

TOWARDS AN UNDERSTANDING OF THE IMPACT OF DEFERRING TRANSIT INFRASTRUCTURE IMPLEMENTATION

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ABSTRACT

This paper presents progress on research into the physical and economic sustainability impact of deferring transit infrastructure investment, particularly rail, in urban growth areas. The topic is relevant to growing cities in developed countries, particularly in Australasia and North America, where development has been influenced by the mass availability of the automobile for some eighty years. The paper draws together a number of threads of current GIS-based research into the subject, encompassing urban form and structure, travel patterns, and the use and role of the transit system. It recognises the issue of path dependency in drawing these threads together and describes the basis of the developing methodology. The research is based primarily on a case study within the metropolitan area of Sydney, Australia. The present stage of the research will later translate to the generalised (economic) costs to the potential user population and other stakeholders, and to non-economic consequences such as loss of amenity and of local environments. The important conclusion from the work to date is that a sound understanding of urban structure – linkages, connectivity and transit orientation at both ends of trips involved (particularly the commute trip) – is fundamental. Consideration of population and employment density is important, but insufficient. Neither does examination of transit-oriented development at one end of the trip offer a complete picture. An understanding of structure at the metropolitan level is essential to the debate on transit-oriented urban form and key to examination of transit-based accessibility and to the factors associated with provision of the necessary infrastructure.

Key Words: urban structure, travel patterns, transit infrastructure, path dependency, GIS applications

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1 INTRODUCTION

Two decades after the Club of Rome *Limits to Growth* discussions led to the concept of sustainable development (Smith and Scott 2006), the milestone United Nations Brundtland Report (Brundtland and Khalid 2007) observed that it was not the growing populations of the developing world that are the major threat to the planet, but rather it is the appetite of the developed countries for scarce resources (Center for a World in Balance 2009). An important sub-set of the sustainability question relates to the role that urban form has in managing it, and the role of transport.

There is a significant literature that argues that the car-dependency of twentieth century suburban growth on the urban fringe is not effective in its use of resources, built environment and amenity, economic sustainability, and equitable access (Sharpe 1978; Newman 1999; Newman 2004; Curtis 2006; Litman 2009). In this context, this paper describes the progress of our research into lack of consistency between metropolitan land use and transport planning; specifically the economic sustainability impact of deferral of implementation of public transport, or *transit*, infrastructure in outer urban growth areas. The primary hypothesis that will be addressed as the research progresses is that the cost (economic benefits lost and collateral damage) of the lack of high quality transit such as that afforded by rail systems to service population growth is high and is measurable. The research is concerned with impacts and implications over time, and the question of path dependency in the unfolding scenarios in the accommodation of growth. It is relevant to growing cities in developed countries, particularly in Australasia and North America, which continue the last century's influence of the automobile.

The objective of this paper is to draw together a number of threads of the research relating to urban structure, travel patterns and the role of transit in addressing economic sustainability objectives. The present stage of the research encompasses the relevant literature on urban form and structure and is examining travel patterns and use of transit. These will later translate to the generalised (economic) costs to the potential user population and other stakeholders, and to the non-economic consequences.

The research is based primarily on a case study within the metropolitan area of Sydney, Australia. English-speaking countries like Australia followed the North American path of dismantling rail-based transit systems (in Australia's case the street tramways of all cities but Melbourne) in favour of providing road space for the automobile, and have invested inconsistently in new transit infrastructure since. It is these countries where the terms *Transit-Oriented Development* and *Smart Growth* are now commonly heard (Cervero 2001) as the new way forward. In Sydney's case, transit infrastructure projects in major growth areas that were part of the Sydney Metropolitan Strategy (NSW Department of Planning 2005) and its predecessors, however, have been deferred more than once. With the exception of a single, rescheduled, rail network extension and minor light rail construction, committed transit plans in Sydney for the next five years are presently confined to the existing rail transit and bus networks, with inherent limitations. The present paradigm has emerged over many years, and the capital cost of extensive catch-up provision of major

infrastructure is now arguably beyond the immediate capability of the state government concerned.

In this paper we first present a review of selected literature on the relationship between transit and urban form that has particular relevance to the research, in particular the urban factors that are apparent determinants of transit use (section 2). We then provide a short history of Sydney's situation and the planning paradigm that that has emerged. We also outline some of the geospatial analysis of Sydney's urbanisation and journey to work data that is being used to inform the research at a baseline level (Section 3). We then draw emerging observations and argument together (Section 4). Finally, we offer a short conclusion and describe aspects of our ongoing methodology (Section 5).

2 CHARACTERISTICS OF TRANSIT-ORIENTED URBAN STRUCTURE – THE LITERATURE

In this section we briefly examine some of the pertinent literature; in particular that which is of potential value in understanding the relationship between transit investment and urban form or structure. It contains three subsections. The first looks at the use of density as a predictor of the use and utility of metropolitan transit. We conclude from the literature that, of itself, density measures are insufficient for our purposes and that there are evident questions regarding widely-accepted application of the theory. The second subsection looks at the literature on Transit-oriented Development, a subject that has become prolific and enthusiastically accepted into urban design and planning practice, certainly in Australia and in the US. Again, we have found its localised focus on individual developments to be useful, but insufficient to provide the metropolitan perspective that we are seeking. The third subsection looks to the literature for guidance on more comprehensive analysis of metropolitan structure and the application of spatial techniques for this purpose.

2.1 Urban Form and the Density Debate

Much of the early work on urban form and sustainability (the 'first wave' described by Williams, Burton et al. 2000, cited in Buxton and Scheuer 2007) was focused on the role of density and consolidation. Kitamura, Mokhtarian et al. (1997, p.126) noted that:

“high density in general means smaller housing units, lower automobile ownership levels, smaller household sizes, lower incomes, a mixture of land use types, higher accessibility to opportunities, and better transit service”.

Our research is not concerned with the density argument *per se*; however density is integral to the planning and decision-making framework that surrounds provision of transport infrastructure. The current generation of Metropolitan Plans, exemplified in Australia by the present Sydney Metropolitan Strategy (NSW Department of Planning op.cit.) and its equivalents in other states, involve strategies of consolidation, infill and densification. There is a very plausible logic to the argument that density promotes energy-efficient transit use because it can place more potential transit users within an easy walk of a transit stop.

