth's urban structure, following the end of the Second World War (WW II) were the:

- revival of the mining and resources industry,
- the rise and fall of the manufacturing industry, and
- the onward and upward growth in the services industry.

These economic drivers can be traced back, firstly to post war industrial manufacturing development and then more importantly to the State's second major resource boom. This resource boom was stimulated in 1962 by the Commonwealth Government lifting the iron ore export embargo that had been in place since 1938 (Department of Trade & Finance (DTF) 2004).

As with the more recent growth in the resources sector, there appears to be an on-going symbiotic relationship between growth in the minerals and resources sector and growth and dominance of the Perth metropolitan area. This is despite Perth's remoteness from much of the mining activity. The 1960s mining-led population boom saw Perth increase its primacy, achieving 73 per cent of the state's population by the 1980s. The impact of the resources sector on the Perth CBD has been more uneven. In the period from 1961 to 1976, the Perth CBD declined, in terms of the number and percentage of jobs, with dispersment of retail, wholesaling, manufacturing and other blue collar employment to the suburbs (Houghton 1981). However, the only occupational categories to increase their numbers within the CBD, up to 1976, were the 'Professional and Technical, and Clerical and Services' occupations (Houghton 1981). Houghton (1981) noted, at the time, the expectation that the Perth CBD or central area would see a further office-based employment as a result of the minerals resource development. Seddon and Ravine

(1986) however, saw it differently some five years later, questioning the future land values and benefits of business being on St Georges Terrace in the heart of the CBD. Seddon and Ravine (1986), perhaps influenced by the sterility² that had overcome the Perth CBD from the 1960s, saw that proximity no longer had much meaning and thought it 'sensible' for Western Mining Corporation head office to be located on the Great Eastern Highway at Belmont, close to the airport, rather than on St Georges Terrace.

The rise and decline of manufacturing in Perth has not been a notable force on the recent urban structure of Perth. Western Australia has, throughout most of its history, been a net importer of manufactured goods, with small manufacturing industries servicing local primary resource industries, mainly agricultural, mining and resources (Crowley 1960, Stannage 1981, DTF 2004). Around each of the urban centres in the Perth metropolitan areas there were small-localised industrial areas. In Fremantle, this was around North Fremantle. In Perth, there were industrial areas in Subiaco, areas north of the railway in West Perth, and more extensively in East Perth. Midland the industrial development was centred on the Midland Rail Workshops. As a result of Perth's and Western Australia's major population growth period, being from the 1960s onwards³ when manufacturing industries had already begun to disperse to suburban locations, meant Perth did not develop large tracts of inner city manufacturing to the same scale as Sydney and Melbourne.

By the early 2000s, Perth's industrial composition reflected the changes in favour of the service industries, with finance and business services, public administration, community services and trade and entertainment growing at the expense of manufacturing, transport and construction and other non-service industries (WAPC 2003, SGS 2011). By 2011, the financial and insurance services sector alone was a larger part of the Perth economy than manufacturing (SGS 2011). Notably, even with much of the mineral processing industry in Western Australia (e.g. alumina refining) being classified as manufacturing, Western Australia's manufacturing as a proportion of the total economy has been lower than that of the rest of Australia (DTF 2004).

The impact of strong economic growth generated mainly by the mining and resources sector has been twofold on urban structure in Perth. By driving economic prosperity since the 1960s, it has driven much of the population growth and the resulting suburbanisation. The revival of mining and resource economic activity, starting in the early 1960s, drove Perth's population growth, which in turn, with the advent of the mass adoption of the

² Seddon and Ravine (1987) lamented the loss of intimacy, human scale, variety, a colourful street life, elegance, urbanity, density of texture and a rich urban fabric in the 1980s Perth CBD with the development that came in the 1950s to 1980s.

³ Western Australia had a relatively (low) consistent share of the national population until the 1960s and 1970s, when substantial resource led expansion of its economy began. As a result, Western Australia's population only exceeded that of South Australia by 1982 (ABS 2012a).

motor vehicle, lead to the suburbanisation of this population (Houghton 1981, Edmonds 1998, Weller 2009). These two key influences of population growth and suburbanisation saw the end of Perth as a traditional monocentric city. Planning for metropolitan Perth has gone through a series of planning strategies which have ebbed and flowed from corridor growth plans to a focus on more restrained sprawl (McManus 2005). Despite this ebb and flow in planning policy, there has been an on-going attempt to create a polycentric Perth metropolitan area.

From 1975-83, urban development planning was focused on the 1970 Corridor Plan (adopted in 1973). Houghton (1981), looking at growth of metropolitan Perth and the changes in the distribution of employment in the period 1966 to 1976, noted that, with the increase in car ownership, workforces were becoming more mobile in their commuting, and this was scattering and suburbanising jobs. At the time, Houghton (1981) noted that, with the decline in the central area, there was a disagreement amongst observers as to whether there be a progression to complete dispersion of activities throughout 'vast sprawling metropolitan regions' or whether the advantages of agglomeration would give rise to secondary centres. In Australian cities of the era, it was observed that, with one or two exceptions (i.e. Parramatta), new sub-centres supporting a wide range of retail, commercial and administrative functions had failed to emerge in Australian cities (Houghton 1981). Houghton (1981) noted that Fremantle had attracted almost no new office development while Nedlands, around UWA, as the largest sub 'centre' for employment outside the central area, had attracted new office-based tertiary education and hospital jobs while lacking a commercial focus and retail. ⁴

By the 1980s, Planning for the Future of the Perth Metropolitan Region was developed as a critique of the 1970 Corridor Plan with a focus on urban consolidation (McManus 2005). However by 1990, Metroplan reverted to the corridor planning philosophy. Network City was a plan for urban consolidation around a network of evenly dispersed centres with a clear agenda for a polycentric city. With Perth 2031, it could again be considered a return to the 'corridor type plan' of stretching the metropolitan area; it retains a focus on polycentric outcomes.

The importance of the most recent (and now passed) resource boom to Perth cannot be underestimated. Investments in the mining sector, particularly gas and iron ore production during 2000 to 2006, led to unprecedented growth levels in the city (WAPC 2010a - *Directions 2031*). By the turn of the 21st century, the Western Australian economy had become a highly specialised trade-dependent economy, with exports of primary commodities (mining and agricultural) dominating production (DTF 2004). Importantly, while iron ore continues as a significant component of the mining industry, an important

⁴ Urbis (2011) working for the City of Fremantle 30 years later identified little change in the attractiveness of Fremantle as a centre for office based employment.

aspect of the resources boom, which started in the 1960s and set it apart from the 19th century gold rush, was the diversity of commodities being mined. This more recent mining boom has led to a revival in knowledge service workers within the CBD, with the CBD absolute job numbers declining, up and until the 1990s, and since then steadily increasing (Department of Planning et al. 2009, BITRE 2012). The City of Perth (the local government for the CBD area of metropolitan Perth) has noted, in its 2010 economic strategy, that Perth is operating in a global economy, competing beyond the domestic market to attract financial capital, skilled workers and business investment (City of Perth 2010a). The economic strategy for the City of Perth identifies the growth in the resource industry as the key driver of the Perth CBD's economy⁵.

By 2003, the WAPC (2003), while recognising the population shift to cities, raised the question that, in the 21st century, with the rise of the Internet and the increasing ability of service sector businesses to conduct their networking and attain their supporting service infrastructure in cyberspace, it would be problematic to see continuing agglomeration of the service sector in a CBD (WAPC 2003). The WAPC (2003) foresaw future job distribution within metropolitan Perth was likely to be more evenly distributed than it has been in the past, with work trip distances and times reduced as jobs move towards the outer regions. It was even foreseen that much of the future long-term employment and population growth of metropolitan Perth did not necessarily have to concentrate within metropolitan Perth. Developing new urban alternatives to the city was thought to be possibly a better option.

The WAPC was forecasting the end of distance at the metropolitan scale. By the early 2000s, Perth's industrial composition reflected these changes in favour of the service industries, with finance and business services, public administration, community services and trade and entertainment growing at the expense of manufacturing, transport and construction and other non-service industries (WAPC 2003). With an increasingly sprawling population, Perth's employment was shifting away from the inner city to the suburbs. Most notably, the Perth CBD's share of jobs had almost halved over the previous 30 years. Jobs or industries were, according to the State Government's Western Australian Planning Commission (WAPC 2003), no longer tied to specific locations, reflecting decentralising population patterns (WAPC 2003). However, this was really two intersecting trends happening. As Perth suburbs grew, so did retail and other population-driven service employment within these suburbs.

The other trend was the employment growth in professionals, associate professionals, and managers and administrators, all which grew from the mid 1990s (Department of

⁵ The City of Perth's Strategy – noting that the Western Australia's state's economy nearly doubled in size between 2000 and 2008 with almost 200,000 new jobs created, mostly in the 'booming' resource sector. As of January 2010, there was about \$278 billion worth of projects classified as either under construction or committed to start construction soon in Western Australia.

Training and Workforce Development ('DTWD') 2010). However the spatial location of professional employees within Perth, rather than dispersing like retail and other service occupations, has concentrated in and around the CBD.

In 2005, the WA Government, following extensive public consultation and involvement, released the Network City plan. Network City was based on a network with a hierarchy of centres suited to serving the different needs of the population at different spatial scales (regional, district, neighbourhood), with the centres also providing a key role in integrating and supporting a transport network of different modal layers (Curtis 2006). Curtis (2006) has argued that the main benefit of a network of activity and transport corridors was in promoting sustainable urban growth through accommodating population growth within higher-density activity corridors containing urban sprawl, and using land more efficiently. Perth's Network City reflected an emerging professional consensus towards a type of multi-centred city form centred on public transport corridors (Curtis 2006).

The plan arguably lacked a comprehensive policy to guide the planning, development and management of activity centres and corridors, and economics firm, PRACSYS, were engaged to assist in the development of a policy to define a spatial framework of activity centres and corridors (PRACSYS 2011). It was identified that many local governments saw problems with regional centres dominated by one-dimensional retail-dominated employment shopping centres. This led to a lack of vibrant activity centres, an inability to attract new businesses, low labour productivity and resulting high rates of unemployment, and a large burden of providing social welfare services in their communities (PRACSYS 2011). Part of the solution proposed was decentralizing knowledge-intensive occupations from the CBD and surrounds into selected activity centres to reduce the frequency and duration of work trips (PRACYS 2011). This would require activity centres to become more services focused and increase the amenities offered. This would require less focus on retail floor space than had occurred under the Metropolitan Centres Policy. Instead there needed to be an understanding of how to attract higher-order, knowledge-intensive employers (PRACSYS 2011).

In 2009, Network City was replaced as Perth's principle planning document by the present metropolitan plan produced by the Western Australian Planning Commission (WAPC); *Directions 2031 and Beyond: Metropolitan Planning beyond the Horizon* (WAPC 2010a). *Directions 2031* is the highest level spatial framework and strategic plan for the metropolitan Perth and Peel region (WAPC 2010a). *Directions 2031* (2010) continued the support for the need to curb urban sprawl in favour of a connected city. In some respects, the differences between Network City's and Direction 2031's infill target masked the similarities on focusing on a polycentric city structure with connected activity centres, with an increasing role for public transport.

The primary focus of *Directions 2031* is very much about strategies to meet strong population growth, and how the planning system could accommodate a city of 3.5 million people. By 2031, the population of Perth was forecasted to grow by at least half a million people to 2.2 million residents. The upper end of the predicted rate of growth had the population potentially reaching 2.88 million by 2031. In order to accommodate 2.2 million people it was estimated that there will need to be another 328,000 houses and 353,000 jobs (WAPC 2010a).

The economic context of the population growth underpinning *Directions 2031* (WAPC 2010a; p. 21) is stated as:

Over the coming decades economic, business and political forecasts indicate that Western Australia will move into a period of sustained population growth and economic development. This is underpinned by our mining and engineering sectors with strong export markets to Asia – particularly India and China. The strength of our economy will depend on our ability to build business confidence, attract foreign investment and create jobs.

