Impact of urban form on transport and economic outcomes

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Abbreviations and acronyms

ARC	Auckland Regional Council
CAU	census area unit
EEM	*Economic evaluation manual* (NZTA 2010)
GFA	gross floor area
GNP	gross national product
GST	goods and services tax
HUE	household unit equivalent
IV	instrumental variables
LGACAA	Local Government Auckland Council Amendment Act
NIP	National Infrastructure Plan
NSCC	North Shore City Council
NZTA	New Zealand Transport Agency
OECD	Organisation for Economic Cooperation and Development
OLS	ordinary least squares
PHAC	Public Health Advisory Commission
SE	spatial error

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Executive summary

Background

The New Zealand Transport Agency (NZTA) commissioned this research into the impacts of urban form on transport and economic outcomes. We use the term 'urban form' to describe the physical shape and settlement/land use patterns of cities and towns. Strategic government documents, such as the National Infrastructure Plan and NZTA's *Statement of intent*, have expressed interest in the impacts of urban form. This report can be interpreted as a response to this strategic direction.

In 2008, the proportion of the world's population living in cities exceeded that of rural areas for the first time (United Nations 2009). Around the world cities continue to grow: in the next 40 years the world's urban population is forecast to double, while the population of rural areas is expected to plateau. In New Zealand over 85% of the population currently resides in urban areas – or in rural areas with 'moderate-to-high urban influence' – a proportion that looks set to increase further in the future.

A strong relationship is emerging between population growth and urban size, which has important implications for how New Zealanders think about their cities. The first implication is that existing urban areas are attracting young people and migrants, who may have needs that vary from the general population. The second implication is that 'scale matters'; the bigger a city is now, the more likely it is to grow in the future. For this reason cities and towns that are important today are likely to remain important in the future, hence a relatively long-term view of urban development should be encouraged.

As the potential scope for a project like this is very broad, we narrowed our focus to address the following two key research questions:

- How urban form impacts on transport and economic outcomes.
- How regional and local council policies can contribute to a more efficient and durable urban form.

Over time the emphasis of this research shifted in response to the evolving interests of the NZTA and changing circumstances, such as the reorganisation of local government in Auckland. The present report reflects the objectives and research methods that were agreed with the NZTA as the research developed.

Literature review

The results of our literature review can be summarised as follows:

- A wide variety of urban form attributes may impact on transport outcomes. Those which emerged most consistently from the literature included:
  - *local accessibility*, ie density and mix of immediate land uses
  - *jobs-housing balance*, ie the ratio of jobs to residents within an area
  - *regional centrality*, ie proximity to regional population/employment opportunities
  - *street network*, ie the structure, block-size, and amenity associated with the street network
  - *land-use engagement*, ie the degree to which adjacent land uses engage with each other.
- While the impacts of individual urban form attributes on transport outcomes are relatively modest, their cumulative impacts may be quite significant. By extension, urban form can have large impacts on the use of public transport and walking/cycling.

- Evidence suggests that urban transport corridors that balance mobility and amenity deliver more optimal economic outcomes. Residential and commercial land use activities seem willing to pay more (by way of rents) to locate close to transport corridors that deliver both amenity and mobility.
- The supply of road infrastructure is positively related to the demand for vehicle travel; expansions in road capacity tend to be largely offset by higher demand. In the long run this suggests the primary impacts of transport projects are on urban form, rather than on mobility outcomes.
- Agglomeration economies suggest that the scale and density of urban areas impact on their economic productivity. Some types of agglomeration economies, such as knowledge spillovers, attenuate rapidly with distance, whereas others extend over a wide area, such as labour market effects. There is some evidence to suggest that agglomeration economies are strengthening over time.
- Insofar as changes to the urban form reduce the demand for vehicle travel and/or increase demand for alternative modes, we can expect positive social and environmental outcomes, such as lower vehicle accident rates, and improved physical activity, population health and energy efficiency.
- When quantifying the impacts of urban form on social and environmental outcomes, it is important to account for differences in underlying population preferences, ie self-selection. Longitudinal micro-data is useful in this respect, because it allows researchers to track the same individuals over time and thereby control (at least partially) for unobserved population characteristics, eg the types of people who like to live in dense urban environments are also those that prefer to walk and cycle.

Impact of urban form in New Zealand

We investigated the impact of urban form on transport and economic outcomes in New Zealand using census and employment data, and considered how two urban form variables, namely residential density and regional centrality, impacted on vehicle ownership and drive mode share. A hypothetical compact urban development scenario was used to illustrate the impacts of urban form on transport outcomes in Auckland.

Accommodating an additional 250,000 residents and 125,000 employees within Auckland's 50 densest census area units would be expected to cause a 1.4% and 0.75% reduction in vehicle ownership and drive mode share respectively over a period of 10 to 15 years, holding other factors constant. While these effects are relatively modest, their impact on travel demands at the margin is not insignificant. For example, if only half of the people who would have otherwise driven to work chose instead to use public transport, then we would expect to see growth of approximately 0.5% per annum in the use of public transport for journey-to-work trips, holding other factors constant.

In our analysis of the impact of urban form on economic outcomes, we first modelled land values in Auckland, before analysing the impact of urban form, specifically the location of employment, on these land values. From this we were able to estimate the economic impacts of a centralised versus a dispersed employment scenario. We found that the centralised employment pattern was associated with additional economic benefits of approximately $30,000 per employee, compared with the more dispersed employment scenario, holding other factors constant. Thus, we have strong evidence to suggest that the shape of urban areas matters insofar as it impacts on agglomeration economies in Auckland.

Improving New Zealand's urban form

We drew on the results of the literature review, our analysis, and our own professional experience to identify opportunities to improve New Zealand's urban form. This identified the following priorities:

- **Street networks.** These provide the 'bones' of an efficient and durable urban form. Important attributes of the street network include structure, street integration and intersection design. Councils should also consider how to make best use of street networks in areas of medium-to-high density to ensure they provide an appropriate balance between amenity and mobility.
- **Public transport.** New Zealand's larger cities and towns would benefit from a step-change in the way urban form is conceived and delivered with respect to the needs of public transport. Key opportunities to improve the effectiveness of public transport (and hence its ability to positively influence urban form) arise from locating key destinations 'on the way', and acknowledging that simple, frequent lines are key to unlocking the benefits of connected public transport networks.
- **Land-use policies.** We considered the extent to which land-use policies may act as impediments to efficient and durable urban forms, namely exclusive zoning, building height limits and minimum parking requirements. We then considered a range of policy responses through which regional and local councils could incentivise a more desirable urban form. To finish, we looked at issues stemming from efforts to manage urban expansion.

Conclusions and further research

We conclude that urban form matters insofar as transport and economic outcomes are concerned. A compact and centralised urban form is associated with modest but not insignificant reductions in rates of vehicle ownership and use. Perhaps more importantly, a compact urban form delivers considerable economic benefits. Regional and local councils in New Zealand have a number of opportunities to improve their urban form through changes to policies on street networks, public transport and land use.

Several opportunities for future research emerged from this study, namely:

- How urban form impacts on New Zealand's ability to retain and/or attract mobile people and businesses. This might consider whether migrants' origins impact on their behaviour in New Zealand, and in turn whether this makes particular urban forms more likely and/or achievable.
- A need for improved data, such as:
  - analysis of a wider suite of urban form variables, such as the supply of public transport infrastructure and services, so as to more fully characterise differences in urban form
  - investigation of alternative transport data sets, especially those that provide a more holistic measure of travel demands than journey-to-work mode share
  - research into the impacts of urban form on transport and economic outcomes at finer spatial resolutions, such as meshblocks
  - developing longitudinal micro-data sets that can be used to analyse the impacts of urban form at the level of individual people, businesses and households
  - including more recent data, such as the 2013 census results, when available.
- Detailed case studies of situations where dramatic changes may shed more light on the relationship between urban form, transport and economic outcomes, eg Britomart in Auckland.
- Investigation of how wider technological and demographic trends might impact on transport outcomes, such as developments in telecommunications and an ageing population.
- The potential for urban form to impact on the efficiency with which public sector services can be provided, eg costs of delivering health, education and emergency services.