The Australian-based international study of urban form by Newman and Kenworthy (1989) was particularly significant and influential in this context. It remains one of the most comprehensive (Rickwood, Glazebrook et al. 2008). However, not all researchers now accept the scale or nature of the impacts and the benefits of density (Stilwell 2000; Moriarty 2002; Davison 2006; Rickwood 2008 op.cit.), and some suggest that densification is fundamentally flawed. One author who has addressed this latter argument over many years is Patrick Troy (1992; 2000; 2003), who, along with more substantive arguments, argues that the Australian backyard is probably more sustainable, and is at least more pleasant, than a high-density, high-rise alternative. Rickwood et al. (2008) noted that density was the most commonly-used measure in transport studies and that other, more complex, measures were still relatively untested. They observed that, despite being of lower density than European and Asian Cities, Australian cities can still support energy efficient public transport. They list four objections to limiting the urban form/ sustainability debate to the density question, suggesting that:

- Density is too simple a proxy for energy use, even though it does seem to be a good predictor of lower automobile ownership and use;
- Density increases energy use by increasing congestion;
- It is too late for wholesale change in Australian and North American cities, and the best that can be done is increasing density around transport hubs; and
- There are other ways, such as road pricing, car-sharing and technological change.

Cervero (2001) and Mees (2009) have drawn attention to Los Angeles, the epitome of automobile dependence, having the highest population density in the US and the least amount of discontinuous growth – ‘it is uniformly amoeba-like’ (Cervero 2001 op cit. p.30). Mees also argues that there is a very weak evidentiary base to the idea that transit utility is governed by density. He suggests that urban form/transit research has been compromised by multiple layers of citation deriving from the 1956 Chicago Area Transportation study, which became the model for many other studies that promoted road (freeway) transportation solutions in subsequent years. As he points out, however, several authors have questioned these density thresholds in the past but few have offered an alternative. Buxton and Scheuer (2007) cite an extensive series of references suggesting that the density theory does not account for other variables, ranging from transit infrastructure quality and service to socio-economic parameters such as employment and income. They also observe that, while the relationship between density and other variables has been studied extensively, there is little that establishes causality - an observation echoed by Troy (2003). However they too note that there has been little research that has actually improved on the Newman Kenworthy methodology. Yiftachel and Betham (1991) researched attitudes to higher densities in Perth, Australia, a city noted extremely low density (and for its high quality rail system), to find that people generally preferred the density of the area in which they lived; i.e. if they lived in a low density area that would be the preference that they expressed. Kitamura, Mokhtarian et al. (1997) posed the question as to whether land use changes can change travel behaviour. Their multivariate study of travel behaviour, neighbourhood characteristics and attitudes concluded that travel behaviour was more directly related to attitudes than to land use characteristics. As such, urban form alone does not necessarily

change travel behaviour, and, as pointed out by Buxton and Scheurer, there may be a process of self selection at play in the choice of transit-oriented neighbourhoods by people who do not wish to use cars.

We conclude that the essence of the density debate is that density has clear relevance to transit use and utility and must be considered as a factor, but it is insufficient to take it as the determining factor. Increasing density is a tool to encourage transit use, but it is not a substitute for a better understanding of the role of the transit system itself. In the case of our research question on growth without the infrastructure, we clearly need that understanding.

2.2 The Literature on Transit-Oriented Development

The second major tranche of research important to the question of the sustainability advantages of transit is that concerned with *Smart Growth* (Litman 2009) or *Transit-Oriented Development* (TOD) (Cervero and Landis 1997; Cervero 1998; Cervero, Duncan et al. 2002; Cervero et.al. for the Transportation Research Board, 2004). The terminology was originally US-based, but the concepts have had a significant influence on Australian planning at the practice level. In essence, Transit-Oriented Development is compact, mixed use development within a walk-in transit catchment (Cervero 2004 op.cit.). Invariably TOD is described in terms of individual projects, driven either by proponents in the planning and development communities or, sometimes, from the supply side in conjunction with new transit infrastructure. It parallels the closely-related concept of *New Urbanism* (de Villiers 1997). New Urbanist principles typically entail a walking scale, a central focal point such as public open space, mixed uses and density increases. Its proponents argue that such urban design promotes the use of transit; although transit infrastructure is not necessarily part of the design. In fact, some writers have suggested that New Urbanism is little more than a new nomenclature for less desirable development concepts such as gated communities than it is a new sustainable urban form (Hall 1998). Also in the lexicon of TOD is *Joint Development*, simply project-specific TOD that makes use of land owned by the transit agency or the public sector.

The nature of TOD developments in the various case studies is highly variable, and they range from relatively modest village-like developments to high-rise campuses of office, hotel and residential construction. For instance, the scale of the developments might range from 16,000 square metres to over one million (Cervero 2004). In the various discussions of the developments – largely emanating from the United States – much is made of the ‘back to the future’ nature of the TOD concept in replicating the urban form of an early, pre-automobile dominant age. The Transportation Research Board (TRB) team’s research notes that TOD is not a new concept; in fact it has its origins in the streetcar suburbs and railway villages of the nineteenth century. This subject, and consistent pattern in the decline in transit use that was essentially the decline in the street tramway (streetcar) networks as rubber-tired transport proliferated, will be more extensively covered in Norley 2010b (forthcoming). This is important to the Sydney case that we shall discuss later. The larger, higher-density variants are somewhat contrary to the ethos of the early nineteenth century ‘garden city’ railway suburb prototypes; however appear to be the form most prevalent.

The typical situations regarded in the literature as candidates for TOD are where the transit-centred earlier form (if it once existed) has been rendered uneconomic (and hence degraded) by the automobile-centred shopping mall or office campus located away from transit, or where access to transit is dominated by free or very cheap parking space. There appear to be variations between some of the older established cities such as Boston and Chicago that have maintained at least some level of transit orientation and the cities further west in the US. In Boston's case, the city has attempted to respond to its core constituencies to recover its urbanity (Cervero 2004 page 183f). In Sydney, however, TOD densification and growth centre concepts are *inter alia* being imposed with little apparent connection to the supporting rail and road transport infrastructure, nor consideration of other issues. High amenity neighbourhoods in north-side Sydney, originally developed as railway villages and which had retained their transit orientation, for example, are being rezoned for high density (Duffy 2006; Dempster 2008). At the same time there is little evident connection between the rate of development and transit-orientation of the outer urban North West and South West Growth Centres and their rail links (Norley, 2010a). For our purposes, TOD is another tool to encourage transit use. However in isolation from effective, informed planning and implementation of the infrastructure it is insufficient.