By 2015, extremely difficult economic conditions impacting on the mining and resources sector and the state's economy generally (DTF 2015) suggests population growth and economic development, underpinned by mining and engineering sectors, may be more difficult to sustain than originally forecasted. A deeper economic strategy aimed at diversifying the Western Australia and Perth economy may be required.

APENDIX 2

Spatial characteristics of data centres

The spatial characteristics of data centres can be divided into either locational or site factors. Site factors relate to the physical and environmental security of data centres. Physical and environmental security is a requirement of ISO 27001:2005⁶. Site, including building factors, relate mainly to reliability and security issues such as:

- perimeter security,
- surveillance capacity,
- security access points, and
- preference for being a purpose-specific building, or at least not having walls adjacent to other offices.

Spatial locational issues for data centres relate to the wider locational needs, beyond immediate site issues. Oley (2010), of the USA based property company, Jones Lang La Salle, contended that the process for finding the best place to locate a data centre was under continual refinement. This was because of the need to accommodate an industry that is evolutionary and constantly changing, based on the concept of developing technologies. Any location to be a preferred site for a data centres needs to be able to address multiple criteria. A review of data centre research and industry position and white papers suggest ten spatial locational factors being identified for data centres (Heare 2001, IsecT 2004 & 2011, Alger 2005, Kishore 2007, Koomey 2007, Phan & Wen-Syan 2008, Fortrust 2008, Greenberg et al. 2009, Oley 2010, Jones Lang La Salle 2010, Huan & Orban 2010, Baliga et al. 2010, Benson et al. 2010, Rath 2011).

These ten locational factors are set out below.

1. Free from human environmental risk to security

Data centres need to be away from any human caused disaster or potential major accident or human activity (such as heavy vibrations) that threatens the physical security of the data centre, or through a lock down, may impede access to the data centre i.e. away from terrorism targets, airport activities, prisons, freeways reserves, stadiums, banks, electromagnetic hazards, noxious industries, nuclear power plant, refineries, pipelines tank farms, hazardous freight routes, and parade routes (Heare 2001, IsecT 2004 and 2011, Alger 2005, Rath 2011).

⁶ ISO 27001:2005 is the international standard for the management of information assets and for safeguarding business continuity. In the Australia site, security requirements are high with a number of data centres following the Australian Federal Government ASIO T4 standards which is a 'protective security' combination of procedural, physical, personnel, and information security measures designed to provide government information, functions, resources, employees and clients with protection against security threats (ASIO 2011, Macquarie Telecom 2011, IsecT 2004 and 2011).

2. Free from natural disaster environmental risk to security

Natural disaster risk is a critical threat and includes climatic, geological, and hydrological events (Oley 2010, Rath 2011). Critical environmental locational issues are considered to be flooding, being above water tables, bushfire, earthquake risk, volcanic activity, cyclone/hurricane, storm surge/tsunami.

3. Internet infrastructure access to fibre networks connections

The availability and quality of fibre (preferably high standard Tier 1) at a potential data centre location is paramount (Fortrust 2008, Greenberg et al. 2009, Rath 2011). Data centres are required to have high speed Internet connectivity to perform their services. Major data centres with their massive computing requirements require extensive communication between servers (which is costly in time and money).

4. Critical power requirements to operate reliably and efficiently

Access to reliable power is an essential factor for the reliable operation of data centres. Data centres are driven by increased computing density being required to support increasingly dense configurations, power and cooling requirement (Ranganathan & Jouppe 2005, Koomey 2007, Hewlett-Packard 2007, Samadiani, Amur, Krishnan, Joshi, & Schwan 2010).

5. Physical accessibility of key technical staff

The spatial characteristics that are apparent with ICT are, in part, the result of the human interaction with the physical ICT infrastructure – most network outages are caused by operator error in configurations (Huan & Orban 2010). ICT networks are dependent upon specialist labour, *so locations within a central location (i.e. within CBD or inner city or where outside the city core there is access via major highway connections)* are desirable. Research and development is working to increase the remote working capacity of IT specialists (Huan & Orban 2010).

6. Physical accessibility for clients including client technical support

Physical access for clients, particularly with collocation services, is a clear desirability for data centres. Generally, access, based on walkability, or reasonable commuting driving distances, would mean same region, city or within the same business district. A European data centre survey, Jones Lang La Salle (2010), indicated that a good distance from 'central control' was still not wholly acceptable amongst occupiers.

7. Land space for larger data centres (to provide for sizable floor area)

Heare (2001) has argued that a data centre should not share the same building with other offices, especially offices not owned by the organization. In the alternative, that is, if a space must be shared due to cost, then the data centre should not have walls adjacent to

other offices. TIA-942 (2006), the US data centre standards overview (promoting four levels of tiered reliability), in setting out key elements for designing data centres notes that data centres should be designed with plenty of flexible space that can accommodate future growth. The need for sizable floor space means that CBD and inner city sites can be too costly, or hard to find, for larger new data centres. In the USA, this has seen data centres locate at business parks or university research parks. In Australia, in addition to business parks, light industrial or logistics centres are favourable locations for larger centres⁷. Larger data centres are being driven by demand for larger corporate and government clients.

8. Diverse locational spread to minimise latency and data disaster recovery

A diverse spread of locations ensures national or regional coverage to minimise latency (Wu-chang & Wu-chi 2003, Arnuk & Saluzzi, 2009 Greenberg et al. 2009, Bernier 2010), and/or to provide for data disaster recovery (Bakshi 2010, Rath 2011). As data travels at the speed of light, latency (or the difference between action and response) or lag can be noticeable and relevant. Certain Internet activities such as gaming (Wu-chang & Wu-chi 2003) and financial trading (Arnuk and Saluzzi 2009) are extremely sensitive to latency.

9. Political and management security

Data centres, being within the country or region of corporate presence, provide greater legal and management capacity, particularly for smaller size businesses, or where national privacy laws may be applicable (Carnbuci & Tropman 2010, Rath 2011).

10. Local government tax or developer locational incentives

Rath (2011) has noted that in the USA, attracting data centres to cities and states is big business, with Internet companies having received, in recent years, incentives and tax breaks to locate their data centres throughout the USA. While not a primary factor for location, Rath (2011) and Oley (2010) have noted that, all matter being equal, tax incentives can influence final location decisions.

Data centres do not spatially exist in the cloud or a virtual world. They are subject to a number of physical risks and influences. Data centres are not removed from the advantages of proximity through legal and political boundaries, economic agglomeration, and importantly, access to established urban energy and ICT (fibre optic broadband and Internet exchanges) infrastructure.

⁷ Hewlett-Packard, in 2010, applied to build a 'data centre complex' on a land parcel of 134,000 m² in Eastern Creek within the M7 logistics business hub in NSW, approximately one hour from the Sydney CBD (The Australian 2010 <http://www.theaustralian.com.au/business/technology/hp-sinks-millions-into-data-centre-project/story-e6frgax-1225966580282>). The data centre was opened in June 2012 (<http://www.blacktownsun.com.au/story/240891/hp-data-centre-opened-at-eastern-creek/>).

APPENDIX 3 - WAIX Participants 2010 and 2012

Table 3A WAIX Participants 2010

	Participants Name	Office location	Distance to WA IX	ABS Industry code
A	HostAway Pty Ltd	Unit 1, 8 Midas Road Malaga WA 6090	11.13	5922 Electronic information storage services
B	AAPT	Sydney		5910 Internet Service providers and web search portals
C	AARnet	AARNet Pty Ltd POD 3 20 Dick Perry Avenue Kensington WA 6151	5.67	5910 Internet Service providers and web search portals
D	Accord Crox acquired by Hostech t/a anitel 2010	3/75 Erindale Rd Balcatta WA 6914	11.06	5922 Electronic information storage services
E	Amcom Pty Ltd	Level 2 44 St Georges terrace Perth WA 6000	0.86	58001 Wired telecommunications Network Operations
F	ANFIUWP Australian Nursing Federation	260 Pier St Perth WA 6000	1.44	9551 Business and professional association services/9552 Labour association services
G	AS112 Servers	WAIX Perth 6000	0	5922 Electronic information storage services
H	AsiaNetcom Acquired by Pacnet 2008	Melbourne	2,735	5910 Internet Service providers and web search portals
I	Bekkers IT	Suite 5. 884 Beaufort St Inglewood WA 6052	4.74	5910 Internet Service providers and web search portals
J	B.E.S./E-Wire	17 Millrose Drive Malaga WA 6090	10.96	5922 Electronic information

				storage services
K	BG&E Pty Ltd	484 Murray Street Perth WA 6000	0.23	6923 Engineering design and engineering consultancy service
L	Bitgravity	Burlingame California USA		5700 Internet Publishing and Broadcasting
M	Brennan IT	Sydney Australia	3,300	5922 Electronic information storage services
N	Silk Telecom	Suite 4B, 200 Wellington Street East Perth WA	1.69	58001 Wired telecommunications Network Operations
O	BroadbandNet Pty Ltd	48 Fairbrother Street, Belmont WA 6104	7.43	5910 Internet Service providers and web search portals
P	CacheFly	Chicago USA		5921 Data processing, web hosting and electronic storage services
Q	Central Data Systems	88 Havelock Street West Perth WA 6005	0/0.70	5922 Electronic information storage services
R	CipherTel	Unit 3, 9 Bourke Street Bunbury 6230	155	5910 Internet Service providers and web search portals
S	Commerce Australia	Level 2 8 Parliament Place West Perth 6005	0.48	5910 Internet Service providers and web search portals
T	Community DNS	Bath UK		5910 Internet Service providers and web search portals
U	cynergic	Subiaco 6008	2.9	5922 Electronic information storage services
V	DALnet	Wayne State University Detroit USA		5910 Internet Service providers and web search portals

X	DC West	Level 1 234 Pier St Perth WA 6000	1.42	5922 Electronic information storage services
Y	DiversIT	28 John St, Northbridge WA 6003	0.87	7000 Computer system design and related services
Z	Eftel	QV1 250 St Georges terrace WA 6000	0	5910 Internet Service providers and web search portals
1	Emerge Technologies Pty Ltd	3/72 Brockman Street Kalgoorlie WA 6430	550	5910 Internet Service providers and web search portals
2	EON Technologies Acquired by Highway 1 July 2010	Level 5 Williams Street Perth 6000	0.6	5922 Electronic information storage services
3	e-vision	Huntingdale Victoria Australia		5910 Internet Service providers and web search portals
4	Fast.hit Web hosting	Level 3, 80 Barrack Street Perth WA 6000	0.93	5910 Internet Service providers and web search portals
5	Foxgold Pty Ltd	Unit 5 88 Walters Drive Herdsman Lake WA 6017	7.25	7000 Computer system design and related services
6	Global Dial	278 Stirling Highway Claremont 6010	7.7	5910 Internet Service providers and web search portals
7	Highway 1	Level 5, 10 William St Perth 6000	0.88 0.61 2.16	5910 Internet Service providers and web search portals
8	Hutchinson	North Sydney, Australia		5802 Other Telecommunications Network Operations
9	iinet	Level 1, 502 Hay Street Subiaco 6008	2.84	5910 Internet Service providers and web search portals
10	Intelligent IP	48 Fairbrother Street Belmont 6104	7.4	5910 Internet Service providers and web search portals
11	Internode	Adelaide SA		5910 Internet Service providers and web search portals