Abstract

Urban form describes the physical shape and settlement/land use patterns of cities and towns. This research addressed two key questions: 1) How urban form impacts on transport and economic outcomes and 2) How regional and local council planning policies can contribute to a more efficient and durable urban form. We found that urban form has modest impacts on transport outcomes, through reductions in vehicle ownership and drive mode share. On the other hand, urban form was found to have relatively large impacts on economic outcomes, primarily by virtue of its impacts on agglomeration economies. Several promising areas of further research have been identified that would seek to strengthen and deepen our understanding of the linkages between urban form, transport, and economic outcomes.

1 Introduction

1.1 Background

The New Zealand Transport Agency (NZTA) commissioned this research to understand the impacts of urban form on transport and economic outcomes, where the term ‘urban form’ describes the physical shape, settlement and land-use patterns of cities and towns. Interest in urban form has grown of late; for example the National Infrastructure Plan (NIP) notes that:

> *Major infrastructure projects, especially transport projects, can have a significant impact on the location and form of economic activity in our cities: they tend to shape urban development, guiding or influencing households and firms to make particular locational choices. In this way, the decisions made about where, when and what infrastructure is constructed, whether it is significant transport investment … can have a significant influence on the future anatomy of a city, locking in patterns of demand for generations. The anatomy of a city can then be a significant influence on the city’s resilience – hindering or helping its adaption to changing environmental, demographic and economic conditions* (National Infrastructure Unit 2010, p22).

There are two key elements to this statement. First it suggests that transport impacts on where households and firms choose to locate, which can in turn influence the efficiency of other investments. Second, the NIP observes how locational choices are ‘locked in’, ie urban form is relatively durable. The *efficiency* and *durability* of urban form are two recurring themes in this report.

The NZTA (2011) *Statement of intent 2011–2014* (SOI) establishes that the purpose of the organisation is ‘creating transport solutions for a thriving New Zealand’. The SOI observes that the Local Government (Auckland Council) Amendment Act 2010 (LGACAA) requires Auckland Council to prepare a spatial plan, which must ‘contribute to Auckland’s … wellbeing through a comprehensive and effective long-term (20 to 30-year) strategy for Auckland’s growth and development’. NZTA’s SOI (p13) goes on to note:

> *Transport and land use are ‘city shapers’, integral to the long-term growth strategy for Auckland region. Accordingly, the planning, investment and implementation requirements of the Auckland Spatial Plan are of keen interest to the NZTA. By articulating a clear approach to the location, timing and sequencing of growth in Auckland, the spatial plan will facilitate more efficient and cost-effective delivery of infrastructure.*

The SOI acknowledges the existence of a bi-directional relationship between transport and land use and that having certainty around Auckland’s future urban form will allow the NZTA to plan, develop and manage the transport network in a way that better supports its strategic and operational objectives.

The need for this research project evolved largely in response to the LGACAA and the SOI. We note, however, that in the time since this research report was first initiated in 2009, the emphasis has changed in line with the evolving interests of the NZTA. We note also that topics of this nature are very broad and complex; as such we have focused the present report on the main research questions identified as being of interest to the NZTA.

More specifically, the following sections of this report will attempt to address two key research questions, namely: 1) How urban form impacts on transport and economic outcomes and 2) How can regional and local policies support a more efficient and durable urban form?

1.2 Trends in urban development

In 2008, the proportion of the world's population living in cities exceeded that of rural areas for the first time in human history (United Nations 2009). And cities continue to grow: in the next 40 years the world's urban population is forecast to double, while the population of rural areas is expected to remain at present levels. In New Zealand, over 85% of people already live in urban areas or in rural areas with 'moderate-to-high urban influence' and this proportion looks set to increase further.

While New Zealand is highly 'urbanised', our urban areas are relatively small and dispersed by international standards (Huang et al 2007). New Zealand's urban form is broadly similar to that found in Australia, and to a lesser extent Canada and the United States, where low density, segregated land use development and extensive, hierarchical road networks prevail. General characteristics of New Zealand's existing urban form include:

- *Transport costs* – economic and technological development has meant that the direct cost of transport (ie borne by the traveller) have fallen steadily for most of the past century.[1]
- *Migration* – many migrants to New Zealand were (and possibly still are) looking to escape overcrowded, unsanitary and polluted urban conditions in their countries or origin (Belich 2001). This has led to a focus on lower density residential development patterns.
- *High risks* – many cities and towns were initially established in proximity to natural resources, which – once depleted – caused the associated urban area to decline (Belich 2001). Risks inherent to development driven by extractive industries have encouraged short-term urban planning decisions.
- *Public policies* – public priorities have had a major impact on urban form. Expansion of the North Island's rail network, for example, catalysed settlement of the rural hinterland. Similarly, in the post-WWII period investment in the state highway network enabled more rapid suburbanisation.
- *Demographic preferences* – the post-WWII 'baby boom' saw a surge in demand for larger, detached family homes. From the 1970s onwards, higher-income households used the new-found mobility afforded by private vehicles and extensive highway networks to escape older, inner-city suburbs.[2]
- *Environmental conditions* – New Zealand's mild climate and generally abundant energy supplies has neutralised some of the energy efficiency gains normally associated with more compact urban forms.
- *Natural amenities* – Cities and towns are almost always located in strategically important locations, such as harbours and rivers, which offer particular natural advantages, such as ports.

New Zealand's urban form has therefore been influenced by various physical factors, such as environmental conditions and natural amenities, as well as wider socio-economic trends, such as demographic preferences and public policies.

But are historical factors still relevant today and will they remain so in the future? Qualitatively a number of 'what ifs' may come into play: We might reasonably suggest that migrant profiles have probably shifted somewhat as the New Zealand economy has matured, while technological improvements have enabled much cleaner and more sanitary urban areas – reducing the relative attractiveness of rural areas and

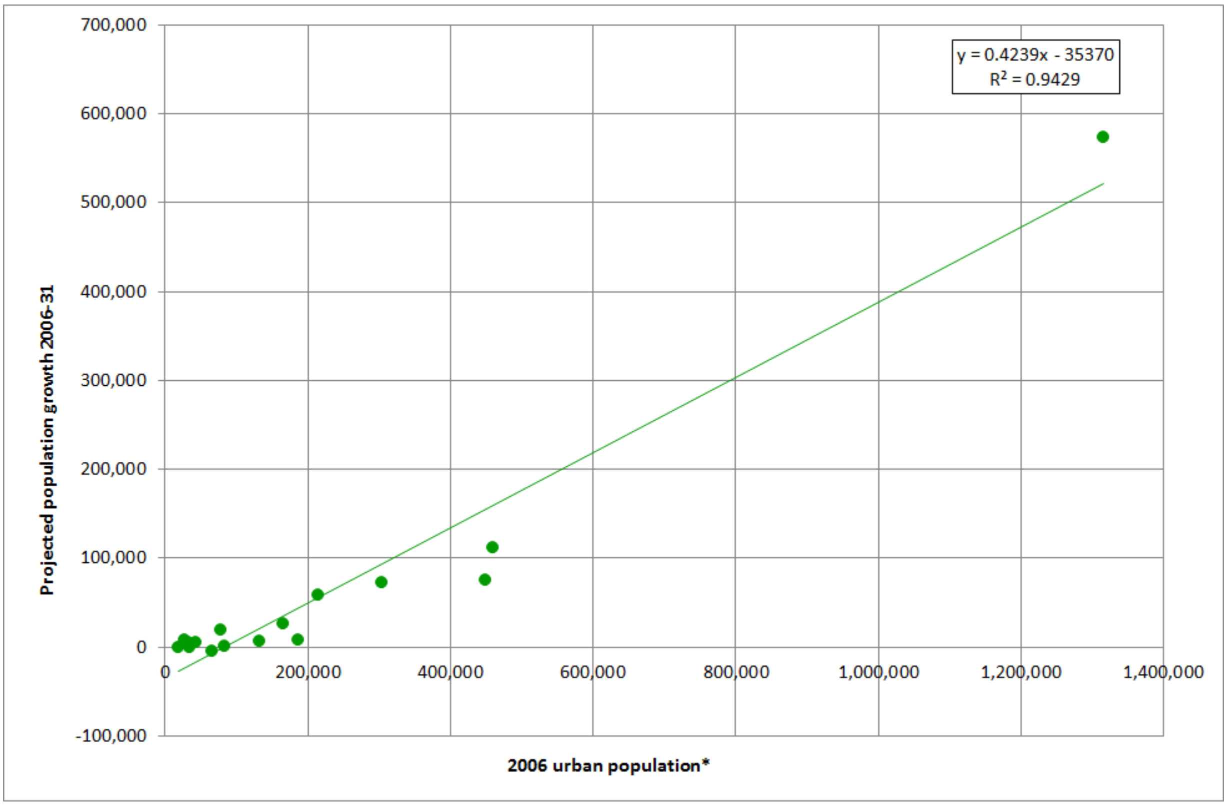
[1] The location of breweries, for example, was previously constrained by proximity to water sources and/or customers. The development of cost-effective freight and water infrastructure has meant this proximity is no longer so crucial.