2.3 Modelling Form and Structure at the Metropolitan Level

The third tranche of relevant research is the question of structure at the metropolitan level and how to analyse it. It is relatively recently that explicit distinctions have been drawn between 'form' (which is about patterns of density and use) and 'structure', which brings into play questions of connectivity (Troy, 2000). Cervero (1998) pointed out that much of the Transit-Oriented development research has been at the neighbourhood and community levels, but the key to making it work is co-ordination at a metropolitan level. It is evident that analysis would be enhanced by examination of structure in this way and also of the role of centres within metropolitan regions (Cervero 1991, Black 2008). Therefore, superimposed on the density and local TOD debates we need to examine arguments around the concept of a poly-nucleated centres and corridor-based urban structure, a metropolitan-level concept also promoted for its sustainability advantages (Bernick and Cervero 1996; Goodman and Moloney 2004; Black 2008; Litman 2009). The development of metropolitan Sydney (and to varying degrees many other cities) throughout the twentieth century has had elements of such a structure, and this is being continued in more recent strategies (Westacott 2004; Johnson 2005; Meyer 2006).

Despite the evident importance of urban structure in transport planning, much of the transport and land use research on travel patterns at a metropolitan level is behavioural rather than geospatial, using well-established transport modelling 'stated preference' logit-based techniques (Hensher and Greene 2003). These are data intensive and require further modelling effort to actually translate the source preference data to network effects (Rickwood and Glazebrook 2009). Such models are useful in modelling travel behaviour under a single land use scenario, but typically less so where land use change may be induced over time, or where car ownership options are limited (Currie 2007). There is some work beginning to establish a spatial dimension to the behavioural models (Mulley and Tanner 2009).

Geospatial techniques are relatively recent, but it is now common to see geospatial data drawn from Census tables presented in map form. Some of the early presentations in this form date back several decades (Davis and Spearitt 1979). These presentations are likely to focus on data that can be drawn directly from the Census such as car ownership, income, household size and demographics, and which can readily be normalised on a 'per area' (hectare or square kilometre) basis. Geospatial analysis is now developing further as an analytical and modelling technique (Scheurer, Curtis et al. 2007) that can draw on network and spatial analysis capability. We see an important application of the use of GIS analysis to create a model of the long-term dynamic of the decision process and its impacts, current and prospective.

3 THE SYDNEY CONTEXT

We now move to the Sydney data and its implications for our research.

3.1 Challenges in Sydney's Planning

Sydney, located on Australia's south-east coast, is the state capital of New South Wales. With a population of approximately 4.5 million, it is the most populous city in the country (Regional Director NSW Australian Bureau of Statistics (ABS) 2004; Australian Statistician 2008). Australia is highly urbanized. Sydney's population represents more than 60% of the state population and this proportion is growing. It has an international profile through its iconic landmarks the Opera House and the Harbour Bridge, its beaches and its hosting of the 2000 Olympic Games. Its geography is governed by its coastal location, its harbour and other waterways, the Cumberland Plain and surrounding hills. Its parkland system in all directions beyond and within the urbanized area is extensive, and the World Heritage listed Blue Mountains lie to the west. Sydney is one of the most multicultural cities in the world, and is a major destination for immigrants to Australia. Sydney prides itself on being 'Australia's only Global City', with 30% of Australia's financial and business services employment. The New South Wales Government's previously-mentioned planning strategy *City of Cities* describes a Centres Policy and a concept of a Global Economic Corridor that accommodates employment of an international standing in the business, finance, technology and information space (NSW Department of Planning 2005 op cit.).

Sydney's great challenge is its growth. The 2005 Metropolitan Strategy was based on a population increase to 5.3 million people by 2031; however this figure has now been increased to 6.0 million by 2036 (NSW Department of Planning 2008), growth of 30-40% on the current population. One third of the increase is expected to come from migration. Reducing household size compounds the urbanization problem by requiring a disproportionate increase in the number of dwellings required to accommodate the growing population. Interestingly in 2007-08 the household size trend in Australia reversed to show an increase (James 2009). This paper, and the research that it describes, is concerned with the transit infrastructure needed to support this.

The existing rail network and extent of urban development (forecast for 2011) based on a threshold of two persons per hectare is shown in Figure 1 over.