12	i-root	Stockholm, Sweden		5910 Internet Service providers and web search portals
13	ITC Global	Level 3, 28 Kings Park Road, West Perth WA 6005	1.08	5802 Other Telecommunication Network Operations
14	JDV Acquired by IWL Limited 2005, acquired by CBA 2007	Level 7, 141 St Georges Terrace, Perth 6000	0.46	6411 Financial Asset Broking Services
15	Nearmap	66 Kings Park Road West Perth 6005	1.53	6922 Surveying and mapping services
16	Nextgen	Level 2, 18-32 Parliament Place West Perth 6005	0.55	5922 Electronic information storage services
17	Ocean Broadband	Suite 7, 295 Rokeby Rd Subiaco 6008	2.55	5910 Internet Service providers and web search portals
18	Orion	Level 2, 231 Adelaide Terrace, Perth WA 6000	1.71	5802 Other Telecommunication Network Operations
19	Pacnet	Sydney, Australia, Hong Kong and Singapore		5922 Electronic information storage services
20	Packet Clearing House	Berkeley, San Francisco		5910 Internet Service providers and web search portals
21	People Telecom Acquired by M2 Telecommunications in 2009	North Sydney (M2 -South Melbourne)		5910 Internet Service providers and web search portals
22	PerthIX		.6	5922 Electronic information storage services
23	PIPE Network	Brisbane		5910 Internet Service providers and web search portals
24	PowerTel AAPT company	Sydney		5910 Internet Service providers and web search portals
25	iprimus	Melbourne		5910 Internet Service providers

				and web search portals
26	R-NAS	Bentley Technology Park Bentley 6102	5.23	5802 Other Telecommunication Network Operations
27	ServiceNet	ServiceNet Department of Treasury Finance Cannington WA 6987	11.20	5922 Electronic information storage services
28	Select Communications	Welshpool, WA 6106	8.71	5910 Internet Service providers and web search portals
29	Service Elements	45 Ventnor Ave West Perth 6005	1.22	5809 Other telecommunication services
30	Soul	Sydney		5910 Internet Service providers and web search portals
31	Symbio Networks	Surrey Hills		5809 Other telecommunication services
32	Syra	Adelaide Terrace Perth	1.81	5921 Data processing, web hosting and electronic storage services
33	TPGi	North Ryde NSW		5910 Internet Service providers and web search portals
34	Vivid Wireless	Sydney		5802 Other Telecommunications Network Operations
35	Vocus	North Sydney		58001 Wired telecommunications Network Operations
36	West Australian Networks	Hillarys WA 6923	20.21	5910 Internet Service providers and web search portals
37	WAnet Acquired by inet	Inglewood 6052	5.19	5910 Internet Service providers and web search portals
38	Webinabox	Leederville 6903	2.04	5921 Data processing, web hosting and electronic storage services
39	Westnet	Level 7 152 St Georges Terrace Perth 6000	0.52	5910 Internet Service providers and web search portals

40	Xenion Communications	Stirling 6021	9.16	5921 Data processing, web hosting and electronic storage services
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Table 3B WAIX 2012 Participants

	Participant's name	Office location/address	Distance to WAIX kms	Other offices	ABS Industry Code
1.	AAPT (AS2764)	Level 14 / 9 Lang Street, Sydney, NSW, 2000	3,300		5910 Internet Service providers and web search portals
2.	AARNet (AS7575) AARNet Pty Ltd	POD 3 20 Dick Perry Avenue Kensington WA 6151	5.67	Australia Head office AARNet Pty Ltd Level 2, Binary Centre, Bldg1, 3 Richardson Place North Ryde NSW 2113 Australia	5910 Internet Service providers and web search portals
3.	Acure (AS45653)	Level 4, 118 Bennett St, East Perth, WA, 6004	2.15		5922 Electronic information storage services
4.	AMC DC(AS55539)	2 MCGRATH RD, MUNSTER, WA 6166	22.25		5922 Electronic information storage services
5.	Amnet (AS9822)	1/45 St Georges Terrace Perth WA 6000	0.85		5910 Internet Service providers and web search portals
6.	ANFIUWP (AS45118)	260 Pier Street PERTH WA 6000	1.44		9551 Business and professional association services/9552 Labour association services
7.	Anittel (AS7631)	Unit 3 / 75 Erindale Road Balcatta WA 6021	10.7	Sydney - Head Office Level 10,	7000 Computer system design and related services

				132 Arthur Street North Sydney NSW 2060	
8.	as112 Project (AS112)				5922 Electronic information storage services
9.	BG Engineering (AS45500)	484 Murray Street Perth WA 6000	0.23		6923 Engineering design and engineering consultancy service
10.	Bekkers IT (AS7703)	Suite 5, 884 Beaufort Street Inglewood WA 6052	4.74		5910 Internet Service providers and web search portals
11.	BigAir AS24093)	Level 1, 59 Buckingham Street Surry Hills, NSW 2010, AUSTRALIA	3,300		5802 Other Telecommunications Network Operations
12.	Bitgravity (AS40009)	700 Airport Boulevard #100 Burlingame, CA 94010	14,740		5700 Internet Publishing and Broadcasting
13.	Brennan IT (AS9738)	Level 14, 45 Clarence Street, Sydney, NSW 2000	3,300		7000 Computer system design and related services
14.	<i>*Broadband Net (AS9549)</i>	<i>Level 1 16 Hulme Crt Myaree 6154</i>	<i>10.86</i>		5910 Internet Service providers and web search portals
15.	Cachefly (AS30081)	209 W. Jackson Suite 700 Chicago IL 60606	17900		5921 Data processing, web hosting and electronic storage services
16.	CBH (AS45207)	30 Delhi Street, West Perth	0.94		3312 Cereal grain wholesaling
17.	Central Data Systems (AS18065)	88 Havelock St West Perth 6005	0.7		5922 Electronic information storage services
18.	Ciphertel (AS24315)	Unit 3, 9 Bourke Street, Bunbury WA 6230	155		5910 Internet Service providers and web search portals
19.	Commerce Australia (AS7607)	Level 2, 8 Parliament Place West Perth, Western Australia 6005	0.48		5910 Internet Service providers and web search portals
20.	Community DNS (AS42909)	Bath University Innovation Centre, Carpenter House Broad Quay Bath, BA1 1UD UK	14,620		5910 Internet Service providers and web search portals

21.	Cynergic (AS18405)	186 Hay Street Subiaco WA 6008	2.9		7000 Computer system design and related services
22.	DALNet IRC (AS31800)	USA	17,990		5910 Internet Service providers and web search portals
23.	Datacom (AS10203)	Level 2 184 Adelaide Terrace East Perth WA 6004	1.97	Level 5 15 Talavera rd North Ryde NSW 2113	5921 Data processing, web hosting and electronic storage services
24.	DC Two (132145)	KARDINYA, WA, 6163	12.8		5921 Data processing, web hosting and electronic storage services
25.	DC West (AS38716)	234 Pier St Perth	1.42		5921 Data processing, web hosting and electronic storage services
26.	Department of Environmental Conservation (AS55881)	168 St Georges Terrace, Perth WA 6000	0.4		7520 State Government Administration
27.	*Diversit (AS45828)	Unit 76 / 20 Royal St East Perth 6004	2.72		7000 Computer system design and related services
28.	E-Vision (AS38714)	Unit 14, 270 Ferntree Gully Road, Notting Hill, Victoria, 3166			58001 Wired telecommunications Network Operations
29.	*Eftel (AS17409)	1141 Hay Street West Perth 6005	0.65		5910 Internet Service providers and web search portals
30.	Exetel (AS10143)	North Sydney	3,300		5910 Internet Service providers and web search portals
31.	*Fasthit (AS24381)	Level 3, 80 Barrack Street PERTH WA 6000	0.93		5910 Internet Service providers and web search portals
32.	FireNet (AS38883)	Level 10 66 King St Sydney NSW 2000	3,300		5910 Internet Service providers and web search portals
33.	Focus Net (AS58408)	98 Burswood Road Burswood WA 6100	4.5		7000 Computer system design and related services
34.	*Foxgold (AS10236)	Hutton St Osborne Park 6017	6.2		7000 Computer system design and related services

35.	GoldNet (AS17635)	Shop 1, 97 Forrest Street, Kalgoorlie WA 6430			58001 Wired telecommunications Network Operations
36.	Hostaway (AS24541)	Unit 1, 8 Midas Road Malaga WA 6090	11.13		5922 Electronic information storage services
37.	i-root (AS8674)	Franzéngatan 5 112 51 STOCKHOLM Sweden			5910 Internet Service providers and web search portals
38.	iiNet (AS4802)	Level 1, 502 Hay Street, SUBIACO, WA, AUSTRALIA, 6008	2.84		5910 Internet Service providers and web search portals
39.	*iPrimus (AS9443)	3/197 St Georges Tce Perth WA 6000	0.23	3/538 Collins Street Melbourne	5910 Internet Service providers and web search portals
40.	Intelligent IP (AS23935)	48 Fairbrother Street, Belmont WA 6104.	7.4		5910 Internet Service providers and web search portals
41.	Internode (AS4739)	150 Grenfell Street in Adelaide			5910 Internet Service providers and web search portals
42.	iSeek (AS9723)	46 Logan Rd Woolloongabba QLD 4102			5922 Electronic information storage services
43.	*ITC Global (AS24039)	48 Mordaunt Circuit Canning Vale, WA 6155 Australia	14.4	1 Progress Plz # 700 St. Petersburg, FL 33701, United States	5802 Other Telecommunication Network Operations
44.	JDV (AS9518)	5/141 St Georges Terrace, Perth WA 6000	0.4		6411 Financial Asset Broking Services
45.	Link Innovations (AS23677)	53/5-7 Inglewood Place Baulkham Hills NSW 2153			5910 Internet Service providers and web search portals
46.	*Nearmap (AS45880)	Suite 8 281 Hay Street Subiaco 6005	2.13		6922 Surveying and mapping services
47.	*NextGen (AS38809)	55 Walters Drive, Osborne Park WA 6017	5.75		58001 Wired telecommunications Network Operations
48.	*Ocean Broadband (AS38595)	4 Leura Street Nedlands WA 6009	4.18		5910 Internet Service providers and web search portals

49.	*Orion Sat (AS45603)	7/16 St Georges Terrace Perth WA	1.34		5802 Other Telecommunication Network Operations
50.	Packet Clearing House (AS42)	572-B Ruger Street, The Presidio of San Francisco, San Francisco, California USA			5910 Internet Service providers and web search portals
51.	*PacNet Aust. (AS7543)	Level 1, 1 Southbank Boulevard Southbank Victoria 3006 (Headquarters)			5910 Internet Service providers and web search portals
52.	PacNet Global (AS10026)	10 Eunos Road 8, #08-01 Singapore Post Centre, Singapore 408600 Singapore/ 18/F Cityplaza Three14 Taikoo Wan Road Taikoo Shing, Hong KongHong Kong)			5910 Internet Service providers and web search portals
53.	PerthIX (AS9820)	1 William Street, Perth WA 6000	0.58		5922 Electronic information storage services
54.	Pipe Networks (AS24130)	Level 17, PIPE Networks House, 127 Creek Street, Brisbane, Queensland, 4000			58001 Wired telecommunications Network Operations
55.	R-NAS (AS38749)	4 Parker Place, Technology Park, Bentley WA 6102	6.18		5910 Internet Service providers and web search portals
56.	RCS	Adelaide Terrace, Durack Centre, Perth WA	1.55		7000 Computer system design and related services
57.	Reseau (AS56035)	74B Brown Street East Perth, Perth, Western Australia, 6004	2.37		7000 Computer system design and related services
58.	*Syra (AS38719)	333 Charles Street, North Perth Western Australia	2.70		5921 Data processing, web hosting and electronic storage services
59.	Service Elements (AS45594)	45 Ventnor Avenue West Perth WA 6005	1.26		5809 Other telecommunication services
60.	ServiceNet (AS17561)	Level 2, Mason Bird Building, 303 Sevenoaks Street Canning WA 6107	11.17		5922 Electronic information storage services
61.	Simtronic (AS55707)	18/19 46-48 Abel St, Jamisontown, NSW			5910 Internet Service providers and web search portals