[2] Some research suggests the ubiquitous availability of private vehicles has enabled low-income households to move towards the urban periphery where property values are lower, so that high-income households are now increasingly re-locating in inner-city areas. These areas subsequently are re-gentrifying, which returns us more to the normal historical urban equilibrium, where high-income households are located in inner-city areas.

suburbs. Maturing of New Zealand's economy away from short-term extractive industries is likely to have reduced the locational risks associated with urban development. Growing awareness of the health benefits of warm, dry homes may give added support to more compact development patterns. An ageing population and changing preferences among younger generations may also cause a shift to more compact, less vehicle-dependent urban forms. This natural demographic shift may get extra legs from regional and local council efforts to improve the attractiveness of urban living, through for example safer and more amenable pedestrian facilities and strategies to reduce the adverse impact of vehicular traffic.

On balance, we suspect these trends will provide additional impetus to New Zealand's on-going urbanisation. But will this growth occur in existing urban areas? Or will new urban areas spring up to meet demand? Here we can draw on more formal quantitative data; the figure below illustrates forecast population growth in the period 2006–31 versus the urban population in 2006 for each regional council (Statistics NZ 2008a). The strength of the relationship between the size of the urban population in 2006 and population growth in the period 2006–31 is clear: the 2006 urban population explains 95% of projected population growth for the next 25 years (NB: We note that Auckland is an extreme value but not necessarily an outlier, ie it fits the general trend quite well).

Figure 1.1 Projected population growth 2006–31 versus 2006 urban population



While this trend is derived from forecast, rather than actual, population data we found a similar trend when using actual census data from 1996–2006. This in turn has several implications for how New Zealanders approach urban development. The first implication is that our existing urban areas look likely to be the driver of New Zealand's growth, primarily because they seem to offer the types of amenities that are able to attract new migrants and young people. The second implication is that urban 'scale matters'; the bigger a city is now, the more likely it is to grow in the future. From this we conclude New Zealand's urban areas seem set to endure; the cities and towns that are important now are likely to remain important in the future; hence a long-term view of urban development is needed.

1.3 A simple transport and urban form framework

A simple transport and urban form framework with four key development stages, which tend to be chronological in their timing, would be:

Stage 1 – Transport investment, eg Auckland Harbour Bridge, road or rail link

Stage 2 – Accessibility and mobility impacts, eg reduced congestion and travel-times

Stage 3 – Localised development impacts, eg increased sub-division, intensification

Stage 4 – Wider economic implications, eg agglomeration economies.

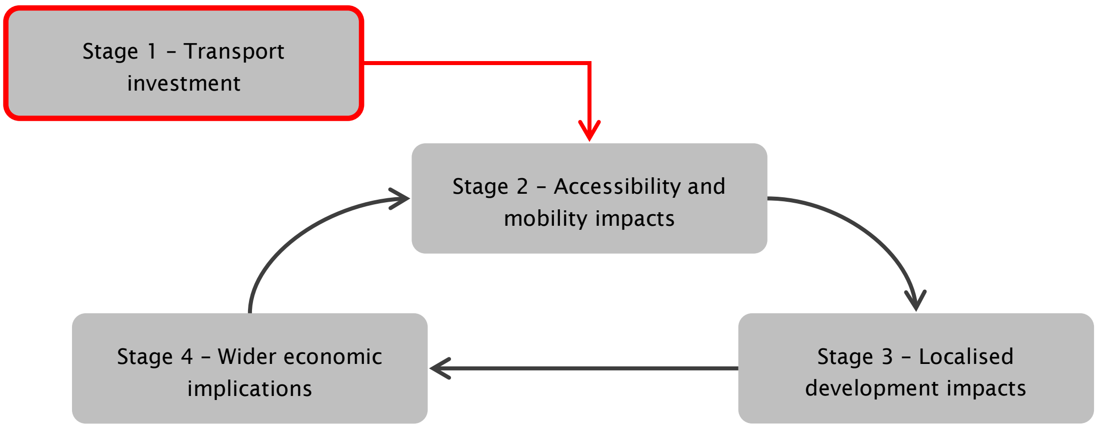
The relative benefits of transport projects have typically been measured in terms of the costs of stage 1 versus the benefits of stage 2; that is the cost of the transport investment in relation to its accessibility and mobility impacts.

In more recent times, regional and local councils have attempted to understand the potential additional economic benefits and costs associated with stage 3 and, to a lesser extent, stage 4. In stage 3, the development impacts of a particular transport investment may result in additional costs and benefits, such as wastewater infrastructure impacts, which ultimately are covered by general rate-payers and/or development levies. Similarly, the NZTA, through the *Economic evaluation manual* (EEM) (NZTA 2010) has recognised and begun to estimate the impacts of transport investment on wider economic outcomes that occur in stage 4, such as agglomeration economies (urban economies of scale).

The different stages of this framework require a similarly diverse range of performance indicators. For example, in stage 1 the most relevant performance indicator is the direct costs of the transport investment. In stage 2, we are interested in indicators of transport performance, such as travel times. In stage 3, we are interested in development indicators and impacts on rates. Finally, in stage 4 we are interested in indicators of economic efficiency, such as land values, wages and productivity.

We emphasise that the stages 2 to 4 are likely to feed back onto each other, as illustrated below, until some form of wider economic equilibrium is reached.

Figure 2: A simple transport and urban form framework



The rest of this report is structured as follows: chapter 2 reviews existing literature; chapter 3 investigates the impact of urban form on economic and transport outcomes in New Zealand; chapter 4 identifies how regional and local councils can improve their urban form; and chapter 5 concludes before making recommendations for further research.

2 Reviewing the urban form literature

In this section we review a number of studies that have considered the impacts of urban form on transport and economic outcomes. Before we do, the following caveats are warranted:

- First, urban form impacts on transport and economic outcomes and vice versa, ie causality runs in both directions. For example, compact urban form supports higher public transport use, while higher public transport use also tends to support more compact urban form. This ‘simultaneous causality’ makes it difficult to identify what came first: compact urban form or higher public transport use? Good studies recognise and subsequently try to disentangle cause and effect.
- Second, we have tended to limit our review to more recent studies (ie mainly post-2000) and those published in peer-reviewed journals. We have also focused on empirical studies that attempt to quantify the impact of urban form on transport and economic outcomes, rather than qualitative or theoretical papers. We sometimes use empirical results as a prompt for more theoretical discussion.
- Third, the wider impacts of urban form on social and environmental outcomes are discussed but to a lesser extent. This is because the NZTA’s primary focus is on transport and economic outcomes, even if they remain cognisant of social/environmental impacts.
- Finally, we note that the purpose of this review is to shed light on urban form attributes that may be of particular relevance for our own research; it is not intended to be exhaustive.

2.1 Transport outcomes

In the following sub-sections we review the impacts of urban form on transport and vice versa. We are primarily interested in how urban form impacts on the demand for vehicle travel, as measured by indicators such as vehicle mode share, distances travelled and vehicle ownership. We focus on vehicle travel because it has more general implications for regional and local council policies across New Zealand.