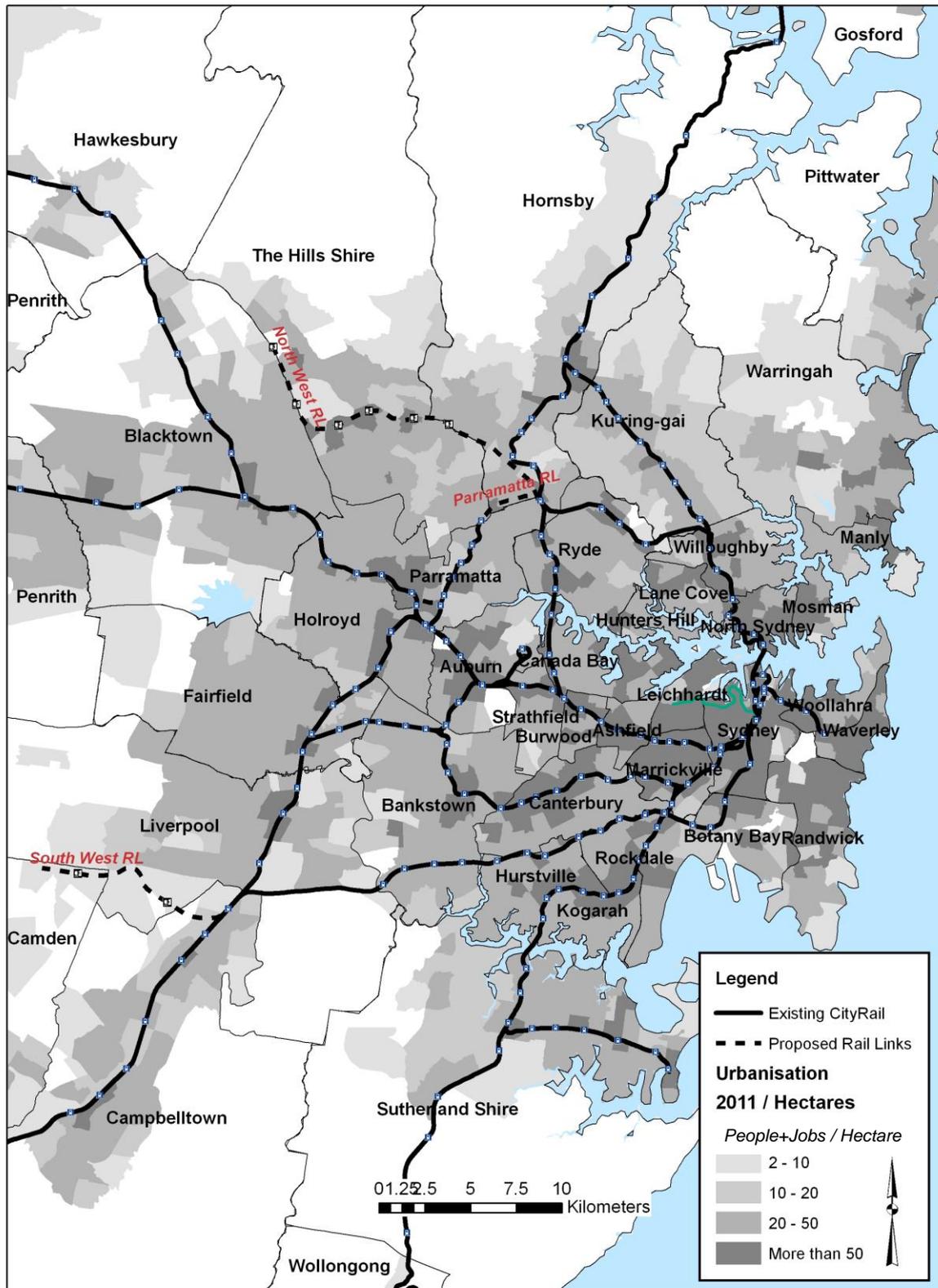


Figure 1: Urbanised Sydney and its Railway Network (2011)

Source: Transport Data Centre 2008a, b; Map Author

Notwithstanding its automobile dependent history, Sydney has a relatively comprehensive transit system, at least by some North American standards. Several authors have commented on its potentially significant role (Mees 2000; Glazebrook 2009). Sydney's transit comprises a 1000 kilometre network of suburban heavy rail lines (branded 'CityRail') with an underground Central Business District core (the 'City Railway'), a network of government-run bus routes in the inner and middle suburbs, private (but government-supported) buses in the outer suburbs including 'T-Way' bus-only roads, plus its harbour ferries and a single light rail line.

The transport centrepiece of *City of Cities* was the *Metropolitan Rail Expansion Program* (MREP). MREP comprised three projects that were to create extensions to the growth centres in the North West and South west and increased capacity in the city, the so-called Harbour or CBD Rail Link. During 2008 and 2009 two state Premiers were successively removed from office by their own party with no mandate from the electorate and there were massive swings in the infrastructure plans. The present Metropolitan Transport Plan (NSW Transport and Infrastructure, 2010) defers much of any new infrastructure some 10 years. The North West Rail Link that is central to the case study in our research will now not be completed until 2024. This equivocation and the content of the most recent plan place the rigour of the process into serious question (Property Council of Australia, 2010).

3.2 Travel patterns in the Sydney Journey to Work

To inform our understanding of the situation, we have commenced a baseline geospatial analysis of published census and travel data for Sydney. This subsection of the paper provides an overview of that analysis. It focuses on the journey to work travel patterns in what we describe in this paper as the Sydney Commuter Belt – defined as within a two hour in-vehicle time range by public transport. Its purpose is to suggest the current role of the rail system in Sydney's travel in such a way as to raise questions about the effect that the deferred growth centre transit extensions may have had. It is based largely on analysis of the 2006 Census data, as enhanced for transport planning purposes by the New South Wales Government's Transport Data Centre. Travel data is sourced from the Transport Data Centre (Transport Data Centre 2008a-e), and demographic data from the Australian Bureau of Statistics (Australian Bureau of Statistics (ABS) 2009), and converted as required to ArcGIS® format. A subset of these data has been mapped to provide a visually rich view of the work travel patterns, and aspects also presented as graphs. The analysis is based on inspection and observation as a preliminary to more formal empirical analysis.

City of Cities emphasised the importance of employment in determining the future of the metropolis. The Strategy sought to focus the growth in employment forecast over the planning period to 2031 in strategic centres and employment lands. There were, on the revised TDC 2006 figures, 2.2 million jobs in the Commuter Belt¹. By 2011 this is forecast to increase to around 2.4 million. The City of Sydney LGA is the dominant employment centre in the Sydney metropolitan area. This is apparent from Figure 2, which presents the employment data for LGAs that are the major employment centres (> 35,000 jobs) in terms

¹ The TDC assesses the Census figures as an underestimate, and has corrected them. The reasons for the underestimate are described in Transport Data Centre a and b

of manufacturing and non-manufacturing. Sydney employment tends to be relatively clustered and there is little evidence that this general pattern is changing significantly (Black 2008). This presentation also emphasises the spread of employment across the Metropolitan area. While the City of Sydney stands out as the centre of employment in Sydney, the long tail in Figure 2 is significant in that collectively it represents three quarters of the employment in the commuter belt. About 610,000 non-manufacturing jobs (34% of the total metropolitan) are located in just four of the Global Economic Corridor LGAs² of Sydney, North Sydney, Willoughby and Ryde, and these, along with Parramatta, include the top locations of such jobs in the commuter belt. The Global Economic Corridor is the centre of the high-end employment activity in Sydney, as it is for services more generally.