62.	SPT (AS9942)	Level 14, 201 Kent Street Sydney NSW 2000 Australia			5910 Internet Service providers and web search portals
63.	Stratus Blue (AS58458)	Level 2, 7 Stirling Street, Bunbury 6230			5921 Data processing, web hosting and electronic storage services
64.	TPG (AS7545)	65 Waterloo Road, North Ryde, NSW 2113			5910 Internet Service providers and web search portals
65.	Verisign (AS26415)	134 Moray St. South Melbourne, Victoria			7000 Computer systems and related services
66.	Vertel (AS9519)	Unit 2-36 Juna Drive, Malaga WA 6090	10.78	Sydney (HQ), Brisbane, Melbourne, Adelaide, Coffs Harbour (5)	5802 Other Telecommunications Network Operations
67.	Vodafone Hutchison Australia (AS18359)	40 Mount Street, North Sydney, NSW , 2060			5802 Other Telecommunications Network Operations
68.	Vivid Wireless (AS38657)	L8, 8 Central Avenue, Australian Technology Park, Sydney, NSW 2015			5802 Other Telecommunications Network Operations
69.	Vocus (AS4826)	Level 1, Vocus House, 189 Miller Street, North Sydney NSW 2060 Australia			58001 Wired telecommunications Network Operations
70.	WAnet (AS9745)	Inglewood WA 6052	5.23		5910 Internet Service providers and web search portals
71.	*WA Networks (AS9301)	60 Hilarion Road Duncraig WA 6023	16.23		5910 Internet Service providers and web search portals
72.	Web in a Box (AS45926)	Leederville WA 6903	2.25		5921 Data processing, web hosting and electronic storage services
73.	Webvault (AS58505)	Ground Floor Quadrant Building, 1 William Street	0.58		5921 Data processing, web hosting and electronic storage

					services
74.	*Westnet (AS9543)	Level 1, 502 Hay Street, Subiaco, WA 6008	2.82		5910 Internet Service providers and web search portals
75.	Woodside (AS38327)	240 St Georges Terrace Perth WA 6000	0.8		0700 Oil and gas extraction
76.	*Xenion (AS38620)	Balcatta 6914	10.72		5921 Data processing, web hosting and electronic storage services
77.	ZettaNet (AS7604)	Level 6 10 William Street, Perth WA 6000	0.58		58001 Wired telecommunications Network Operations

APPENDIX 4

List of Perth's Open Data Centres[#]

([#] As of November, 2011 that offer services to commercial or government sectors as colocation or managed services – as distinct from enterprise data centres or internally-managed private data centres)

Company name		Corporate address/postcode	Data centre location and distance to the CBD GPO
Datacom*	The Metro iX site was constructed in 2008 and includes tier 3 redundancy throughout the centre, the industry benchmark for data centres in WA and is Datacom's ninth data center in the region.	Lvl2/ 184 Adelaide Terrace East PerthWA6004	Metro IX Robinson Avenue Belmont 6.5km of CBD
Amcom Pty Ltd	Amcom Data Centres provide a secure, centre directly connected to the Amcom fibre-optic network.	44 St Georges Terrace WA 6000	Amcom Perth #1 – Adelaide Terrace Perth CBD <i>"For security reasons this is not the exact location of the data centre. However, it is located within a radius of 2km from CBD GPO."</i> www. http://www.datacentermap.com/australia/perth/
			Amcom Perth #2 – CBD <i>"For security reasons this is not the exact location of the data centre. However, it is located within a radius of 2km from CBD GPO."</i> www. http://www.datacentermap.com/australia/perth/
			Amcom Osborne Park #3 <i>"For security reasons this is not the exact location of the data centre. However, it is located within a radius of 8km outside CBD."</i> www. http://www.datacentermap.com/australia/perth/
Vocus* Perth iX	The CBD facility features overlapping power grids, redundant power supplies and comprehensively maintained infrastructure, providing	Head office Level 1 Vocus House, 189 Miller Street North Sydney	1 William Street Perth WA – 1km of CBD GPO

	excellent levels of protection for your critical IT equipment		
HostAway*	Co-Location service at premises with high speed network backbone.	HostAway Pty Ltd Unit 1, 8 Midas Road Malaga WA 6090	Unit 1, 8 Midas Road Malaga, Western Australia - the complex is used by both Host Away and WA Data Pty Ltd - a sister company to Host Away. 12km of the CBD GPO
Central Data Systems*	Data centre and operates two cloud platforms.	88 Havelock Street, West Perth, WA 6005	Basement QV1 Building, 250 St Georges Terrace, Perth WA 6000 1km of CBD GPO
Ovation Data (formerly Spectrum Data)	The Australian Data Management Centre (ADMC) Perth offers a very safe and secure location for data storage as it is isolated from potential "hot spots", pollution and larger population areas, but is connected by regular daily flight services to many international cities.	The Australian Data Management Centre 14 Brodie Hall Drive Technology Park Bentley WA 6102 Australia	Bentley Technology Park 6102 6km of CBD GPO
ASG Ltd	Anchor tenants at ASG's new facility include the WA Government's shared services infrastructure, a major West Australian power utility, two large customers in the resources sector and ASG's own 'cloud computing' platform.		Bentley Technology Park 6102 6km of CBD GPO
Fujitsu Perth Data centre	The Fujitsu Perth Data Centre comprises 3 main		Mugul Road, Malaga 12km of the CBD GPO

	data halls suitable for cabinet and cage installations, as well as 3 smaller data halls for dedicated private suites. The new complex will provide more than 3,000m2 of Tier 3-style highly secure raised floor space.		
National Data Centre Pty Ltd		630 Murray St, West Perth, WA, 6005	1km of CBD GPO
HPC DCs AMC Data Centre*	The AMC Data Centre which is strategically located at the Australian Marine Complex 23km south west of the Perth CBD	AMC Data Centre PO Box 3494 SUCCESS 6964 Western Australia	23km south west of the Perth CBD and 11 kilometres south of Fremantle,
DC West*	Data centre located on Metro Fibre Ring for redundancy WAIX peering and connectivity	Level 1 / 234 Pier Street Perth, Western Australia, 6000	234 Pier Street Perth CBD 1km of CBD GPO
aCure*	Telco, IT consulting, data centres	78 Hasler Road Osborne Park	Sub basement 2, 45 St Georges Terrace Perth 6000 Murchison Terrace Perth 1km of CBD GPO
Web Click (PerthWeb Pty Ltd)	Colocation and hosting	5 Coolgardie Terrace, Perth WA 6000	5 Coolgardie Terrace, Perth WA 6000 2km of CBD GPO
Next DC*	ASX-listed NextDC has identified a 9000 square metre site, including a 3000sq m data hall, in Malaga.		Malaga, 12km of the CBD GPO.

Metronode East Perth (Leighton Contractors)	The location was strategically selected on the fringe of Perth's CBD in a low risk environment.		East Perth 2.5km of CBD GPO
	Built as of Dec 2011 as purpose built data centre		Shenton Park 6km of CBD GPO
ISA Technologies			1 Brodie Hall Drive Bentley Technology Park 6102 6km from CBD GPO Bunbury, 155km south from CBD GPO
CSC	CSC is one of the world's largest and most respected providers of information technology services –operates a small data centre as part of broader service offering		Subiaco 4km of the CBD GPO
Telstra	The full suite of Telstra Wholesale products is already in the building, making it faster, easier and more cost-effective to access these products and expand networks quickly and efficiently to meet changing business needs.		Wellington Street, (Telstra Exchange Perth CBD) 1km of CBD GPO

*** Participants in the WAIX**

APPENDIX 5

Australian university types and spatial characteristics

To understand the potential of Australian universities as activity centres first requires consideration of the different types of Australian universities. In Australia, Marginson and Considine (2000) have identified and categorised five university types⁸ that not only suggest spatial characteristics but also historical and socio-cultural characteristics. These university types are:

- *sandstone* (superior economic resources, classic sandstone architecture, strong networks with their alumni, the professions and international scholars),
- *redbrick* (more corporate and modernised than the sandstone, generally the second university in capital cities, the *redbrick* term being adopted from early 20th century urban UK universities built generally in red brick),
- *unitech* (post WW II, formed from institutes of technology with strong professional cultures),
- *gumtree* (from the 1960s and 1970s, bushland settings featuring natives flora and gumtrees, nationalistic, usually the school leaver's second, third or fourth choice), and
- *new universities* (formed post 1986 from merger of Colleges of Advanced Education, often a number of branch campuses across metropolitan, regional and rural areas).

Sandstones

Australian universities adopted many of the cultural characteristics of the English university (Benneworth et al. 2009) system, none more so than the older, more traditional sandstone universities (Marginson & Considine 2000, Davison 2009, Raciti 2010). The first universities⁹ in each of the Australian capital cities followed the British university model, even mimicking the monastic Oxbridge classical architectural styles (Stock 2009). Similar to cities with 'first-starter' advantage, where the initial advantage or success was reinforced with other productivities, the sandstone universities have a notable 'head start' advantage in Australia (Marginson & Considine 2000). Again, similar to the ranking of cities, where in urbanised countries the uppermost rung in national city size over time tends to be relatively stable¹⁰, once universities become part of the top group of universities they are unlikely to change

⁸ Moodie (2012) categorised universities slightly differently, mainly by their university associations and age; sandstone and redbrick universities combine formally in the 'Group of Eight', the unitechs combine formally in the 'Australian Technology Network', the gumtrees are referred to as the '1960s-70s universities', the 1980s and newer universities are referred to as the 'new generation' universities, and a category that somewhat cuts across the previous categories, the 'regional universities' including for example, in with the newer regional universities, is the University of Tasmania, formed in 1890.

⁹ Universities of Sydney and Melbourne (1850s), University of Adelaide (1874), with the University of Western Australia (UWA) (founded in 1911 and established on its Crawley site in late 1920s and early 1930s), and University of Queensland (UQ) (founded 1910 and establishing on St Lucia site 1930s and 1940s). Both UWA and UQ followed similar early patterns of moving from CBD sites to river peninsula campus sites.

¹⁰ See Polese and Denis-Jacob 2009.

(Marginson & Considine 2000). Time has provided the sandstone (and redbrick) universities with academic and institutional capital, where success has bred success leading to a self-sustained position over other universities (Marginson & Considine 2000). Not surprisingly, the universities with the highest research rankings have also tended to be the sandstone universities (along with the second starter redbrick universities) (Marginson & Considine 2000, Abbott & Doucouliagos 2003, Australian Research Council 2012). This was despite the sandstones not always operating or teaching as effectively, efficiently or innovatively as other universities (Marginson & Considine 2000). They have however attracted the brightest students, with their research performance operating as the universal indicator of excellence that has sustained the reputation of sandstone and redbrick universities (Marginson & Considine 2000). Recent research rankings and international rankings suggest the conclusions of Marginson and Considine (2000) are largely unchanged (Australian Research Council 2012).

Marginson and Considine (2000) have argued that the strongest universities are those that combine positional advantage with institutional coherence and scholarly cultures that are broad-based and vibrant.¹¹ Sandstones with all three elements, according to Marginson and Considine (2000), have prospered and thrived. The earlier development of the sandstone universities has provided them with a spatial agglomerative advantage. This was particularly the case with the inner-city location of the sandstone universities of Melbourne, Sydney and Adelaide. This allowed these universities to take advantage of the inner-city gentrification that was not seen until much later in Brisbane, Perth or Hobart with their more suburban (though inner-suburban) sandstone universities (Davison 2009). Arguably, the sandstones are combining network advantage with agglomeration advantage, in that they have traditional linkages to government and business, but are also generally spatially located within or close to the CBD-centric urban agglomeration.

Ironically, the unintentional falling away of some of the monastic spatial traditions in Australian has been more significant with some of the now more urbanised traditional sandstone universities. The newer 20th century, and in particular the post WW II, universities are characterised by a more isolative 'return to the past' spatial context, as promoted by Lord Robbins with the UK greenbelt universities. For the sandstone universities, Davison (2009), in his study of the gentrification of inner-city Carlton and the influences from Melbourne University, identified a number of social and economic changes that led to a breaking down of the sandstone monastic culture and a greater engagement in a diverse urban 'Jacobs' type agglomerative experience. These changes originated beyond Melbourne University and related to the gradual expansion of the university-educated middle

¹¹ A university with institutional coherence Marginson & Considine (2000) described as being an 'enterprise university'.

class in Australia post WW II. Davison (2009) has argued that the expansion of the university middle class was a powerful force in the wider remaking of Australia's inner city.