2.1.1 Impacts of urban form on transport

On balance, our review of the literature found evidence to suggest that urban form impacts on a range of transport outcomes, albeit to varying degrees. Key findings in the literature include:

1. Dieleman et al (2002) used 1996 data from the Netherlands to investigate how modal choice and kilometres travelled (for work, shopping and leisure purposes) varied in response to personal characteristics and urban form variables, most notably the size of the urban environment. They found that the three largest urban areas supported consistently lower levels of vehicle use and shorter travel distances, although potential causes of these effects were not identified. One potentially confounding factor was the degree to which individuals who were more predisposed to lower rates of vehicle travel might be over-represented in larger urban areas, ie the self-selection bias.
2. Krizek (2003) used travel data from 2000 households to investigate the effects of neighbourhood and regional accessibility on mode choice and vehicle travel in the Puget Sound Region, Washington State from 1989 to 1996. Because the data recorded when and where households relocated, it allowed the author to control for fixed household effects and individual preferences (ie self-

selection bias).[3] Krizek measured 'neighbourhood accessibility' as a function of three variables, namely population density, land use mix and street patterns. His measure of 'regional accessibility' used a gravity model based on weighted proximity to regional employment. Results showed that locations with higher neighbourhood and regional accessibility generated less vehicle travel overall (in terms of distance travelled), but this reduction in trip distance was partially offset by an increase in trip frequency.

3 Bento et al (2005) considered the effects of urban form on mode choice and vehicle travel, using data from 1990 for 114 US cities. The authors found that population centrality, jobs-housing balance (as measured by the ratio of jobs to residents within a particular suburb), city shape and road density had statistically significant effects on the distance travelled by vehicle, and smaller effects on vehicle mode share. While the effects of individual variables were relatively modest, they had reasonably large cumulative impacts. For example, shifting the same household from Atlanta to Boston would be expected to reduce total household vehicle kilometres travelled by approximately 25%, on average. We suggest that such a comparison, however, would seem to implicitly assume that comparable households in both cities have the same cultural norms – which may or may not be true.

4 Giuliano and Dargay (2006) compared the effects of urban form, namely population density and urban size, on vehicle use and ownership in Great Britain and the US. An increase in population density was found to decrease daily vehicle travel, with a stronger effect in the US than in Great Britain, presumably because the latter started from lower densities. Higher density and proximity to public transport was found to have significant effects on vehicle ownership, although self-selection effects were not explored. Their results suggest that the impacts of urban form are likely to be a combination of direct and indirect effects. That is, certain urban forms directly reduce the need for vehicle travel, which in turn contributes to lower vehicle ownership.

5 Vance and Hedel (2007) analysed German data on 4328 individual travellers in 1899 different postcodes for the period 1996–2003. They considered how four urban form variables, namely accessibility to public transport, street density, commercial density and commercial diversity, impacted on vehicle mode share and vehicle travel. While all four urban form measures had statistically significant negative effects on vehicle travel, the most economically significant were accessibility to public transport and commercial density; a doubling in these variables reduced the likelihood that people travelled by car by 3% and 5% respectively.

6 Horner (2007) conducted an exploratory analysis of urban form and commuting changes in Florida between 1990 and 2000. He formulated measures of urban form, namely the jobs-housing balance (regionally and locally) and average commute distance (out from and in to each zone). A strong correlation (0.80) was found between the average commute distance from a zone and the minimum possible average commute distance, which suggested that the location of jobs with respect to housing impacted on the quantity of commuting that occurs, as one might reasonably expect.

7 McMillan (2007) focused specifically on the impact of urban form on children's travel to school. Perceptions of safety, traffic speeds, land use engagement with the street, and mix of land uses were found to have statistically significant effects on children's travel mode. Living within one mile of a

[3] 'Self-selection' describes how households that value certain amenities or attributes tend to locate where they are available. For example, density may attract households that are less attached to using their vehicles, which in turn creates a correlation between density and reduced vehicle travel. However the relationship between density and vehicle travel is not causal, but instead related to the personal preferences of households. Because longitudinal micro-data follows the same households over time the risks of self-selection are reduced (although probably not eliminated).

school, for example, was associated with a threefold increase in the likelihood that a child would walk or cycle to school. Neighbourhood safety and traffic speeds were also important.

8 Susilo and Maat (2007) considered the influence of urban form on trends in commuting journeys in the Netherlands, using data from 1985–2005. While they found evidence to suggest that commuting distances decreased with increased urbanisation, this was somewhat offset by an increase in travel times, most probably due to increased congestion. As with other studies, a more even jobs-housing balance was found to reduce cross-commuting between cities, while proximity to train stations increased public transport patronage. Susilo and Maat did not consider potential impacts of urban form on vehicle ownership, which previous studies, such as Giuliano and Dargay (2006), found were important.

9 Brownstone and Golob (2009) considered the relationship between household density and vehicle use in California using data from the 2001 National Household Travel Survey. They found that a standard deviation increase in density (from the mean) was associated with a 4.8% reduction in vehicle travel (this captured the net effects of both lower vehicle ownership and shorter trip distances). Based on their results the authors concluded that urban form had modest impacts on transport outcomes. We note, however, that this analysis considered only one measure of urban form, namely residential population density; the earlier study by Bento et al (2005) suggested that a wider range of urban form variables was able to exert larger cumulative impacts.

In summary, urban form attributes, such as jobs-housing structure; street network connectivity; and land use density/diversity; appear to reduce the demand for vehicle travel via a combination of direct and indirect channels. First, urban form seems to directly suppress the demand for vehicle travel by reducing travel distances and increasing the attractiveness of non-car transport modes. In turn, this tends to reduce vehicle ownership, which may in turn cause further reductions in vehicle travel. While proximity to public transport may be relevant, we are wary of self-selection bias – people who prefer not to travel by car will tend to locate closer to public transport. Thus the cause of the increase in public transport may be related to individual preferences, not urban form. While the impacts of urban form are modest they are not insignificant, with reductions in vehicle travel of between 3% and 25% found in various studies.

2.1.2 Impacts of transport on urban form

The previous sub-section reviewed studies that investigated the impacts of urban form on transport outcomes, primarily in terms of the impact on vehicle travel and ownership. But how about the reverse direction, that is, how does transport impact on urban form outcomes?

Noland (2001) investigated the relationship between highway capacity and the demand for vehicle travel. He identified several ways in which increased road supply might 'induce' additional demand for vehicle travel, namely mode shift (ie changing from bus to car), route changes (ie travelling from A to B via another route), trip redistribution (ie travelling from A to C instead of A to B), generation of new trips (ie more frequent trips from A to B), and land use changes (ie new origins and/or destinations).

Noland then analysed how the supply of road capacity (as measured by lane miles) affected the demand for vehicle travel (as measured by vehicle miles travelled) in 48 US states in the period 1984–96. Analysis found short and long-run elasticities of +0.2-0.5 and +0.7-1.2 respectively, which suggested that extra highway capacity was eventually almost completely 'used up' by induced demand. Noland's analysis also suggests that long-term effects are as large as the short-term impacts – that is, induced demand arises as much from long-term changes in urban form as it does from short-term changes in behaviour.

Noland's results, however, have been criticised on the grounds that they fail to control for a potentially endogenous relationship between the provision of road capacity and the vehicle travel. This relationship arises because we would expect effective transport planning to anticipate increased demand for vehicle travel and supply the requisite infrastructure accordingly. In such cases the supply of infrastructure will deliberately lead, rather than cause, the subsequent growth in vehicle travel.

In order to investigate these effects, Cervero (2003) implemented a more sophisticated 'path analysis', which controlled for long-term feedback between the demand for highways and supply (ie the endogenous 'planning' effect). His framework considered short- and long-term paths between road supply and demand. Cervero then applied a system of regression equations that attempted to disentangle these various effects. His results confirmed that while there was a planning effect, an increase in the road supply still induced additional demand, with most of the increase associated with changes in behaviour, such as route switching and development activity. Overall, Cervero's results suggest that induced demand effects do 'eat up' approximately 81% of the travel-time benefits associated with an increase in supply. Hence, Cervero's results tend to confirm Noland's previous findings.