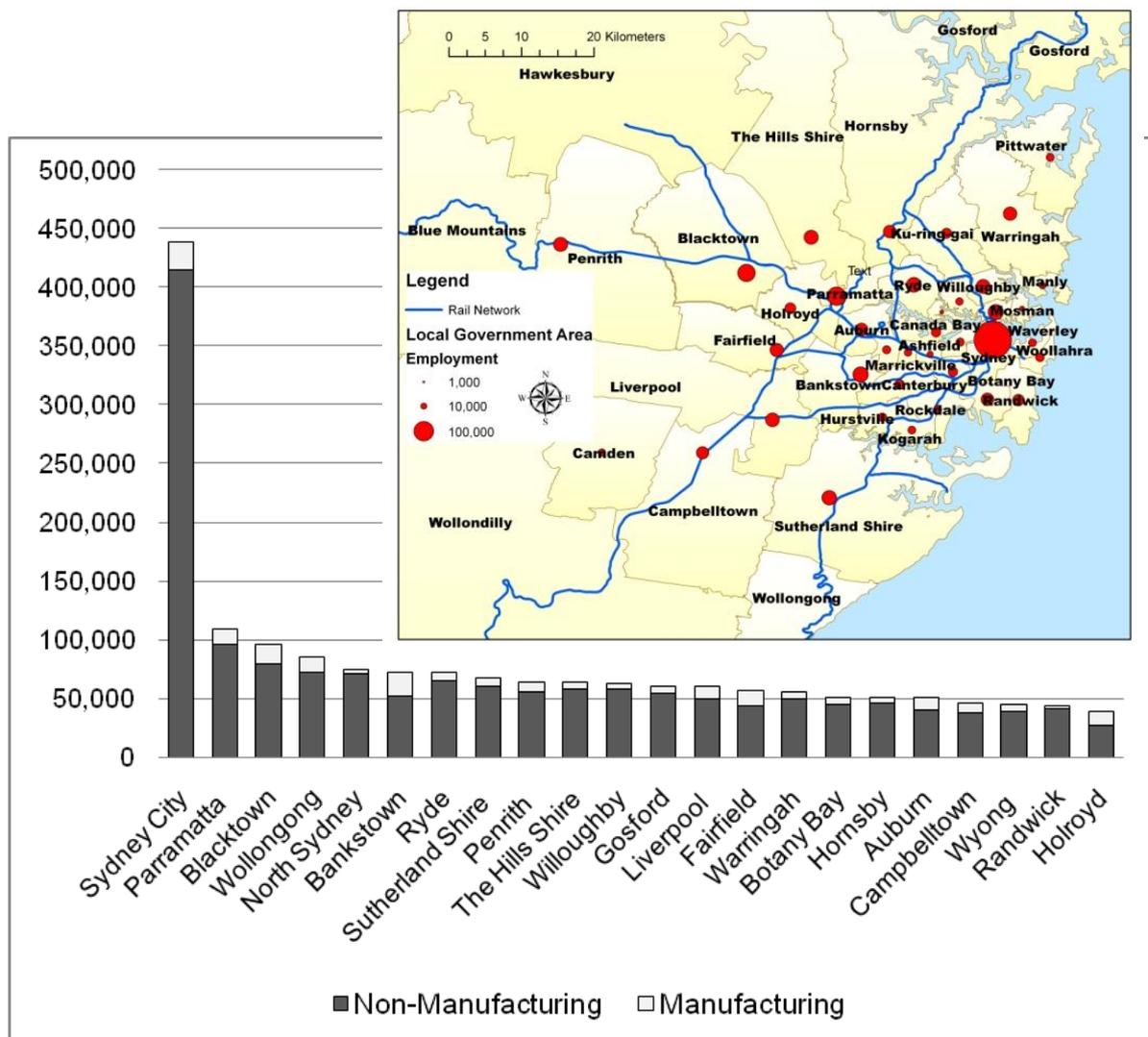


Figure 2: Employment in Sydney - Major Centres (LGA Basis)

Source Data: (Transport Data Centre 2008c)

Map inset shows LGA locations. The Global Economic Arc is the area covering Botany Bay through the City of Sydney to Ryde.

² LGA = Local Government Area: the shire or municipal council area

Nearly half of the Commuter Belt jobs are accessible by rail. Table 1 below shows the rail accessible jobs based on TDC estimates for 2011. 'Accessible' is defined simplistically as within 800 metres of a railway station; it takes no account of the level of service offered, nor of the connections necessary to access the location. 800 meters has been adopted as the figure used in state planning regulations (SEPP) for the implementation of planning policy (for example NSW Department of Planning, 2009), although our research suggests that the walk-in catchment of many stations extends further. The table does not distinguish between jobs of differing types, and therefore does not allow for shift work, trades requiring use of a motor vehicle or 'dirty' occupations.

Table 1: Rail Accessible Jobs in Sydney (2011)

	Total Jobs	Rail Accessible	%
The Harbour Cities and Global Economic Arc			
Sydney City	455,561	407,141	89.4%
Sydney & North Sydney	533,338	467,302	87.6%
Total Global Arc	841,874	592,002	70.3%
The River Cities			
Parramatta	113,175	69,690	61.6%
Liverpool	65,653	17,689	26.9%
Penrith	71,115	20,145	28.3%
The Commuter Belt			
Total Sydney	2,378,439	1,084,344	45.6%

Source Data: Transport Data Centre 2008a, ArcGIS®- based estimates: Author

With these qualifications, Sydney's existing rail network will provide accessibility to some 1.1 million estimated jobs in the Commuter Belt, or 46% of the total jobs forecast. The distribution is important. In 2011, the 'Harbour Cities' of the Sydney City and North Sydney LGAs – effectively the major Central Business District of the Sydney Metropolitan area – are expected to offer over 500,000 jobs in 2011, 88% of which will be accessible by rail. For the Global Arc 70% are rail accessible. From this perspective alone employment in the Global Arc effectively determines the role of the railway network and that of the transit system more generally. It should be noted that much of the Global Arc falls into the inner suburban area that is well serviced by the bus network, and so the 70% figure is an understatement of this area's transit accessibility overall. Analysis of the origins of work trips shows that the catchment of the City of Sydney and North Sydney LGAs extends some 50 kilometres in radius to three sides, the fourth to the east being constrained by the Pacific Ocean.

Table 1 also contrasts the other designated Business District centres – the so-called metropolitan 'River Cities' centres of Parramatta, Liverpool and Penrith – in terms of their rail accessibility. Parramatta, which is approximately the geographic population centroid of the Sydney Metropolitan area, is forecast to offer some 113,000 jobs in 2011, of which 62% are rail accessible. However, Parramatta is only directly served by one rail corridor, albeit

heavily used with relatively frequent services. A very limited direct service is offered from the south. Thus its rail catchment is largely restricted to locations to the corridor to the east and west. Penrith is much further out to the west, its rail access is based on a single corridor, and over 70% of its employment is out of the rail catchment. Likewise, two thirds of Liverpool's employment is away from rail. Liverpool, however, is relatively well served by a network of rail lines from four directions.

Figure 3 shows the transit mode share from selected Commuter Belt LGAs to Sydney and North Sydney, arranged in order of transit mode share. This chart presents the transit share in terms of the Priority Mode concept used by the NSW Transport Data Centre (Transport Data Centre 2008c) which, where multiple modes are used, orders the modes in terms of the longest part of the journey.