Prior to the post-war student expansion, Melbourne University's student population resided at their family homes in suburban Melbourne or at university residences within denominational colleges (Davison 2009).¹² These colleges drew their students from regional areas or interstate, with a steady flow from elite private schools "which cultivated something of an aura of the Oxbridge colleges that they modelled themselves on" (Davison 2009 p. 255). The expansion of the university (and academic numbers) saw a steady overflow into the surrounding inner-city suburbs such as Carlton. It was not just a matter of increased student numbers; there was an increasing desire to associate freely as part of the wider societal change of greater student self-determination and self-realisation (Little 1975, Davison 2009). This new openness to experience, to intellectual and social difference, shaped the inner city, creating a celebration of density and sociability (Davison 2009). It also created more (unintentional) opportunity for knowledge spillover than the previous monastic tradition. Ultimately, the attractiveness that was created or identified within the inner city drew in wealthier people, displacing those of less economic wealth (including the next generation of student). What happened in Melbourne happened elsewhere in Australia's major urban cities, though at differing times. The inner-city location of sandstone universities in Melbourne, Sydney and Adelaide drove the inner-city gentrification much earlier than what was seen in Brisbane, Perth or Hobart with their more suburban sandstone universities (Davison 2009).

Redbrick Universities

The redbrick universities of the 1940s and 1950s followed the UK 'civic' or 'redbrick' university model, and represented a more meritocratic and less class-based society (Marginson & Considine 2000). Their development, particularly following WW II, came with the major student intake expansion in the period from 1945 to 1981 (Marginson & Considine 2000, Davison 2009, Raciti 2010). For the UNSW and Monash University there was, from the 1950s onwards, a clear rivalry with Sydney and Melbourne universities respectively. Australian National University (ANU), UNSW and Monash's performance and prestige has been enhanced considerably since the 1960s (Marginson & Considine 2000) and they are now part of, with the sandstone universities, the 'Group of Eight' elite research university grouping in Australia (Moodie 2012). The scale and size of the redbrick universities developed over time has provided them with a clear 'second starter advantage'. The spatial location of the redbricks has generally been on larger campuses, remoter from the CBD than the 19th century sandstone campuses (for example, UNSW Kensington Campus, while

¹² Post war, from 1958 to 1972, Melbourne University's numbers more than doubled (Davison 2009)

smaller than Sydney University, is more distant from the Sydney CBD). ANU, while remote from the major state capital metropolitan areas, is the largest of the Group of Eight campuses at 147 hectares (but adjacent to the CBD of Canberra, the national capital).

Unitech

The unitech universities developed in the 1960s to 1980s out of the pre-existing institutes of technology (Marginson & Considine 2000, Moodie 2012). Marginson and Considine (2000, pp. 197-198) saw the 'unitech' universities as being strong in their teaching of occupational skills, on their graduates' reputation among employers, their links with industry, and their capacity to move into new markets. Recent research rankings and international rankings reconfirm the findings and conclusions of Marginson and Considine (2000) that the unitechs (are still) behind sandstone and redbrick universities, but in front of the 'gumtrees' and 'new universities' in term of research standing (Australian Research Council 2012).

All the 'unitechs', except Curtin University in Western Australia, have large city-based campuses which, according to Marginson and Considine (2000 p. 198) "strengthen their engagement with industry and government" as well as their role in postgraduate vocational education. Marginson and Considine (2000 p. 198) however noted that the downside of the unitech city locations has been "crowded ugly sites, with grim drabness and modern disasters in their architecture". Curtin University's origins were from WA Institute of Technology (WAIT), which evolved from the Perth Technical College, originally located in James Street on the northern edge of the CBD close to the main Perth train station. WAIT's relocation to a greenbelt location was more a relocation to a 'blackened belt' location. The decision was taken to move to a burnt-out pine plantation at Bentley, 6km south of the CBD, because of the "limitations of space" in the city (Curtin University 2014a). Similar space issues were not so problematic with the other Unitech universities in the larger, denser capital cities. The Curtin University Bentley campus, at 116 hectares, is one of the largest metropolitan campuses in Australia, larger than any of the Group of Eight university campuses (Curtin University 2014a).

Gumtrees and New Universities

Since the 1980s, the push towards greater non-government funding has meant that the gumtree and new universities have struggled in comparison to the sandstone, redbrick and unitechs (Marginson & Considine 2000, Abbott & Doucouliagos 2003). This has been particularly with respect to reputation and research rankings, both of which are very clearly stratified and stable within the Australian university sector (Marginson & Considine 2000, Australian Research Council 2012).

The spatial development of the post WW II Australian universities, in particular the 'gumtree' and the 'new universities', closely followed the Robbins approach of the partial return to the 'ancient' notion of learning as a 'lived' activity, providing scenic landscapes on green-belt campuses (though in Australia with gum trees and other native species) where students could 'retreat' or maintain their suburban existence away from the 'real world' for the duration of their studies.¹³

¹³ See Marginson & Considine 2000 for the isolative development of gumtree and new universities.

APPENDIX 6

Knowledge intensification potential of major non CBD Activity Centres in the Perth metropolitan area

Major non CBD Centres	UWA QEII	Curtin	Murdoch Activity Centre	Edith Cowan Joondalup	Perth Airport	Subiaco ¹⁴	Stirling	Morley	Midland	Fremantle	Armadale	Cannington	Rockingham
Activity Centre categorisation (State Planning Policy 4.2 Activity Centres for Perth and Peel (WA Government Gazette 2010))	Specialist Centre with tertiary hospitals	Specialist Centre	Specialist Centre with tertiary hospital	Strategic Regional Centre	Specialist Centre	Secondary Centre	Strategic Regional Centre	Strategic Regional Centre	Strategic Regional Centre	Strategic Regional Centre	Strategic Regional Centre	Strategic Regional Centre	Strategic Regional Centre
University (Considine and Marginson 2000) and or shopping centre (Yamashita et al. 2006) type	Sandstone	Unitech	Gumtree	New university, Newer constructed outer suburban centres	n/a	Older inner or middle shopping street	Stand alone large suburban shopping centre attracting other functions	Stand alone large suburban shopping centre attracting other functions	Traditional town centre in low density outer suburb	Older inner or middle shopping street	Traditional town centre in low density outer suburb around	Stand alone large suburban shopping centre attracting other functions around	Newer constructed outer suburban centres
Notable other mix uses	Private hospital and research organisations	Bentley Tech Park	Private hospital	Regional hospital	Industrial and logistics	Tertiary hospital, Private hospital	Scarborough Beach Road Activity Centre, Osborne Park Industrial area, Herdsman Specialist Centre, Glendalough	n/a	Regional hospital	Regional hospital	n/a	n/a	n/a

¹⁴Subiaco has been included in with the Specialised Centres and Strategic Regional Centres because of its relatively high employment density (BITRE 2012) and number of major hospitals

Rail or freeway transport ¹⁵ within 800m	n/a	n/a	Rail/freeway	Rail/freeway	Highway	Rail	Rail/freeway	n/a	Rail	Rail	Rail	Rail	n/a
Catchment and international role	International teaching and research	International teaching and research	International teaching and research	International teaching and research	International and national passenger transport	Regional commercial	Regional retail	Regional retail	Regional/rural hinterland	International and metropolitan tourism/Regional retail	Regional retail	Regional retail	Regional retail
Centrality (Distance ¹⁶ in km to CBD and to three other nearest major centres (average distance))	4.7 CBD 3.2 Subiaco 7.7 Curtin Uni 9.1 Stirling (6.2)	5.5 CBD 4.9 Cannington, 7.7 UWA/QEII 8.5 Subiaco	12.8 CBD, 9.1 Fremantle, 9.2 Curtin Uni,	24.5 CBD, 16.9 Stirling, 20.9 Morley, 22.8 Subiaco (21.28)	10.5 CBD, 8.4 Midland 7.3 Cannington, 8.7 Curtin Uni (8.7)	3.6 CBD, 3.2 UWA/QEII, 5.7 Stirling, 8.6 Curtin Uni	8.3 CBD, 5.7 Subiaco, 8.7 UWA/QEII, 8.8 Morley	7.3 CBD, 8.8 Subiaco, 8.8 Stirling, 10.9 Midland	15.3 CBD, 8.4 Perth Airport, 10 Morley, 16 Curtin Uni	15.2 CBD, 9.1 Murdoch, 10.9 UWA/QEII, 14.9 Curtin Uni	26.3 CBD 16.7 Cannington, 18.7 Murdoch, 20.7 Curtin Uni, (20.6)	10 CBD, 4.9 Curtin Uni, 7.3 Perth Airport, 10.4 Murdoch (8.2)	38.5 CBD, 25.9 Murdoch, 26.1 Fremantle, 29.7 Armadale (30.1)
Centrality – times in other centres top 3	5	8	4	0	2	5	4	3	2	2	1	3	0

¹⁵ As crow flies

¹⁶ As crow flies, using a single point in each centre for all measurements

Top 3 employing industry by Destination zone ¹⁷	2010 Research Income \$ (Research publication Total weighted score) ²⁸	Excellence in Research Ranking 2012 ²⁹	Immediate LGA pop over 15 - % of Bachelor degrees and higher ³⁰
Nedlands: Health and Community Services, Property and Business Services, and Education	172,754,470 (2052.65)	6	Subiaco 46% Nedlands 45.56%
South Perth (2011) ¹⁸ : Property and Business Services, Health care and social assistance, Education	58,472,280 (1640.96)	26	South Perth 33.79% Victoria Park 27.34%
Melville (2013): ¹⁹ Retail trade, Health Care and Social Assistance, and	35,125,067 (602.4)	23	Melville 28.93% Cockburn
Joondalup South and North ²⁰ : Retail, Health and Community Services, Education	15,312,463 (514.17)	29	Joondalup 19.56%
Belmont ²¹ : Transport and storage and warehousing, Manufacturing, Wholesale Trade			Belmont 16.68%
Subiaco: Health and Community Services, Property and Business Services, and Education			Subiaco 46%
Stirling Central: Retail trade			Stirling 24.61%
Morley ²² : Retail, Accommodation Food & Services, Health Care and Social Assistance			Bayswater 21.12%
Midland ²³ (2006): Retail, Public Administration and safety			Swan 10.82%
Fremantle ²⁴ : Health and Community Services, Manufacturing, Retail Trade	853,677 (164.58)	29	Fremantle 29.25% East Fremantle 29.25%
Armadale ²⁵ : Retail trade, Public Administration and safety, Accommodation Food & Services			Armadale 7.7%
Canning ²⁶ : Manufacturing, Wholesale Trade, Retail,			Canning 24.29%
Rockingham ²⁷ : Retail, Health Care and Social Services, Public Administration and Safety			Rockingham 8.77%

¹⁷ BITRE 2012 (unless otherwise noted)

¹⁸ <http://economy.id.com.au/south-perth/workers-key-statistics-lite>

¹⁹ <http://economy.id.com.au/melville/employment-locations>

²⁰ <http://economy.id.com.au/joondalup/employment-locations>

²¹ <http://economy.id.com.au/belmont/workers-key-statistics-lite>

²² <http://www.economicprofile.com.au/easternmetro/economy/employment#geography>

²³ http://www.swan.wa.gov.au/Business/Business_support/Key_Business_Areas

²⁴ <http://economy.id.com.au/fremantle/employment-locations>

²⁵ <http://economy.id.com.au/armadale/employment-locations>

²⁶ <http://economy.id.com.au/canning/employment-locations>

²⁷ <http://economy.id.com.au/rockingham/employment-census>

²⁸ <http://docs.education.gov.au/documents/2010-research-income-and-publications-data-sub-category>