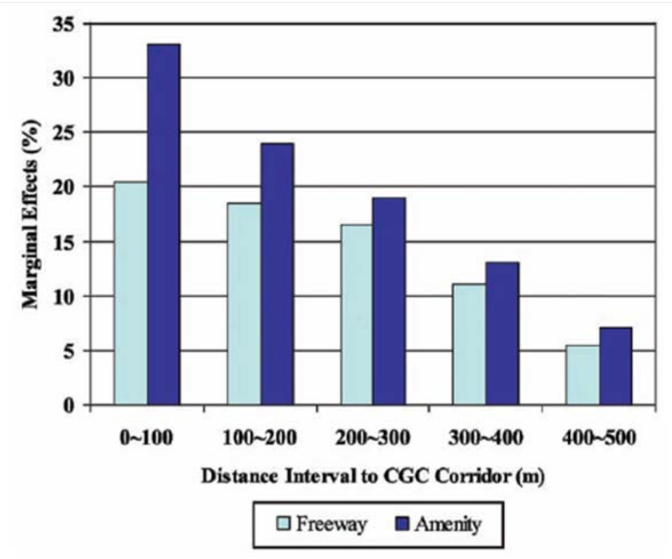
Venables (2007) developed a microeconomic model of the relationship between transport and employment locations decisions. His model considers how a transport improvement can lower the generalised costs of commuting from peripheral residential areas to a city centre and thereby increase the supply of labour to the latter. A subsequent increase in employment associated with the increased labour supply is predicted to generate additional agglomeration economies, which are captured by way of higher wages and tax. Equilibrium is regained when marginal commuting costs are equal to the marginal benefit (in the form of higher post-tax wages) associated with travelling to work in the city centre.

The relationship between the supply of and demand for transport has recently led to claims that the travel-time benefits of road transport investment are a largely transient phenomenon, rather than an enduring benefit (Metz 2008; Noland 2008). The implication of this line of reasoning is that the long-term economic impacts of transport investment are not travel time savings, but how they affect people's travel and locational choices. While we note that the jury is still out on these debates, empirical and theoretical research by the likes of Noland, Cervero and Venables have nonetheless raised serious questions over standard economic appraisal techniques used to evaluate transport projects.

A striking example of how transport impacts on urban form is found in the city of Seoul, which recently deconstructed a major elevated freeway and reconfigured surrounding arterial roads so as to create space for an inner-city park, as illustrated in figure 2.1 (Cervero 2009). Replacing the freeway with the park was effectively a decision to sacrifice some degree of vehicle mobility in order to provide improved local amenity. Kang and Cervero (2008) found that proximity to both the freeway and the subsequent park had positive effects on surrounding land values; demonstrating that both mobility and amenity are desirable attributes. Nonetheless, the positive effects of amenity appear to be approximately 25% to 50% higher than those associated with the freeway, ie the park is more beneficial for surrounding land uses than the previous freeway. This land value uplift can be expected to catalyse changes in urban form, by encouraging more intensive development adjacent to the corridor.

Figure 2.1 Cheong Gye Cheong Freeway and Park – Seoul, Korea

Figure 2.2 Comparing the land value uplift associated with the CGC Freeway and Park – Seoul, Korea



In New Zealand, there is some research that considers the impact of transport on urban form in terms of their impacts on land values. Grimes and Young (2010) and Grimes and Liang (2008), for example, analysed the impacts of the western rail line double-tracking and the northern motorway extension on land values in Auckland. Results suggest affected areas experienced large land value uplift (NB: In the case of the western rail line these effects were anticipatory, rather than ex-post).

2.2 Economic outcomes

Section 2.1 summarised studies that considered the impacts of urban form on transport outcomes and vice versa. In this section we focus on studies that find a link between urban form and economic outcomes. We define economic outcomes in a 'narrow' sense to mean widely recognised (and commonly available) indicators of economic performance, such as productivity, wages and land values. Again we focus on more recent studies that are found in peer-reviewed journals. We also exclude studies that consider macro-economic outcomes at the national level, primarily because this research is interested in the impacts of urban form at the regional and/or local levels.

The richest vein of literature showing links between urban form and economic outcomes is concerned with agglomeration economies, which describe the external economies of scale that arise from spatial concentrations of economic activity (Glaeser et al 1992; Ciccone and Hall 1996). The term 'agglomeration economies' is actually a general rubric used to explain several nuanced micro-economic channels through which urban economies of scale might arise, such as labour market pooling and knowledge spillovers. These individual agglomeration channels are discussed in more detail in appendix A.[4]

Cervero (2001), for example, investigated the impacts of urban form and transport variables on economic productivity (GNP/worker) using a cross-sectional model based on metropolitan wide data for 47 US cities in 1990. His model predicted economic productivity for each city in response to a number of urban form and transport variables, namely: freeway usage, centralised employment structure, employment density, port tonnage, and employment in finance, insurance and real estate industries. Results suggested that productivity was positively related to employment density but not the size of the metropolitan area, which was generally consistent with agglomeration economies that operate via density, rather than urban size (confirming earlier findings by Ciccone and Hall 1996).

Cervero (2001) refined his analysis by considering impacts of urban form on economic productivity within just the San Francisco metropolitan area. Results showed that productivity was again positively related to employment density. Positive impacts were also found for what Cervero called 'labour market accessibility', which simply measured the number of workers located within 60 minutes travel time. This suggests that jobs located in areas with greater access to other jobs are more productive.

Some studies have suggested that the emergence of the 'knowledge economy' has strengthened agglomeration economies and enhanced the comparative advantages of large city centres over outlying areas (Horner and O'Kelly 2007; Whitehead et al 2006). Cervero (2009) argued that because knowledge and service-based industries have become the primary drivers of economic growth, the knowledge economy has become increasingly important to cities that are conducive to these types of industries. The implication is that not only does urban form impact on economic outcomes, but that this impact may also be strengthening over time in response to changes in industrial composition.

The degree to which agglomeration economies attenuate, or decay, over distance is also relevant because it captures the primary channel through which transport investment can help realise greater agglomeration benefits. Arzaghi and Henderson (2008), for example, found strong evidence that agglomeration economies among advertising companies in New York were local and limited to the maximum distance that people were prepared to walk. Other studies have suggested that agglomeration economies decay to negligible levels after approximately 5 to 25 miles, or approximately 30 to 60 minutes travel time. Variation in the degree to which agglomeration economies attenuate with distance is likely to reflect the various channels through which they operate: labour market effects of agglomeration are likely to be felt over the area for which commuting is a viable option (say one hour's travel time), whereas knowledge spillovers are likely to be more limited to the areas in which informal casual meetings are possible.

Maré and Graham (2009) presented the most detailed analysis of agglomeration economies in New Zealand. They found that a doubling in density would increase economic productivity by 6% to 7%, holding other factors constant. Such elasticities are relatively high by international standards, where elasticities of 4% to 5%

[4] If there are economic benefits from concentrations of economic activity, this raises the question of why all economic activity is not concentrated in one place. The primary countervailing factor, it seems, is congestion (as modelled by Venables) and reduction in local amenity associated with high densities. Thus, we can expect that urban areas that experience net positive agglomeration economies will continue to grow in size and density until the point when their further growth is stymied by too much congestion and/or a lack of amenity.

are more common. This may reflect that New Zealand's urban areas are starting from a relatively low density and hence have more to gain from increased scale. Maré and Graham's elasticities have subsequently been incorporated into the EEM to evaluate the agglomeration impacts of transport investment.

Other studies have considered the impact of more local urban form characteristics on economic outcomes. Song and Knaap (2003), for example, considered 50,000 property transactions in Washington County, US covering 10 years from 1990–2000. They included a wide range of variables, many of which related to specific urban form outcomes, for example network connectivity, length of street network, block size and nature of road connections. Variables that control for land use density, land use diversity and pedestrian walkability were also included. Their results suggest residents are willing to pay 15.5% more for properties with particular urban form qualities, where most of the premium is attributable to the street network.

In a similar but separate study, Enström and Netzell (2008) modelled the effects of street network connectivity on commercial office rents in Stockholm, Sweden. They found that a 10% increase in the connectivity of a street was associated with a 5% to 10% increase in commercial office rents. Together these studies suggest the impacts of urban form on economic outcomes manifest not only at larger regional scales, but also at relatively local levels.