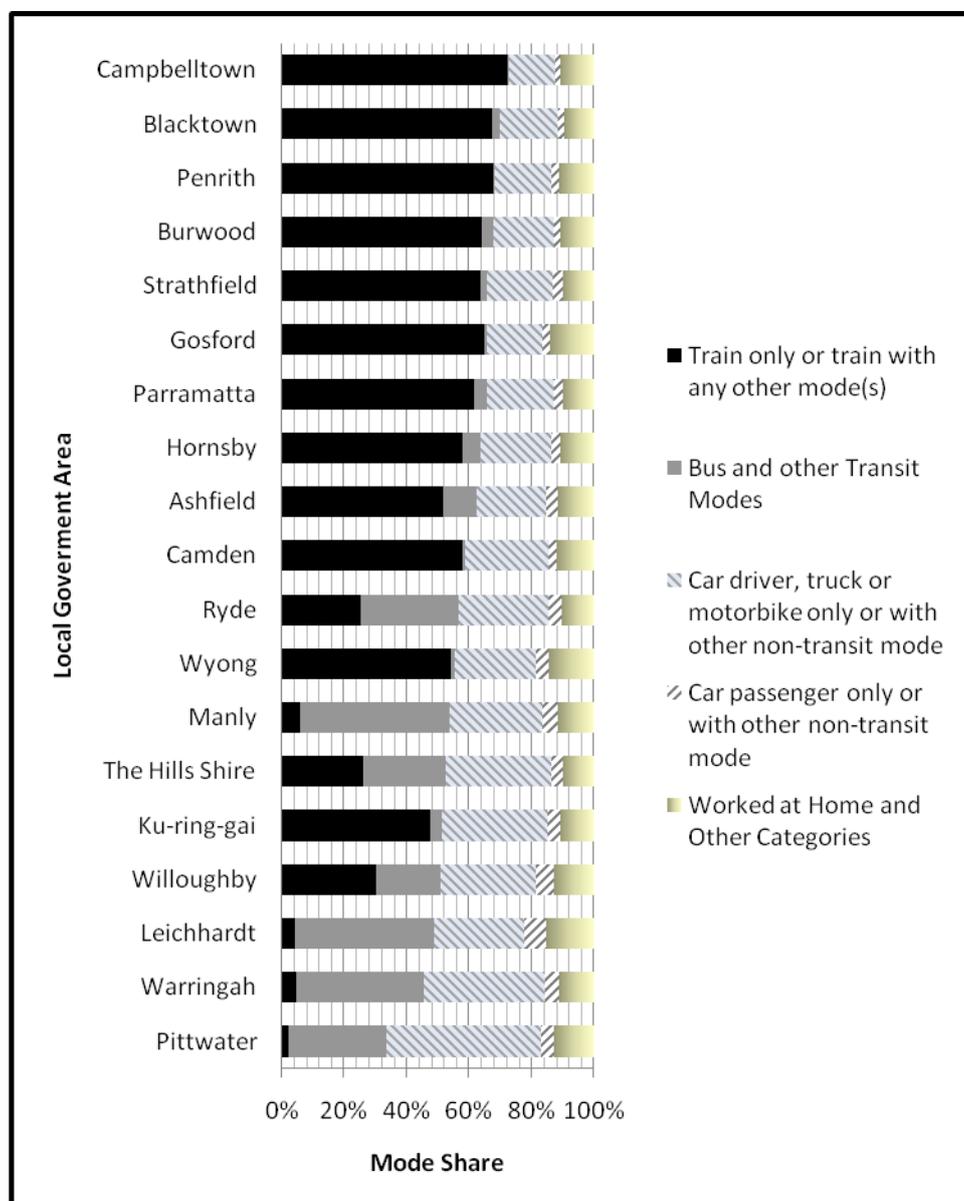


Figure 3: Mode Share from Selected LGAs to the Harbour Cities

Source Data: Transport Data Centre 2008d

The details of these data tell a particularly interesting and important story. The Harbour City work trip is very strongly transit-oriented. More than half of the work trips to these LGAs (51%) used public transport – train, bus, light rail or ferry – and a further 17% either used other active modes (walk, cycle etc.) or worked from home. Only 31% travelled by motor vehicle as a driver or passenger. The highest share comes from Campbelltown, 40 kilometres south of the city on the Main South railway. Other very high mode shares (of the order of 65% or more) are clustered around middle and outer LGAs that follow the Main West railway line to the Blue Mountains. Generally all of the very high shares follow the main rail corridors.

On the other hand, transit shares in the bus-served LGAs tend to be 55% or lower. The bus-served areas include the inner western LGAs away from the railway typified by Leichhardt, the eastern suburbs of Randwick and Waverley (not shown in the figure) and the northern beaches suburbs of Warringah and Pittwater.

In contrast to the Harbour Cities, the data show low levels of transit use in the River Cities of Penrith, Parramatta and Liverpool, potentially related to a combination of the distribution of the jobs in these LGAs and access from the transit nodes (a question of permeability and distance) and the relative ease motor vehicle access and parking. The Harbour Cities offer their jobs in a very compact area, have multiple rail stations for distribution, and car access and parking is both difficult and expensive. The Transport Data Centre lists 'avoids parking problems' as the primary factor in using public transport for work and 'arrives closer to destination' as the least important (Corpuz 2007). Our mapping (not reproduced here) and that of others (Rickwood and Glazebrook 2009) shows a distinct pattern of heavy transit and active mode (walking and cycling) use in those zones closer to railway stations on those lines that offer reasonable service levels, and the inverse for car use. This pattern, at least in part, represents the railway villages pattern that is presented in the City of Cities documentation (Johnson 2005). At this stage of the work this is offered simply as an observation, but it will be pursued further at later stages.

The ABS/TDC data present clear evidence of the relationship between location near good transit service (particularly the railway system) and choice of mode for the journey to work. Despite long distances (indeed the evidence says because of them) Metropolitan Sydney's urban form appears not to be a barrier to transit use, at least in respect of the rail system. The data show a distinct pattern of high transit use to the Harbour Cities of Sydney and North Sydney that follows the rail lines; but which is not replicated in the River Cities of Parramatta, Liverpool and Penrith. We conclude that these data confirm both the significance of the rail network and the need to understand structure, connectivity and the role of the rail system if we are to measure the costs of not providing the rail links in the growth centre strategy.

4 APPROACH AND DISCUSSION

In this penultimate section we provide a short outline of the approach to our research and the case study that we are developing. We then turn to an emerging theme of the importance of path dependence to our work and the interrelationship between the decision-making, especially in respect to deferred infrastructure across several areas – land use, urban development, transit and transport more generally.

4.1 Approach - next steps

For our purposes, geospatial techniques are being used to assemble a database and analyse travel patterns, housing and employment, relevant demographics and land use characteristics over time. The database will be used to test impacts and costs, and to generally inform the work. The approach parallels that used by the US Centre for Transit-Oriented Development (CT-OD) (2005) and with Australian work (Scheurer, Curtis et al. 2007) in the assessment of transit systems and accessibility. The research addresses a different research question than those cited; however there are common elements that can be deployed, albeit at a less comprehensive level. Ultimately the qualitative path data is intended to be combined with the GIS data to create a model of the long-term dynamic of the decision process and its impacts, current and prospective.

The methodology will include construction and assessment of a small number of scenarios reflecting infrastructure development, historic and future. These will include a base case with no new rail transit infrastructure in the upper north side as is the present situation, and several scenarios where infrastructure had been constructed. The latter will be informed by 'official' plans and the work of other observers (Christie 2001; Glazebrook 2009). Each of these scenarios will be constructed so as to envision a pattern of consequent decisions based on the research, including road capacity and land use change. Each of the cases for 'new' infrastructure will be constructed with travel patterns modified by data from existing rail-served areas. The objective is not to speculate on a single outcome under each scenario; rather it is investigate a spectrum of implications over time. These will represent plausible futures, informed by the research and presented in terms of physical outcomes and economic costs. They will incorporate a decision matrix, designed to represent relationships between decisions about alternatives (for example, motorway vs. transit), recognising that these may not be mutually exclusive. The assessment of economic cost will adapt standard economic evaluation methodology (Australian Transport Council 2006) to the broader sustainability framework. This will take into account changes in practice now emerging internationally in the treatment of risk and wider economic benefits (Graham, 2007). The analysis will estimate the generalised cost of travel in the sector, by mode, for each of several scenarios. Recent work on time poverty (Currie 2010) will also be valuable in this regard.