²⁹ http://www.arc.gov.au/era/era_outcomes.htm

³⁰ ABS Census 2011

Dedicated ICT Infrastructure - dedicated fibre network	AARNet member	AARNet member and Point of Presence	AARNet member	AARNet member									
ICT characteristics	Academic ICT up to PhD/Research data management plan	Academic ICT up to PhD/Research data management plan	Academic ICT up to PhD/Research data management plan	Academic ICT up to PhD/Research data management plan									

APPENDIX 7

University campus spatial characteristics and opportunities

Western Australian universities	Year main/existing campus established	Distance from the CBD (km)	Main campus size (ha)	Border types	Urban design characteristics	Comment and observation of author
University of Western Australia	1932	5	65	North – highway, residential colleges East/South - regional road/river West - suburban	Garden campus with river and suburban setting	Has opportunities for urban and commercial development along Hampden Road running north south linking UWA with QE11 medical complex. Heritage value means garden campus not suitable for redevelopment
Curtin University	1968	5.5	116	Largely surrounded by excess open space and at grade car parking – suburban isolated campus	Suburban campus surrounded by open space and car parking	Opportunities for development of excess open space and at grade car parking. Potential development opportunities with integration to the north with Bentley Technology Park
Murdoch University	1976	12.8	227	Largely surrounded by excess open space and at grade car parking – suburban isolated campus. Major roads to north and to the east, wetlands to the south	Suburban campus surrounded by open space and car parking	Opportunities for development of excess open space and at grade car parking. Potential development opportunities with integration to the east with Murdoch Activity Centre/ Fiona Stanley tertiary hospital
Edith Cowan University	1977	24.5		Surrounded by open space and at grade car parking to west and north – suburban isolated campus. Adjacent major regional shopping centre to the north and other education facilities to the east with rail station to the north	Suburban campus surrounded by open space and car parking	Some limited opportunities for development of open space and at grade car parking. Potential development opportunities to the north with Joondalup shopping centre. Residential developed on southern border
Notre Dame University	1989	15.2	n/a	University located in various purchased buildings in the west end of Fremantle with in heritage 19th century grid	Within largely mixed use traditional centre	Arguably Notre Dame has limited urban activity and diversity by purchasing and reusing public use corner buildings as internal use functions ie purchasing pubs and turning them into class rooms. Might be better to divest itself of corner properties to encourage more mixed use and diversity

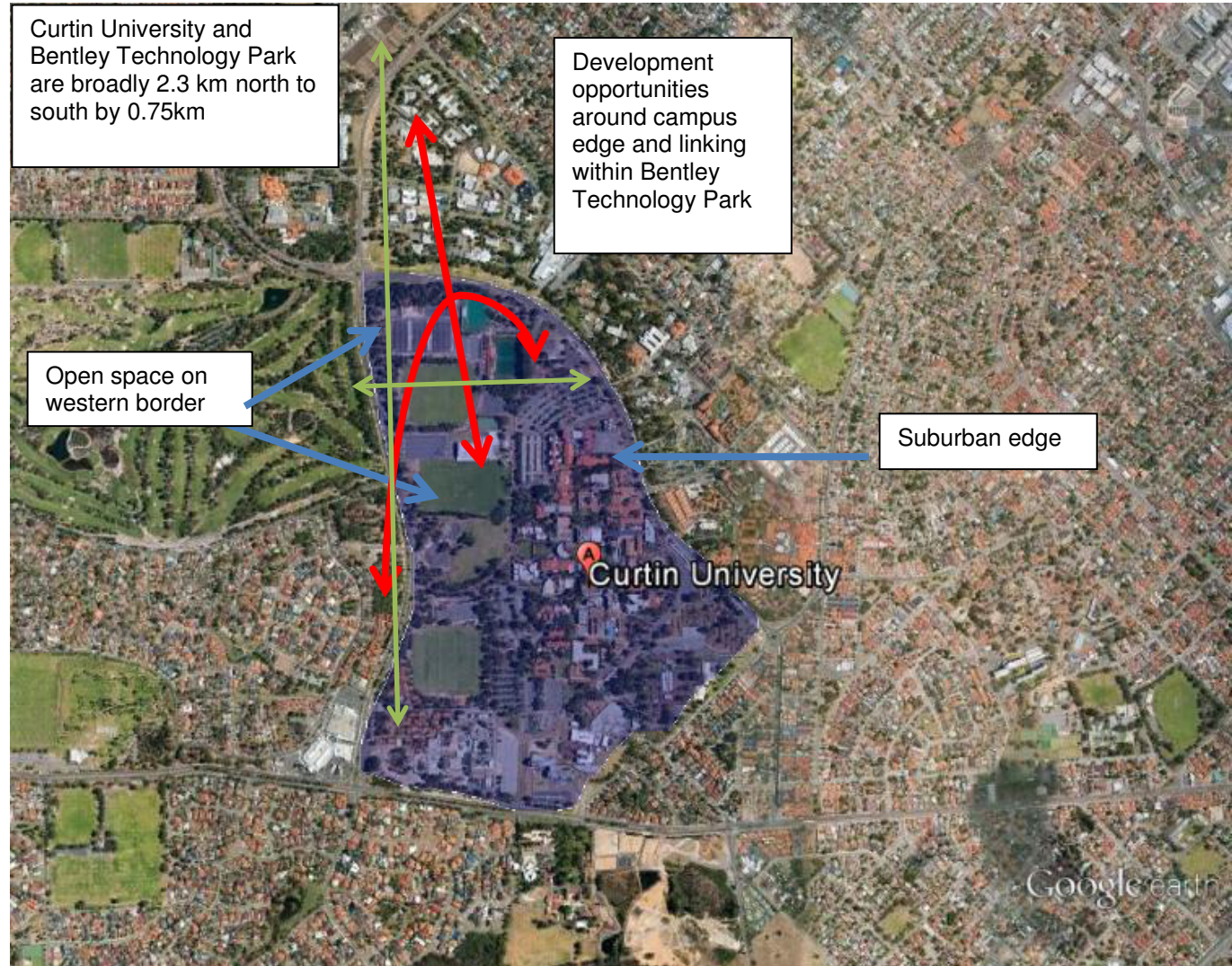
University aerals

Western Australian 20th century monastic universities (with possible redevelopment opportunities highlighted) Nb For comparison the *Perth (C) Inner Statistical Local Area* ABS 2011 (effectively the CBD from the Mitchell Freeway to the west, the Fremantle – Midland rail line to the north, the Swan River to the south and Victoria Street to the east) is 1.8 km² (roughly 0.9km by 2km)

University of Western
Australia



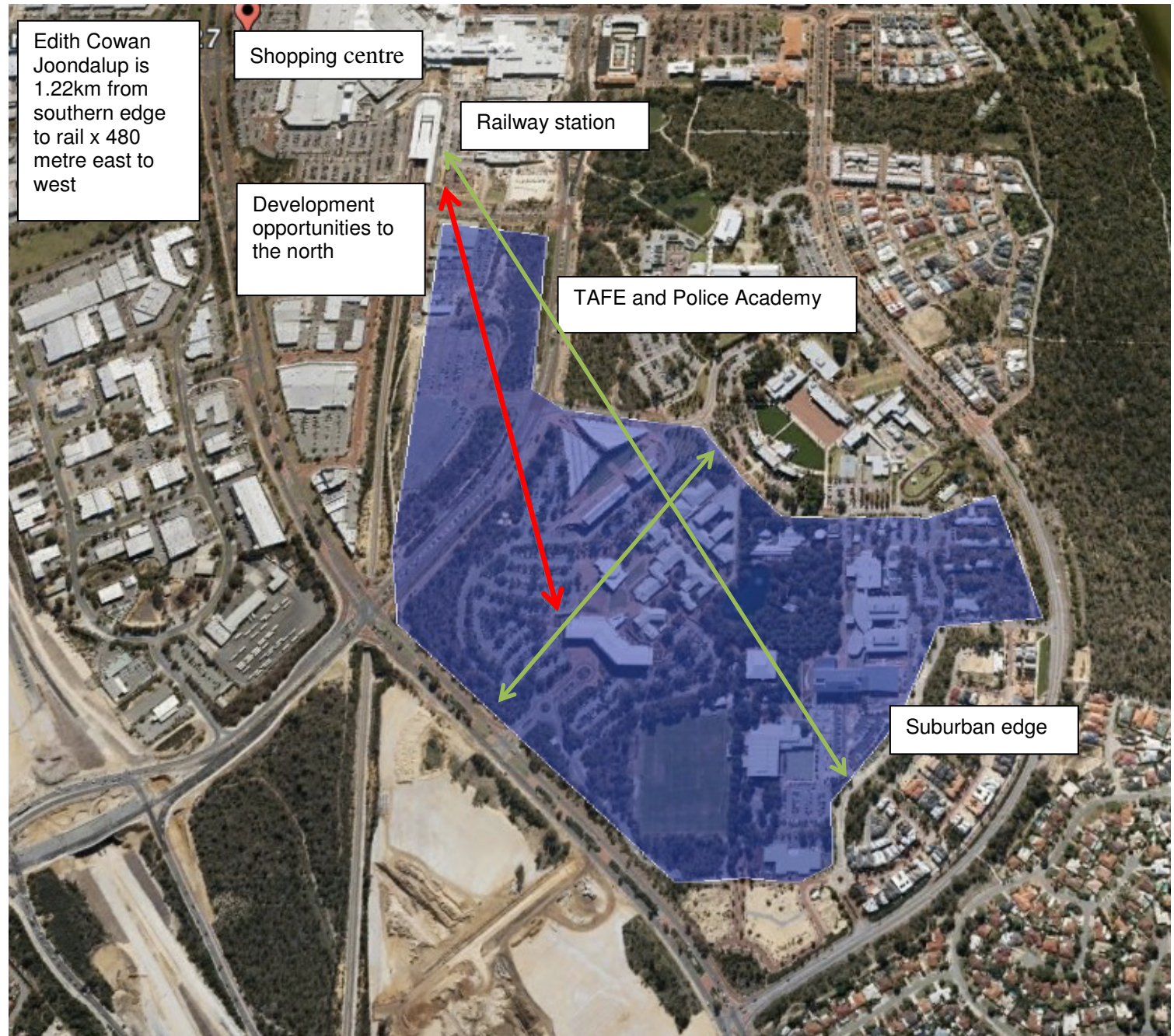
Curtin University



Murdoch University



Edith Cowan University



University	19th and 21st examples of urban universities, contrasting with 20th century monastic campus
<p>Adelaide University (1874)</p> <p>Urban design of 19th century university</p>	 <p>Longer buildings running parallel to the street are set back to create public squares.</p> <p>Narrow fronted building on street mirroring urban form of city</p> <p>Narrow front building on street</p> <p>Replicates walkable legible grid pattern</p> <p>Imagery Date: Feb 10, 2008 34°55'17.56" S 138°36'21.43" E</p> <p>Google</p>



Photo by author

Narrow fronted building on street mirroring urban design of the Adelaide CBD, longer building parallel to the street are set back to create public square



Photo by author

Urban design continued with 20th century buildings, long building fronting street with narrow front – avoids domination of the street by 'border' buildings

Melbourne University

(1853)



Urban interface within grid street pattern with higher density inner city Carlton

Urban interface within grid street pattern with tertiary hospital precinct – Parkville Knowledge Precinct