A few studies suggest that agglomeration economies can also benefit consumers, through for example the availability of more specialised goods. Tabuchi and Yoshida (2000) used a sophisticated framework to disentangle agglomeration economies in consumption and production, finding positive evidence of both. Their primary finding was that people who lived in larger urban areas actually had a lower real income, once the cost of living and lack of environmental amenities were considered, which in turn suggested that larger urban areas should offer some compensating consumer benefits. This is an important finding that requires more attention: agglomeration economies seem to benefit not just firms, but also consumers.

Hence we find that urban form does impact on economic outcomes, both regionally and locally. It seems that both urban density and – to a lesser extent – size can provide positive external benefits that should be of interest to regional and local policy makers in New Zealand.

2.3 Social and environmental impacts of urban form

In this section, we expand our discussion to consider the impacts of urban form on social and environmental outcomes.

While these impacts cannot often be directly linked to economic indicators, we would intuitively expect that urban form and transport combinations that result in social and environmental benefits would ultimately have some economic value, even if the precise channels are complex.

Studies suggest that urban form can impact on a range of social outcomes, such as health, safety, and personal security. In 2010 the Public Health Advisory Committee (PHAC 2010) issued a report called *Healthy places, healthy lives: Urban environments and wellbeing* that focused on the links between urban form and health. The report noted that urban environments can impact:

- **Road traffic injuries** – the number of accidents and fatalities is strongly related to kilometres travelled and speed, both of which are increased in urban areas where more driving occurs. Pedestrian and cyclist injuries and death rates are higher in urban areas. In 2009 road traffic injury costs in New Zealand were estimated to be $3.6 billion per annum (MoT 2009).
- **Physical inactivity and associated diseases** – including obesity, obesity related illnesses, hypertension, and heart and abdominal problems. These diseases have been found to be more

common in areas displaying characteristics of urban sprawl. Obesity and Type-2 diabetes alone cost the health system approximately $500 million per annum (Public Health Advisory Committee 2007).

- **Respiratory and cardiac conditions** – vehicle emission exposure affects drivers, passengers and pedestrians. Costs of respiratory and cardiac illness to the New Zealand health system are estimated at $415 million per annum (Fisher et al 2007). The respiratory health of young children appears particularly sensitive to traffic-related air pollutants (Morgenstern et al 2007).

PHAC (2010) goes on to highlight the strong international shift in focus to improving the links between urban planning and health outcomes, noting that the UK and Australia have both started to implement policy with this specific intent. Urban form factors commonly associated with increased physical activity include intersection density, land use mix, floor area ratios and the presence of supporting infrastructure, such as bicycle lanes and footpaths.

While most studies find evidence of links between urban form, transport and health outcomes, these links are not undisputed. Eid et al (2008), for example, used longitudinal data from the US to track the movements of individuals over time. This data allowed the authors to control for the fact that 'individuals who are more likely to be obese choose to live in more sprawling neighbourhoods'. Ultimately they 'find no evidence that urban sprawl causes obesity' and suggest that studies which find a positive relationship between urban sprawl and obesity may not adequately control for individual preferences. By extension, modifications to the built environment designed to improve health outcomes may be ineffective. We note, however, that Eid et al defined 'residential sprawl' as 'the share of undeveloped land in the square kilometre surrounding an average residential development in the individual's neighbourhood'. This indicator measures proximity to open space more so than urban sprawl. Eid et al also did not include variables for the wide variety of urban form characteristics that have been noted in other studies, such as street network connectivity. For these reasons we suggest the authors' conclusions are premature, even if they do demonstrate the importance of controlling for individual preferences.

Other studies have highlighted relationships between urban attributes and personal security. Painter and Farrington (2001) reported on two experimental studies looking at the effects of street lighting on crime in the UK. They found that areas where street lighting had been improved experienced reductions in crime of approximately 30% to 40%. Subsequent cost–benefit analysis suggested improved street lighting in these areas had a cost–benefit ratio of 2.4–10.0. In another study, Harrison et al (2007) found that levels of physical activity were very strongly related to perceptions of crime and safety. This suggests the impacts of urban form on social outcomes are complex and interdependent.

Turning now to the impacts of urban form on environmental outcomes, we note two key areas:

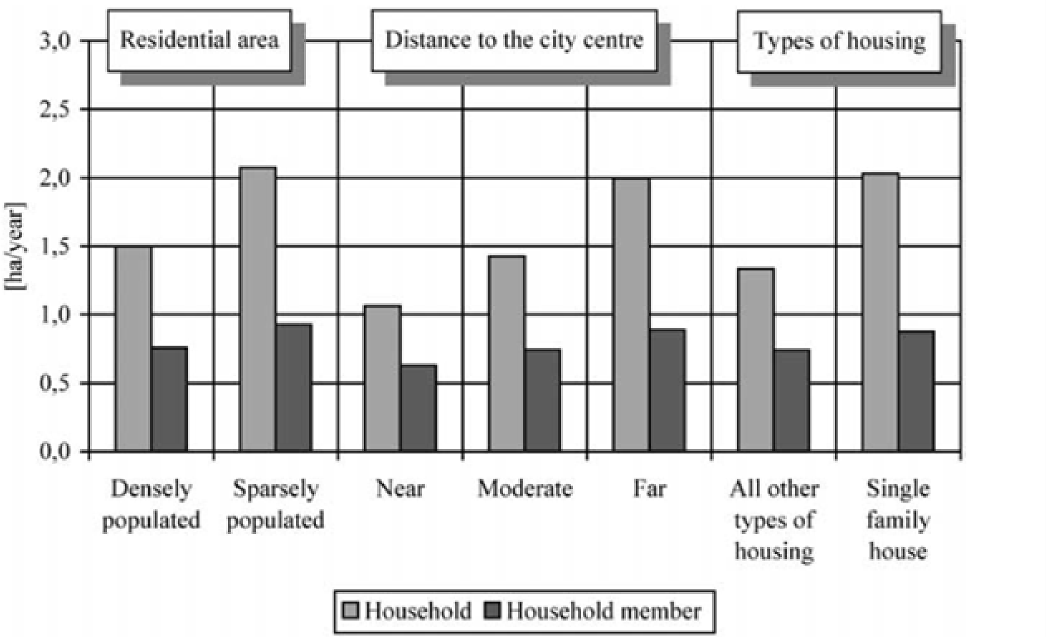
- **energy consumption** – associated with both travel and housing patterns
- **ecological degradation** – mainly household's footprint and exposure to contaminants.

Ewing and Rong (2008) developed a model linking household electricity consumption to characteristics of the occupants and urban form. They found the average household would consume 20% less electricity in a compact urban environment (defined as one standard deviation above the mean density index). Previous sections noted Brownstone and Golob's finding that a one standard deviation increase in residential density was associated with a 5.5% reduction in fuel consumption per household. This suggests urban form impacts not just on transport energy needs, but on wider household energy needs as well.

The impact of urban form on ecological degradation is a larger topic and a full review lies outside the scope of this study. Here we consider two areas, namely land requirements and harmful emissions. In terms of land requirements, the relationship is fairly straightforward clear – more compact urban forms occupy less land and thereby have a smaller ecological impact, all other factors being equal. In terms of environmental contamination, the impact of urban form occurs mainly via emissions to air, water or soil caused by degrading building materials and the combustion of fossil fuels.

Holden (2004) compared the 'ecological footprint' (a measure of the land area required to generate the resources needed to sustain one person) of different development patterns in Norway. Results were disaggregated based on residential density, distance to the city centre, and types of housing, as illustrated in figure 2.3 (where results are presented both per household and per capita). The author found that densely populated areas, locations close to the city centre, and attached housing types had a smaller ecological footprint than other urban typologies (even without controlling for higher incomes in denser urban areas). The difference was smaller when considered on a per capita basis, because these types of urban areas also tended to support households with fewer members.