4.2 The North-side Case Study

The upper north-side of Sydney, the case study being pursued in this work, has a number of important structural relationships with the Harbour Cities, and a number of barriers. The lack of rail transit to the area designated as one of *City of Cities'* two growth centres makes it an area of major interest. The choice of the North West, rather than the South West, has been reinforced by the State Government's intention to progress the deferred South West Rail Link to an area largely devoid of existing development, and which by 2021 will service a catchment of only one quarter of that of the indefinitely deferred North West Link to established areas (Norley 2010a). Key amongst the differentiators for the north-side relates to Sydney's geography, in that the eastern (coastal side) half of the metropolitan area is divided north-south by the Harbour and its westward reach, the Parramatta River. Rail and road crossings are limited, the most significant being the Harbour Bridge. The Harbour also divides Sydney's demography, as noted above, potentially making the north-side an important catchment for general and specialist managers and professionals in a range of high-end sectors working in the Global Economic Corridor.

Similarly, the north-side has a number of key transport-related differentiators. The rail lines (the North Shore and Northern lines, which do not extend westward beyond the middle suburbs) are similar to those serving the rail-served corridors to the West and South. The difference lies in the North West motorway links and the bus services they carry, and the observable time and monetary costs to the users of these facilities. The transit service on the upper north-side (the North West) comprises a bus network that includes Motorway bus lanes (on the M2 Motorway) and several 'T/Way' busway routes. Table 2 compares existing timetabled commute travel times to those estimated for the key rail-based infrastructure projects that have been proposed over the past decade, clearly showing the extended travel times for North West commuters.

Table 2: Existing and Projected Transit Times to Sydney CBD (Wynyard)

From	Existing Timetabled	NW Rail Link	NW Metro
Castle Hill	60	47	30
Hills Centre	70	50	32
Norwest	72	54	36
Rouse Hill	86	60	42
Carlingford	51	48	36
<i>Carlingford (Train)</i>	<i>59</i>	<i>48</i>	<i>36</i>

Source: (GHD Pty Ltd for TIDC 2006; MetroLink 2008; NSW Ministry of Transport 2009)

It should be noted that the existing times are timetabled times. Anecdotal reports (Carlisle 2009) suggest typical travel times of three to four hours per day and complaints about reliability and crowding. These travel times, with potential time savings of up to one and one half hours per day for CBD commuters, represent the key to the potential economic savings from the deferred rail links. These commuters have a road option which, because of the history of motorway construction in north-side Sydney as a series of toll roads, involves a toll

of over A\$20 per day. Tolls, where they occur, are reimbursed for residents in the South and West as a matter of political expediency; not so the North West. The motorways are heavily congested during peak periods and travel times are extended (Sinclair Knight Merz Pty Ltd 2007) – average road commuter speeds in 2001 of approximately 30 km/hour are expected to reduce to 18 km/hour by 2021 (GHD Pty Ltd for TIDC 2006).

In response to increasing population and transit demand, the NSW Government has announced increased numbers of buses for the North West and had reached agreement in principle with the M2 owner/operator for widening of the motorway and for other capacity enhancements (Business Day 2009; NSW Roads and Traffic Authority 2009). Over and above the direct impacts on commuters from the North West, these give rise to two examples of the collateral issues associated with the lack of rail transit in the North West. These examples are also indicators of the path dependence (Mahoney 2000) issue that is emerging in our research. The widening of the M2 Motorway will offer capacity for no more than 3,000 passengers per hour in the peak direction, compared to at least 10,000 per hour on the Rail Link, and there are questions as to whether the planned road speeds are achievable with increased volume (Ewing 1997). Sections of this motorway run through prime examples of remnant Sydney Indigenous Open Forest (Maunsell Pty Ltd. 1991), and are threatened by the widening proposal. At the CBD end, the Harbour Bridge is presenting as a significant pinch point, with buses queuing onto the Bridge in the morning peak. The constraint is bus congestion in the city streets rather than the Bridge itself. Micro-simulation (Hidas, Aitken et al. 2009) has indicated that the present stopping pattern cannot accommodate additional services, and that additional CBD street routes and kerb space will be required.

4.3 Path Dependency

The obvious dis-benefits of poor-quality transit are linked to the impacts on residents of the growth areas, primarily in the form of time-deprivation. In parallel, downstream collateral damage occurs in the form of increased automotive dependence, decisions by the private sector to promote solutions that benefit them, and government decisions that to agree to less effective solutions. Troy (1999) described path dependency in terms of the historic development of the cities he examined and their growth outwards from their point of origin, typically the early landing places. He discussed the development of institutions and governance processes that evolved and how they influenced the structure and form of the city. He concluded that some of these governance structures have become undemocratic, have lost transparency and have lost accountability. Cervero (2003) took a more technical perspective towards path analysis. He used the concept to examine the issue of induced demand resulting from highway construction. He suggests a short-term (1-year) model whereby service level improvements directly affect travel demand, and a long-term model where improvements lead to land use shifts that have two-way feedback linkages with the transportation effects. The short term model reaches equilibrium as the induced demand lowers service levels; the longer term model suggests that the land use changes extend this timeframe to at least six years.

The path dependency that we are examining would appear to be longer again. At the extreme it encompasses the international decline of the tramway (streetcar) systems, the growth of automobile dependence and the beginnings in the 1960s of recognition that highway construction was not necessarily the answer to accessibility and mobility. In Sydney's case a turning point may have been the 1968 Metropolitan Plan (State Planning Authority NSW, 1968), which identified the need for extension of the rail system into growth areas. However, the continuing inability (for whatever reason) of successive state governments to follow through on such investments has created the paradigm that we find today.

It may be argued that the processes outlined above are dynamically degenerative. Where infrastructure is inadequate and development has been allowed (or encouraged) to occur, redressing the situation involves retrofitting, which is more costly than construction on a green-fields site, more disruptive and requires established travel patterns and destination choices (and associated investment) to be changed. This is likely to be exacerbated as the structured urban form needed for effective transit service is compromised by development-led decision-making. There is little in this paradigm to reduce car dependency, while the cost of belatedly providing the necessary transit infrastructure is demonstrably higher than building it contemporaneously with the development. The position thus continues to spiral downwards, as suggested in Figure 4.