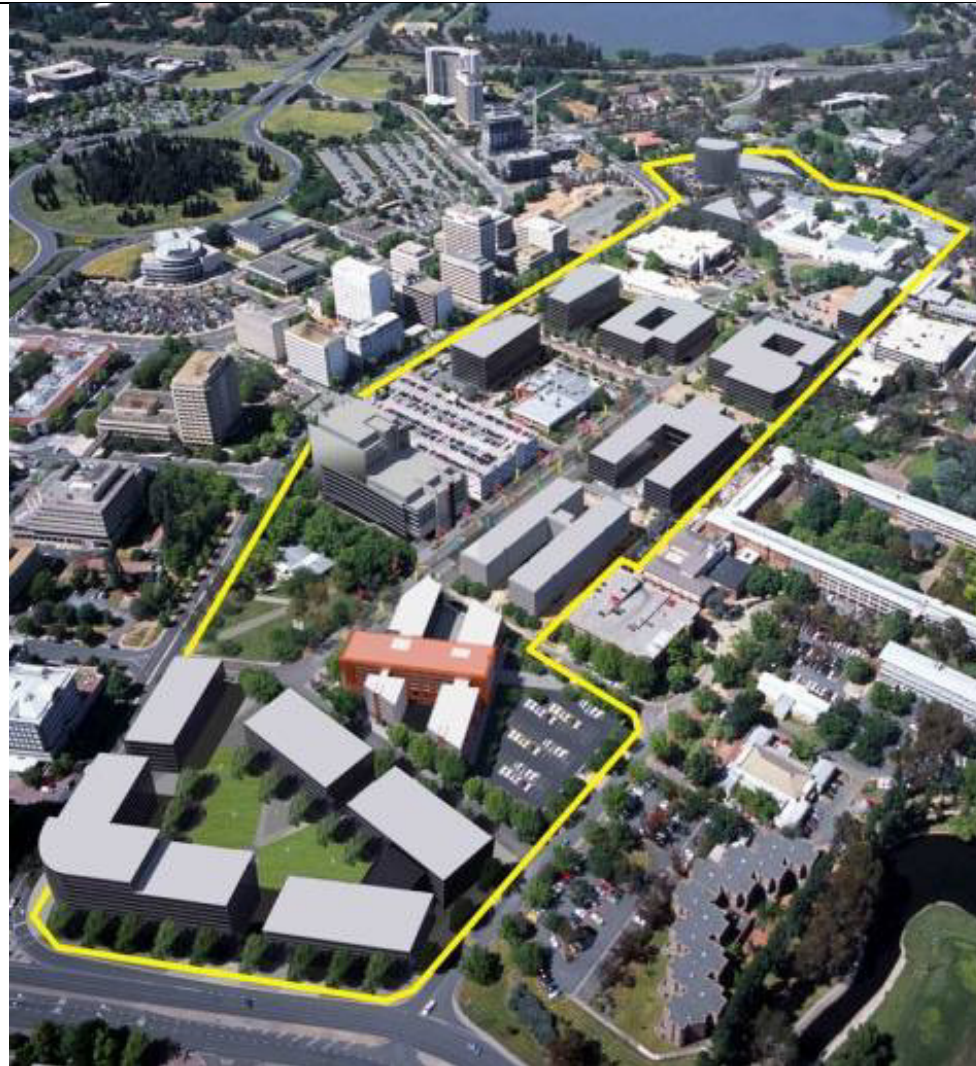
Walkable grid street pattern - walking access to CBD

Queensland University of
Technology – Kelvin Grove
Urban Village.
Redeveloped during 2000s



Source: Hassell

ANU Exchange –
Redeveloped from 2010



Source www.anu.edu.au

APPENDIX 8

Rail network policy and infrastructure strategies for Perth: The Knowledge Rail Network

*This Appendix proposes a Knowledge Rail Network (see **Figure 8A**) that aligns with the urban network principles set out in **Figure 46**.*

Perth, with 78 per cent of Western Australia's population, is the overwhelmingly dominant and primary urban centre in Western Australia. The reason for Perth's primacy can be understood by considering the context of the Australian 'system of cities', which, due to the nation's relatively low national population, means an increasing need for agglomeration in just a few major large scale metropolitan urban areas. Perth is predicted to achieve Sydney's present population of 4.7 million sometime around 2043 - 2050 (ABS 2013b). Perth is, however, growing much quicker than Sydney. The projections are that Perth's population will increase by 2.9 million within 29-37 years, compared to Sydney which will add 2.51 million in 51 years. In demographic timeframes, Perth is hurtling towards Sydney's present day population. This means that the infrastructure investment issues for Perth are likely to be particularly acute.

There is strong and increasing evidence that knowledge intense economy activity, human knowledge capital and ICT infrastructure is characterised, increasingly, by urban concentration and intensification. While Perth's population, and jobs to a lesser extent, has been dispersing out of the inner core since the 1960s, the Perth CBD and immediate surrounds, in recent decades, have seen growth in knowledge-intensive industries and in high-skilled 'knowledge workers' in professional and intermediate occupations. Perth CBD's growth has resulted in the agglomeration and clustering of knowledge service industries, in part, servicing largely distant mining and resources industries. Also increasing is the role of the city centre as the location for agglomerative tacit knowledge spillover activity for the resources and other industries. This is evident by the growth in mixed use hubs of commercial, economic and social activity, with increases in drinking and dining establishments.

Perth does not exist within the polycentric city-region (as per Batten 1995, Glaeser et al. 2000, Burger et al. 2010) seen with other more densely populated nations in Europe, Asia and the USA. As an isolated primary city, there are no effective edge cities or network of cities, or conurbations to provide alternative dense centres. The dispersement of population-driven economic activity in the Perth metropolitan area, driven by the motor vehicle prior to the turn of the 21st century, is now being over layered by an agglomeration of knowledge economic activity in and around the Perth CBD. The increasing dominance of knowledge-

intensive industries (SGS 2011) in Perth is arguably re-establishing the monocentric nature of the Perth metropolitan area (i.e. the CBD as the mono-centre surrounded by dispersed rather than polycentric development). Perth meets the definition of a monocentric city (see Kraus 2004)³¹.

However outside the central city, there is dispersed population driven employment patterns, with economically vulnerable and disconnected outer suburbs. The lack of borrowing capacity in the absence of neighbouring cities means that suburban edge sub-centres in Perth lose opportunity to increase their scale and develop their own localised agglomeration. This is consistent with the findings of Trubka (2009) in respect to Perth having a weak to non-existent local agglomeration outside of the CBD (recognising that Trubka (2009) noted some limitations with his data sets). However, without sub-centre knowledge-intensive development the Perth metropolitan area will remain largely monocentric in terms of its knowledge-intensive economy. A lack of sub-centre knowledge-intensive activity centre will likely mean, as with other monocentric cities, higher levels of disagglomeration stifling greater economic activity.

Based on the spatial distribution of knowledge-intensive economic activity and employment, Perth can be described as largely monocentric AND dispersed with its population driven economy. Bertaud (2002) has argued that classing cities as purely monocentric or polycentric can be misleading, as most cities operate in a mixed mode with a city being mono centric or poly-centric by degree only. The spatial requirements for a successful agglomerative knowledge economy is also being addressed in the Perth CBD, with the focus on high capacity rail public transport at the expense of road based private transport, and an urban design renaissance (supported by a series of State Government and the City of Perth initiatives) addressing the urban amenity necessary for tacit knowledge spillover. Perth, therefore, naturally has a high degree of centrality in terms of knowledge-intensive employment.

In terms of metropolitan planning strategy, Perth has adopted many of Sydney's strategies particularly in regard to centre strategies. What is perhaps more the case is that Perth is naturally going to favour a high degree of centrality in knowledge-intensive activity and employment. This is not to say this needs to be within a single centre. Recognising the spatial characteristics of knowledge-intensive agglomeration, it is likely to be optimal to have

³¹ Kraus's (2003) definition of a monocentric city provides the following:
1. The price of housing is a decreasing function of distance to the CBD,
2. Individuals who live farther from the CBD consume more housing,
3. The rental price of land decreases as distance from the CBD increases,
4. Structure density decreases as distance from the CBD increases,
5. Population density decreases as distance from the CBD increases.

knowledge-intensive employment at least *partially* centralised. However, without effective development of knowledge-intensive sub-centres, the Perth metropolitan area will remain largely monocentric, meaning a higher level of unnecessary disagglomeration pushing away or stifling prospective knowledge-intensive economic activity. Lower knowledge-intensive economic activity is also likely to be disadvantaged because of high disagglomeration costs. Effectively, Perth's urban structure could limit its economic development in the 21st century. If potentially knowledge-intensive major sub-centres are isolated, and disconnected from the CBD and the wider populace because of the lack of high-level public transport, they will not develop the required urban density and scale to create and add to agglomeration.

It would appear that there is a twist to Alonso's (1964) theory that cities move from being monocentric to polycentric. Perth is, at least with its most knowledge-intensive economic activity, returning to a monocentric city. This has seen intensification in economic activity, ICT infrastructure and activity and human capital in and around the Perth CBD. The explanation for this would appear to be that Perth's knowledge economy is dependent on a dense central core for agglomeration. Effectively, there is a strong centrality to knowledge-intensive activity in Perth (which is also evident in other Australian cities such as Sydney). However, following Alonso's (1964) reasoning as to why cities ultimately move towards polycentric cities from monocentric, there is likely to be pressure for Perth's knowledge-intensive economy to develop in other metropolitan activity centres. This leads to the question - where is the knowledge economy most likely to grow beyond the CBD and inner city?

The underpinning thinking behind *Directions 2031* and its predecessor plan, *Network City*, was on increasing the role of strategic metropolitan activity centres (anchored around regional shopping centres), dispersed across the metropolitan area. The intention was for increasing self-containment and reducing the transport task of the city. However this prioritising of strategic centres is to deny the opportunity for the most fertile places for agglomeration and the growth in the knowledge economy within a regional city dominated by a monocentric knowledge economy centre. In many ways, the lack of research and understanding of urban agglomeration is negatively impacting on Australia's metropolitan regional planning. There needs to be a focus and prioritisation, with spatial structural change to our cities, which supports agglomerative knowledge production and innovation, particularly with the limitations of the existing dispersed polycentric centres strategy in a monocentric-dispersed primary city such as Perth.

Planning policy and intent cannot defy market reality. Jobs are often suited to density or to dispersement. Knowledge-intensive jobs in knowledge-intensive industries are suited to