Figure 2.3 Ecological footprint of different urban form typologies in Norway (Holden 2004)



2.4 Summarising the urban form literature

The results of our literature review can be summarised as follows:

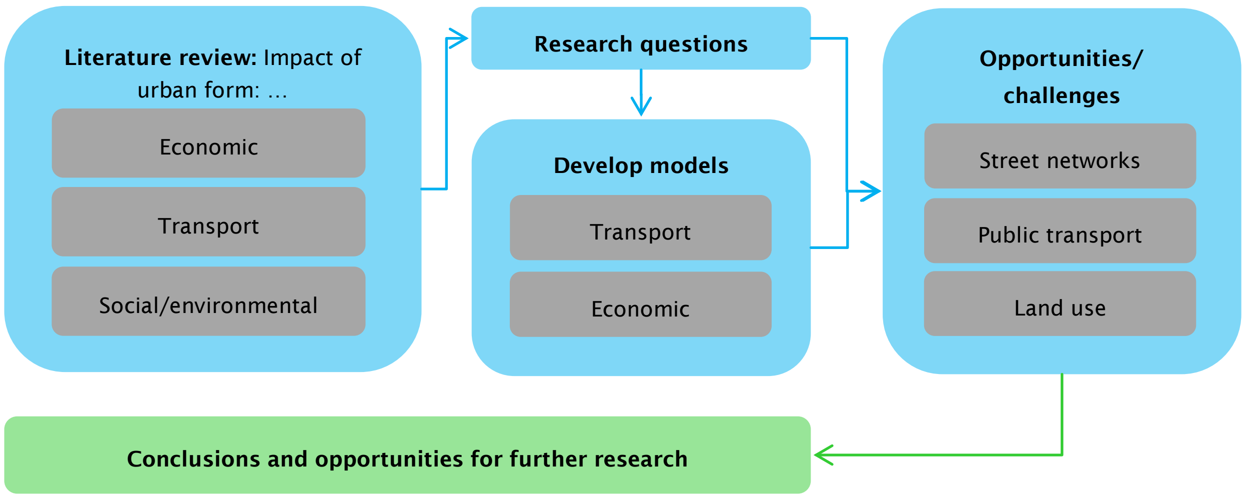
- A wide variety of urban form attributes may impact on transport outcomes. Those which emerge most consistently from the literature include:
  - local accessibility, ie density and mix of immediate land uses
  - jobs-housing balance, ie the ratio of jobs to residents within an area
  - regional centrality, ie proximity to regional population/employment opportunities
  - street network, ie the structure, block-size, and amenity associated with the street network
  - land use engagement, ie the degree to which adjacent land uses engage with each other.
- While the impacts of individual urban form attributes on transport outcomes are relatively modest, their cumulative impacts may be quite significant. By extension, urban form can have large impacts on the use of public transport and walking/cycling.

- Evidence suggests that urban transport corridors that balance mobility and amenity deliver more optimal economic outcomes. Residential and commercial land use activities seeming willing to pay more (by way of rents) to locate close to transport corridors that deliver both amenity and mobility.
- The supply of road infrastructure is positively related to the demand for vehicle travel; expansions in road capacity tend to be largely offset by higher demand. In the long run this suggests the primary impacts of transport projects are on urban form, rather than on mobility outcomes.
- Agglomeration economies suggest that the scale and density of urban areas impact on their economic productivity. Some types of agglomeration economies, such as knowledge spillovers, attenuate rapidly with distance, whereas others extend over a wide area, such as labour market effects. There is some evidence to suggest that agglomeration economies are strengthening over time.
- Insofar as changes to the urban form are able to reduce the demand for vehicle travel and/or increase demand for alternative modes, then it may be expected to have positive benefits for social and environmental outcomes, such as vehicle accident rates, physical activity, population health and energy efficiency. Improved street-lighting seems to be particularly effective at improving the safety and security of urban areas.
- When quantifying the impacts on urban form on social and environmental outcomes, it is important to account for differences in underlying population preferences, ie self-selection. Longitudinal micro-data is useful in this respect, because it allows researchers to track the same individuals over time and thereby control (at least partially) for unobserved population characteristics, eg the types of people who like to live in dense urban environments are also those that prefer to walk and cycle.

But what does all this mean for our research? First, we suggest that urban form does appear to impact on transport and economic outcomes. We have identified some key quantitative channels that should be explored in a New Zealand context; this is the topic of chapter 3. Second, it hints at the types of transport and land use policies that regional and local councils might pursue in order to improve the durability and efficiency of their urban form; this is the topic of chapter 4.

The implications of the literature review for our research methodology are summarised in figure 2.4.

Figure 2.4 Outline of our research methodology



3 Analysing urban form impacts in New Zealand

The previous section identified general relationships between urban form, transport and economic outcomes. In this section we use the results of our literature review to guide our research in a New Zealand context. We first model how urban form impacts on some wider transport outcomes in New Zealand, before modelling the impacts of urban form on economic outcomes in Auckland.

We note that many of the following sections are technically dense. While we have where possible consigned detailed technical information to the appendices, it is nonetheless important to present the core parts of our methodology 'upfront', if only to illustrate the relationships on which results are subsequently based. Without wanting to sound patronising, we note some sections are not for the faint-hearted; non-technically minded readers are referred to sections 3.1.2 and 3.2.2, where case studies are used to summarise key results in a more accessible way.

The relationships we identify are not materially different from those identified in the previous section; our contribution is to show that they exist in a New Zealand context.

3.1 Transport outcomes

We consider the impact of urban form on transport outcomes in two key areas, namely vehicle ownership and journey to work mode share. The following variables are incorporated into our models:

- *Residential density*, calculated from 2001 and 2006 census area unit (CAU) data.
- *Regional centrality*, calculated using the definition of effective density specified in Graham (2007). This defines effective density based on proximity and size of surrounding areas (measured by shortest path by road and size of workforce they support respectively).
- *Control variables* for household income and percentage of population with postgraduate degrees. These two variables attempt to capture differences in individual preferences that may be correlated with residential density and regional centrality and thereby introduce statistical bias into our results.

We expect the 'residential density' and 'regional centrality' variables to be positively correlated because the former will tend to decline as distance to the city centre increases, which will in turn reduce regional centrality. We also note that residential density is measured by CAU, which is typically a neighbourhood of approximately 2000 households. Similarly, while centrality is regional in terms of its spatial structure, it is highly influenced by more proximate locations.

3.1.1 Data and methodology

Our data was sourced from:

- *Open street maps* – used to calculate the shortest path by road between every two CAUs in our analysis, which was in turn used as an input into the calculation of regional centrality.
- *Census of population and dwellings 2001 and 2006* – New Zealand's national census data on socio-economic characteristics at several levels of spatial aggregation (Statistics NZ 2006a). Our analysis is undertaken at the level of CAU, which was used to calculate residential density.
- *Business demographic statistics* – this is an annual snapshot of the structure and characteristics of New Zealand businesses. Statistics are collected for all economically significant enterprises that

produce goods and services in New Zealand, which generally includes all employing units and enterprises with GST turnover greater than NZ$30,000 per year (Statistics NZ 2006b).

Business demographic statistics are defined in terms of 2011 CAUs. Because Statistics NZ's definitions of CAUs have changed slightly since the last census was undertaken there are some mismatches between new and old CAUs; we have dropped these CAUs from our analyses. We also dropped CAUs for which residents or employed population numbered less than 30, in either 2001 or 2006. Ultimately, our analysis was based on 1173 out of 1919 CAU in total.

We estimated the impacts of urban form on transport outcomes using a panel regression model, which incorporated both cross-sectional (ie across CAUs) and temporal (ie across time) dimensions. This allowed us to control more precisely for fixed effects that were unique to a particular CAU. While this was not quite as good as having longitudinal data for individual people/households, it did allow us to partly control for population preferences that are fixed in time. This in turn allowed us to draw stronger economic inferences than would be possible from standard cross-sectional models.

Our hypotheses are relatively simple:

- *Urban form variables* – we expect drive alone mode share and vehicle ownership are negatively related to our urban form variables, namely residential density and regional centrality
- *Control variables* – we expect drive alone mode share and vehicle ownership are positively related to income, but negatively related to the proportion of the population with post-graduate qualifications.

The following sections present our regression models for vehicle ownership and drive mode share.