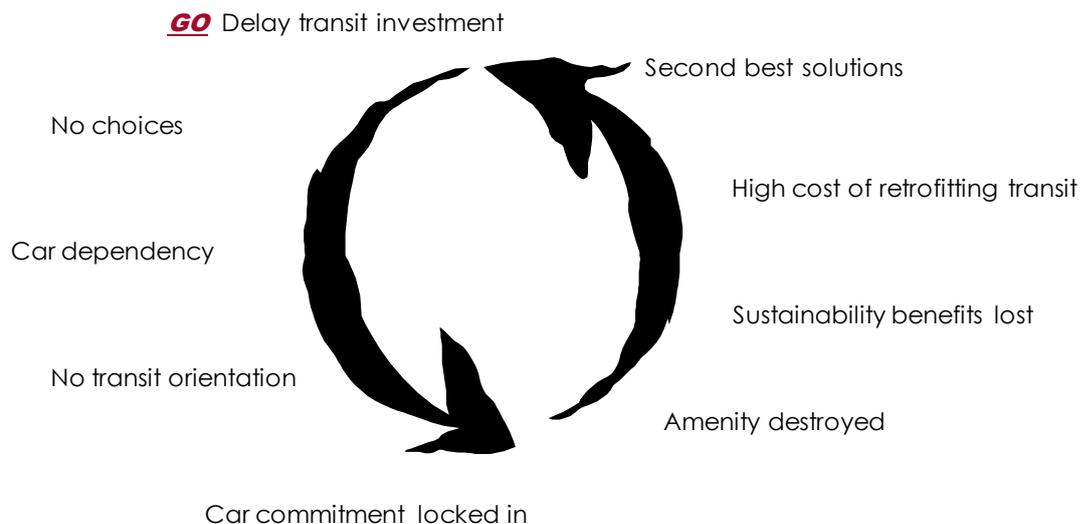


Figure 4: Vicious Cycle of Decline in Transit/Land Use

Source: Author

This research is seeking to track this vicious cycle and to quantify the results, focussing primarily on the physical and consequent economic impacts.

5 SUMMARY AND CONCLUSIONS

The paper has drawn together a number of threads of the literature and our current GIS-based research into the subject of growth, development and the value of transit infrastructure, encompassing urban form and structure, travel patterns, and the use and role of the transit system. The subject is complex and its multi-dimensional nature demands an appreciation of the detail of the data.

We observed that much of the first tranche of the literature on transit and urban form at the metropolitan level focused on density as a predictor of transit use, with its inevitable conclusion that high density has been seen to be a prerequisite for effective rail-based transit systems. We recognised that it is eminently reasonable to argue that higher population densities in the vicinity of transit nodes increases the probability that transit will be used for trip ends in that concentration. However, our work confirms population and employment density measures to be insufficient to establish the value and use of the transit system, and their application in planning practice is now being questioned. Neither does examination of transit-oriented development at a single location (one end of the trip) offer a complete picture. We noted too that much of the literature on Transit-Oriented Development is locally focused, in that it is primarily concerned with activity in the vicinity of single transit nodes. Given the importance of connectivity and significance of the other trip end, a network-based spatial perspective on TOD would appear to be valuable. The spatial attribute in transport modelling is a relatively recent development that needs to be pursued further for this reason.

The Sydney data provide a number of perspectives that are important to our research question. First, the data make it clear that the suburban 'CityRail' railway network has had a long history of influence on travel patterns, even as automobile dominance has risen. Sydney's urbanisation in the late nineteenth and early twentieth century was in the form of the classic 'streetcar suburbs' and 'railway villages' following and serviced by the tramway and railway networks, and this process has continued. These networks and nodes continue to be the focus of high transit mode share, even in the outer suburbs. The rail-served locations beyond the inner suburbs show higher shares than the equivalent bus-served locations, and this appears to be significant to the debate about provision of quality transit. There are also several anomalies that are important, in the commuter behaviour in the LGAs of Camden and The Hills Shire. These have no rail lines and are bus-served, but nevertheless have notably high rail commuter shares. Therefore, the Hills Shire is the major focus of the case study we have selected for our research into the lack of rail infrastructure.

Secondly, the Sydney data draw attention to the importance of the trip destination. Transit share to Sydney's Central Business District – the 'Harbour Cities' – is much higher than it is to the smaller employment centres and, of course, to other spread employment. It is argued from time to time that concentration of activity in central business districts distant from less accessible parts of metropolitan areas is undesirable from the point of view of accessibility and equity, and provision of infrastructure to service it exacerbates that problem. In Sydney's case the location of the CBD to the eastern (coastal side) of the metropolitan area

creates the asymmetry and distance from Sydney's western suburbs. This is of course not unique, and other coastal or lakeside cities (for example Melbourne, Chicago, San Francisco) have similar asymmetry. *City of Cities* draws attention to this in mapping Sydney's wealth (largely to the North and East) and unemployment (to the West and South), with the implication that a solution to the inherent social issues is needed. The present research is, however, concerned with provision of infrastructure to meet demand, rather than for social engineering purposes. As such, the research is pointing to the importance of the Global Economic Corridor as a transit-oriented destination, linkages with its catchment, and the transit-orientation of the nodes in this catchment.

At this relatively early stage of the research, as we noted earlier, an understanding of urban structure – linkages, connectivity and transit orientation at both ends of trips – is essential to the debate on transit-oriented urban structure. This structural understanding is key to examination of transit-based accessibility and to the factors associated with provision of the necessary infrastructure. Furthermore it is essential that there is recognition of the importance of path dependence on transit use. Simply building transit-oriented development may be of limited value unless it attracts transit-oriented tenants, and it could be counterproductive. The concern that this leads to is how long it will take for residents of areas that have had no quality transit alternative to adjust their travel patterns to more sustainable alternatives.

Sydney has now moved into a phase where its growth has taken it beyond the reach, and capacity, of the rail network. Residents of some of the outer growth areas are reaching back to the railways that do exist to complete their commuting trips by driving some distance to the rail network. The alternative is a lengthy bus ride on congested motorways, or driving and paying multiple tolls and parking charges. It is the difference between these options and service levels that might be offered by extensions to the rail network that represent the costs of non-provision of infrastructure in the first instance.

Sydney, like many cities with similar influences, now has to face the effects of years of accumulated lack of investment in its transit infrastructure. The state government has the difficult task of prioritising finite funding between a number of expensive options in a rapidly growing city. It is hoped that this research can make a timely scholarly contribution to the debate that has gripped the Sydney media and public over the past several years.

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