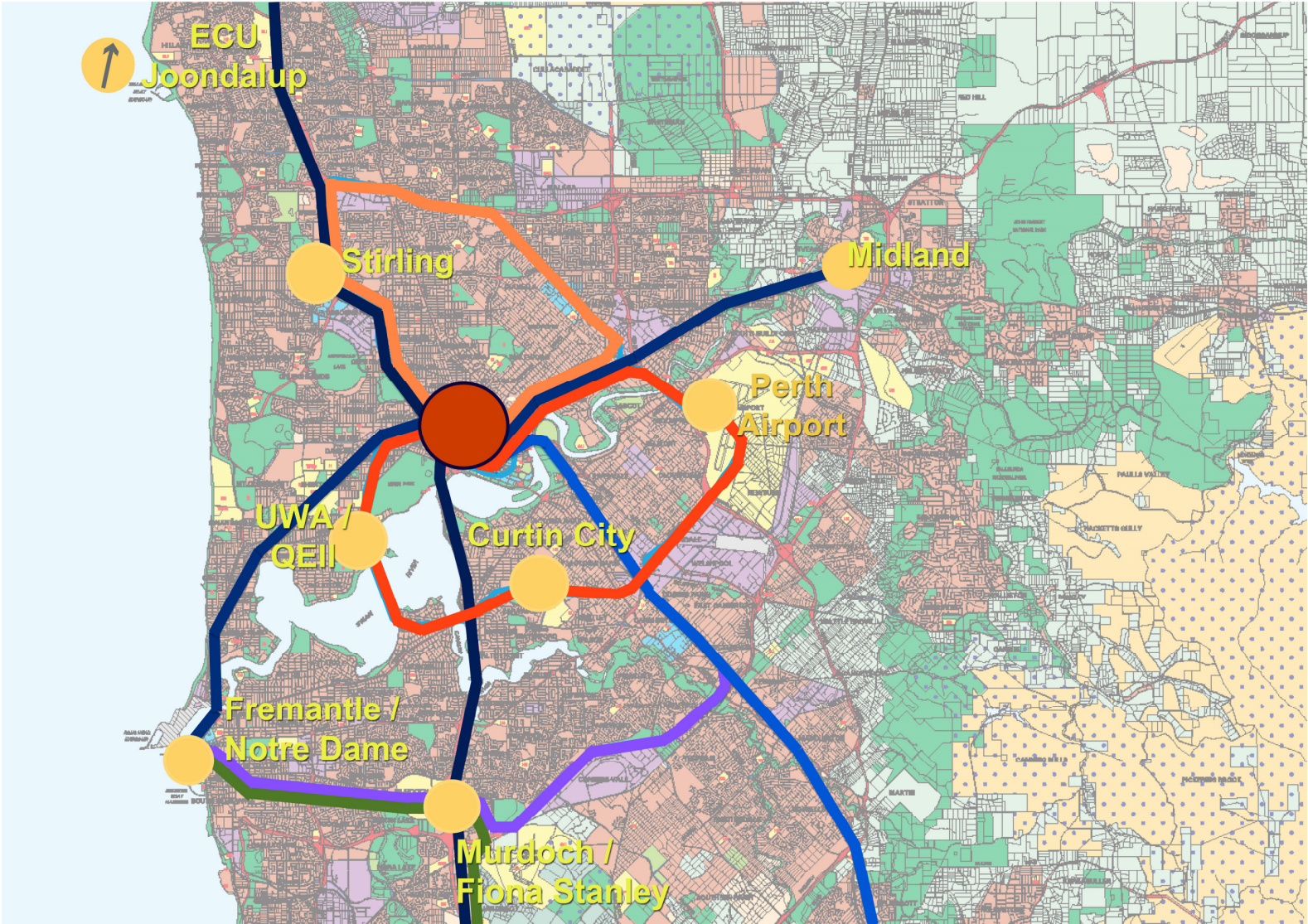
dense employment centres and cannot be created or survive in low employment density, particularly where the regional population and labour market catchments are relatively small. The lack of high-density employment sub-centres in metropolitan Perth, outside of the CBD, calls into question whether there are presently any major non-CBD activity centres. The opportunity for knowledge-intensive sub-centres is ultimately linked to their connectivity (in terms of accessibility and capacity). Non-CBD activity centre productivity is weakened by the relative inaccessibility of transport to a broader labour market. This inaccessibility has productivity impacts. Ideally, larger cities with spatially intense transport modes and infrastructure provide opportunities for greater accessibility and scale and therefore much higher productivity. An alternative approach to developing Perth's urban structure, underpinned by the recognition of the long-term trend of knowledge intensification, is required. Possibly the ideal model for the Perth metropolitan regional structure is for the city to be planned and designed to operate in two modes (the post-modern highly compact city, and the dispersed consumption and industrial/logistics city). There are a number of complexities in proposing new urban structures and public transport infrastructure strategies. Scheurer (2010), in comparing Perth future scenarios with the status quo in Copenhagen, concluded that many of the structural features of both the activity centre and movement networks were sufficiently entrenched as to render a full ascension, within a 25-year time frame, of an Australian city to a European standard of public accessibility unrealistic, even under the most favourable assumptions. This suggests the need to embed long-term strategies (consistent with an understanding of the long-term knowledge intensity trends in the Australian economy) into the government statutory planning and infrastructure policy framework so as to give effect to the necessary changes in Perth urban structure and transport system to fully enable a knowledge-intensive economy.

A rail network focused on knowledge intensification, to be known as the 'Knowledge Rail Network' ('KRN') is proposed (as per **Figure 8A**). This proposal is an updating of a proposal first proposed by Kane (2010). The proposed urban network (as per page **Figure 46**) effectively aligns knowledge intensity with regional transport spatial intensity; with knowledge-intensive centres being the main destination focus of the most spatially intense transport modes. In terms of passenger rail, it is proposed that the KRN would focus on, in terms of destinations, the 'Capital City' (the Perth CBD) and 'Specialist Centres' (as mixed use knowledge centres anchored universities and tertiary hospitals).

'Strategic Regional Centres' are proposed for rail stations as both origin and regional destinations. As noted in **Appendix 6**, the strategic metropolitan and specialist centres in Perth (Murdoch, Stirling, Subiaco, Joondalup and Fremantle) that do have an existing rail connection, only have a single radial rail line. Effectively, Perth CBD has almost a complete exclusivity on being a public transport hub. This reinforces Perth metropolitan area's

monocentric knowledge intensity. It also weakens opportunities for polycentricity and limits capacity for a thicker labour and service market. Despite the recognition of the wider metropolitan reach of 'specialist centres' (as per WAPC 2010a), the key specialist centres of UWA/QE11 and Curtin University have no high order public transport. A key knowledge economic exchange point or node should, by definition, not be a station along a radial line on a public transport system. It should be a hub or node with multiple trunk lines and services providing maximum accessibility for the broadest city knowledge ecosystem.

Figure 8A Knowledge Rail Network proposed for Perth



The proposed four new lines are as follows:

Line 1 (RED) – *Central orbital* – (west to east) Perth to Bayswater Station along the Midland line alignment then under to Perth Airport, then along Leach Highway alignment, crossing the Armadale line and then under Curtin University, crossing under the Perth to Mandurah line at Canning Bridge Station, continuing under the Swan River to UWA, continuing under the QE11 hospital precinct, connecting onto Fremantle line alignment before Subiaco Station and into Perth Station.

Line 2 (ORANGE) - *Northern orbital* – (west to east) Perth to Bayswater Station along the Midland line alignment, north along Tonkin Highway alignment, under Morley Galleria Strategic Regional Centre and continuing under the Mirrabooka district centre and onto the Reid Highway alignment and then south on the Joondalup to Perth rail alignment just north of Stirling Station and onto a new underground station and line re-alignment at City West (providing a non-CBD Fremantle-Joondalup lines hub station), and then onto the Perth Station.

Line 3 (PURPLE) – *Southern orbital* – (north to south and then west) Extension of the existing Thornlie line to Jandakot Airport and then under to Murdoch Station, under to Murdoch University and then onto Fremantle Station (and possibly as a Fremantle to Perth service completing the circle).

Line 4 (GREEN) – *Fremantle to Mandurah line* – (south to north and then west) Mandurah to Cockburn Central on the Mandurah to Perth rail alignment, and then deviating into unused tunnel intended for the Mandurah to Perth via the southern Thornlie alignment and then onto the Southern orbital alignment under to Murdoch Station, under to Murdoch University and then onto Fremantle Station.

The KRN proposal is for the key knowledge-intensive (and potentially knowledge-intensive) centres; the Perth CBD (as the 'Capital City'), UWA-QE11, Curtin City, Murdoch as 'Specialist Centres', and Fremantle, Subiaco³², Stirling, Morley, Midland, Armidale, and Joondalup as 'Strategic Regional Centres' to be inter-linked through rapid high capacity rail public transport to create a radial-orbital rail network (rather than a radial only rail system). The proposed KRN and urban structure can be described as following a 'cluster of pearls' approach as distinct from the radial public transport 'string of pearls' analogy used by Cervero (2007). The KRN reflects not only a transport strategy but an alternative approach to developing Perth's key knowledge-intensive 'Specialist centres'. The KRN provides accessibility and capacity opportunities for the major 'Specialist centres', effectively creating an agglomeration spillover from the CBD and from other centres within the knowledge-

³² Subiaco as per Attachment B is included as a strategic metropolitan centre due to its employment density and high level of centrality.

intensive 'centrality'. The rail connectivity seeks to address the isolation and absence of metropolitan and local scale within the potential knowledge-intensive 'specialist centres'. Effectively, the lack of sufficient local or internal agglomeration is sought to be overcome by high-level public transport connectivity to the CBD, other potential knowledge-intensive centres, and the wider metropolitan area. The KRN therefore facilitates the maximising of the overall metropolitan urban agglomeration by focusing on the strongest potential knowledge-intensive agglomerative locations, and, as a result, seeks to maximise Perth's knowledge (and tradable) economic activity.

The KRN has a number of key characteristics that provide high levels of 'accessibility', 'capacity', and 'flexibility'. KRN, as heavy rail, provides for high levels of accessibility and capacity not only into the CBD but also into Specialist and Strategic Metropolitan Centres across the broader metropolitan area. This is delivered by the existing radial network (with its integrated rail-bus services, park and rides and origin TODs) interlinking with the new proposed radial-orbital lines. Key to this interlinking is a series of new public transport rail hubs (outside the existing Perth CBD hubs) providing a high level of rail-to-rail transfers. The new lines converge or cross with existing lines allowing for a radical increase in the number of potential transfer or hub stations. Transfers, in addition to the main hub Perth station, are possible at the following stations; Stirling (two lines), City West (three lines), Subiaco (two lines), key stations from Claisebrook (five lines - up from three lines) to Bayswater station (three lines), stations from Claisebrook to a new or merged station at Welshpool/Queens Park (three lines, providing transfer from the Central Orbital line/Southern Orbital/Armadale lines), Cannington station (two lines- no change), Canning Bridge (two lines), Murdoch (three lines), Cockburn Central (two lines) and Fremantle (three lines).

The multiple rail transfer hubs ensure a rail-to-rail network effect previously largely absent in the Perth radial rail public transport system (or any other Australian rail system with dominance in radial lines). A networked rail system connecting dense non CBD centres is likely to lead to much greater contra flow or bidirectional public transport movements. Cervero (2006) has found that a number of cities with bidirectional public transport were characterised by urban and employment density across multiple centres and much higher mode shares for public transport.

The increases in accessibility, capacity and flexibility of movement across the entire metropolitan area provided by the KRN applies, not only for the inner areas of Perth, but also for outer suburban fringe areas (where there is an already relatively high level of accessibility onto the radial network: see Curtis & Scheurer 2012, McIntosh et al. 2013). In particular, the resulting orbital-radial KRN would provide high level of accessibility (working with existing bus and park-n-ride infrastructure) and capacity to-and-from key specialised

and strategic metropolitan centres. Kane (2010, p. 81) found that a radial-orbital system adopting the Mandurah and Joondalup lines' station spacings and relatively high speeds achieve significant time savings of between 27 per cent to 35 per cent on a journey or trip from outer suburban Strategic Regional Centres on radial rail lines to Specialist Centres such as UWA and Curtin University. Trips speeds are an important element of ensuring competitive generalised costs of public transport against car commuting (Hensher & Chen 2010, McIntosh et al. 2013). Notably, the KRN interlinks across multiple radial lines, with the Central Orbital line connecting with five rail lines (the Midland, Armadale, the proposed Southern Orbital, Mandurah, and Joondalup lines); providing a high level rail network effect. In addition to the passenger feeds from the radial lines, the orbital rail lines would also benefit from bus and/or light rail connections. As such, light rail and bus infrastructure investment will also be essential for the radial-orbital network to maximise its accessibility across the whole of the metropolitan area. For the poorly serviced outer suburban areas, the orbital rail line would also provide opportunities for additional radial bus rapid transit (BRT) or light rail connections.

To a significant degree, the reliance on rail has arguably already been set for Perth by the existing high speed radial rail lines being the increasingly dominant part of the public transport system. While rail is required to facilitate sufficient urban density and urban agglomeration, it is important to recognise the accessibility limitations of rail, with its relatively limited route catchment in Australian cities. This, with the low suburban density nature of Perth, sees the existing rail system relying heavily on bus and car (through park-n-rides) for connectivity. This means any future developed rail network in Perth, such as the KRN would, with increasing urban scale and density, be heavily dependent on other spatially intense transport modes. In comparison, light rail or BRT alone, to key specialist centres are unlikely to provide an adequate network effect, particularly given the inability of land-based light rail or buses to network across more than two radial rail services or to meet speeds achieved by the Joondalup or Mandurah lines (see high speed rail comparisons in McIntosh et al. 2013).