3.1.1.1 Vehicle ownership

The preferred functional form for our vehicle ownership regression model is:

$$V_{it} = \beta_1 . ln(ResDensity_{it}) + \beta_2 . Centrality_{it} + \beta_3 . ln(Income_{it}) + \beta_4 . PostGrad_{it} + k \quad \text{(Equation 3.1)}$$

Where:

- V_{it} is average household vehicle ownership of CAU i at time t
- $ln(ResDensity_{it})$ is the natural log of the residential density of CAU i at time t
- $Centrality_{it}$ is the regional centrality of CAU i at time t
- $ln(Income_{it})$ is the natural log the median household income for CAU i at time t
- $PostGrad_{it}$ is the proportion of the CAU population with post-graduate qualifications
- $\beta_1, \beta_2, \beta_3, \beta_4$ and k are coefficients to be estimated.

Regression results for the vehicle ownership model are summarised in table 3.1.

Table 3.1 Regression results for vehicle ownership model

Variables	Parameter	Coefficient	t-stat	P-value
Residential density	β_1	-0.05382	-3.46	0.001
Regional centrality	β_2	-1.74e-0.6	-2.20	0.028
Household income	β_3	0.5070	47.22	0.000
Postgraduate population	β_4	-1.100	-5.34	0.000
Constant	k	-3.3759	-24.87	0.000

The model has an overall R-squared of 0.682 and an F-statistic of 849 (p-value 0.000). All coefficients are statistically significant at the 1% level and, most importantly, the residential density and regional centrality variables are both negative (ie they have a negative impact on vehicle ownership). We tested another model that excluded the regional centrality variable. In this model, the coefficient for residential density increased to -0.06432, which confirms our earlier observation that residential density and regional centrality are likely to be correlated.

3.1.1.2 Drive mode share

Before introducing our drive mode share regression model, it is worth commenting on the dependent variable, namely drive mode share. This is defined as the percentage of journey-to-work trips made by drivers of private vehicles, commercial vehicles and motorcycles. It does not include people who worked-at-home, or those journey-to-work trips made by car-passengers, public transport or walking/cycling.

The other thing to note about mode share is that the values it can take are constrained to lie between 0 and 1, ie it is a percentage. For this reason we follow Small and Verhoef (2007) and model not the drive mode share itself, but instead its logistic transformation, which is defined as:

$$z = ln\left(\frac{D}{1-D}\right) \quad \text{(Equation 3.2)}$$

Where z denotes the logistics transformation and D denotes drive mode share. Transforming mode share in this way enables us to get around some of the distortions introduced by natural limits on the values that mode share variables can assume (ie they are limited to lie between 0 and 1). We then define the preferred functional form of our drive mode share regression model as follows:

$$z_{it} = \beta_1.ln(ResDensity_{it}) + \beta_2.Centrality_{it} + \beta_3.ln(Income_{it}) + \beta_4.PostGrad_{it} + k \quad \text{(Equation 3.3)}$$

Where:

- z_{it} is the logistics transformation of the drive mode share of CAU i at time t
- All other variables are defined as per the vehicle ownership model presented earlier.

Regression results for the drive mode share model are summarised in the following table. The model has an overall R-squared of 0.08 and an F-statistic of 46 (p-value 0.000). Again, all variables again have the expected sign. All variables are also statistically significant at the 1% level, except for the regional centrality variable, which is significant at the 5% level.

Table 3.2 Regression results for drive alone model

Variables	Parameter	Coefficient	t-stat	P-value
Residential density	β_1	-0.06957	-2.24	0.026
Regional centrality	β_2	-2.53e-06	-7.76	0.000
Household income	β_3	0.2900	13.50	0.000
Postgraduate population	β_4	-3.1967	-7.76	0.000
Constant	k	-2.0593	-7.58	0.000

We tested another model that excluded the regional centrality variable. In this model the coefficient for residential density model increased to -0.0950, which again confirms that residential density is positively correlated with regional centrality.

3.1.2 Case study

Based on the results of our two regression analyses we have fairly strong empirical evidence to confirm our initial hypothesis, namely:

> *Urban form attributes (namely residential density and regional centrality) impact on transport outcomes (namely vehicle ownership and drive mode share).*

In this section we use a hypothetical, but realistic, case study to demonstrate the relative importance of the relationships between urban form and transport outcomes, specifically vehicle ownership and drive mode share. Our urban form case study assumes:

- *Population* – Auckland's residential population increases by 250,000, which is distributed across the 50 densest CAUs in proportion to the 2006 census population
- *Employment* – Auckland's employment increases by 125,000 jobs, which are distributed across the 50 densest CAUs in proportion to the number of jobs they accommodated in 2006.

This scale of urban growth is broadly comparable to what Auckland would expect to experience in a 10-year period, which if we use the 2006 census as a baseline would suggest we are effectively modelling an urban development that could plausibly occur by 2016–21. We assume that our other factors, namely income and the proportion of postgraduate population, remain constant.

The impacts of the compact urban development scenario were estimated as per the following steps:

- Step 1 – assign additional population and employment to affected CAUs
- Step 2 – calculate change in residential density and regional centrality for new urban form
- Step 3 – use regression results to estimate the change in vehicle ownership and drive mode share.

With this process, we predicted that average household vehicle ownership would decline from 1.750 in 2006 to 1.725 in the compact scenario, which equates to a reduction of approximately 1.4%. Meanwhile drive mode share would decline from 62.7% to 62.2%, which equates to a reduction of approximately 0.75%.

The impacts of urban form on these transport outcomes are therefore relatively marginal in an absolute sense, but can accrue relatively rapidly in the case of a fast growing city such as Auckland. When one considers that there are around 1 million registered vehicles in Auckland (or approximately 600 vehicles per capita) then this equates to an estimated 15,000 fewer vehicles than would otherwise eventuate.

Similarly, with 400,000 to 500,000 people expected to drive to work every day by 2016–21, a 0.75% reduction in drive mode share would equate to approximately 3000 to 4000 fewer vehicle trips. If even half of those people who would otherwise have driven chose instead to use public transport, then this would increase the number of public transport journey-to-work trips by approximately 5%. This, in turn, would equate to 0.5% growth in public transport journey-to-work trips per annum alone, simply from a more compact urban form (assuming the growth assumptions in our case study manifested over a 10-year interval). Thus a more compact and centralised urban form could be expected to have modest but not insignificant impacts on transport outcomes in Auckland.

3.1.3 Summary of results

Based on these results we suggest that urban form has relatively modest but not insignificant impacts on transport outcomes, specifically vehicle ownership and drive alone mode share. The impacts are particularly important for non-car transport modes, which are starting from a relatively low base.

To finish, it is important to place some caveats on our empirical results, namely:

- Our analyses are based on the 2001 and 2006 census. The robustness of our regressions (and the inferences we have subsequently drawn) would be significantly strengthened by the inclusion of more recent census data. The next census in March 2013 presents such an opportunity.
- Our regression models incorporate urban form variables that are straightforward to calculate at a CAU level. Further work could consider other potential urban form variables, such as the nature of the street network and public transport service levels. Our literature review identified a range of urban form variables that may have larger cumulative impacts on transport outcomes.
- Perhaps most importantly, the census measures only journey-to-work travel. It is plausible to suggest that the impact of urban form may be larger for non-work trips, eg educational and shopping trips, for which proximity is likely to play a larger role in determining the travel choices made by people, households and firms.

3.2 Economic outcomes

Our literature review identified how increased urban scale (both size and density) can result in agglomeration economies. In this section we first estimate agglomeration economies in Auckland and then use them as a lens through which we can simulate the economic impacts of different urban forms, or more specifically centralised versus dispersed employment scenarios.

Before proceeding we should first justify our choice of land values as our preferred economic indicator. We have selected land values because the impact of urban form on economic outcomes is more readily capitalised into land values than other economic indicators, such as wages. This is because land is fixed both in location and in supply, so that changes in price are more closely linked to changes in demand.

On the other hand, land values have some limitations. First and foremost is the problem that they are not observed separately from the buildings they support; land values must therefore first be estimated. Despite these weaknesses, land values are the most appropriate economic indicator for understanding the impacts of urban form.

3.2.1 Data and methodology

Our analysis draws on the following three data sets:

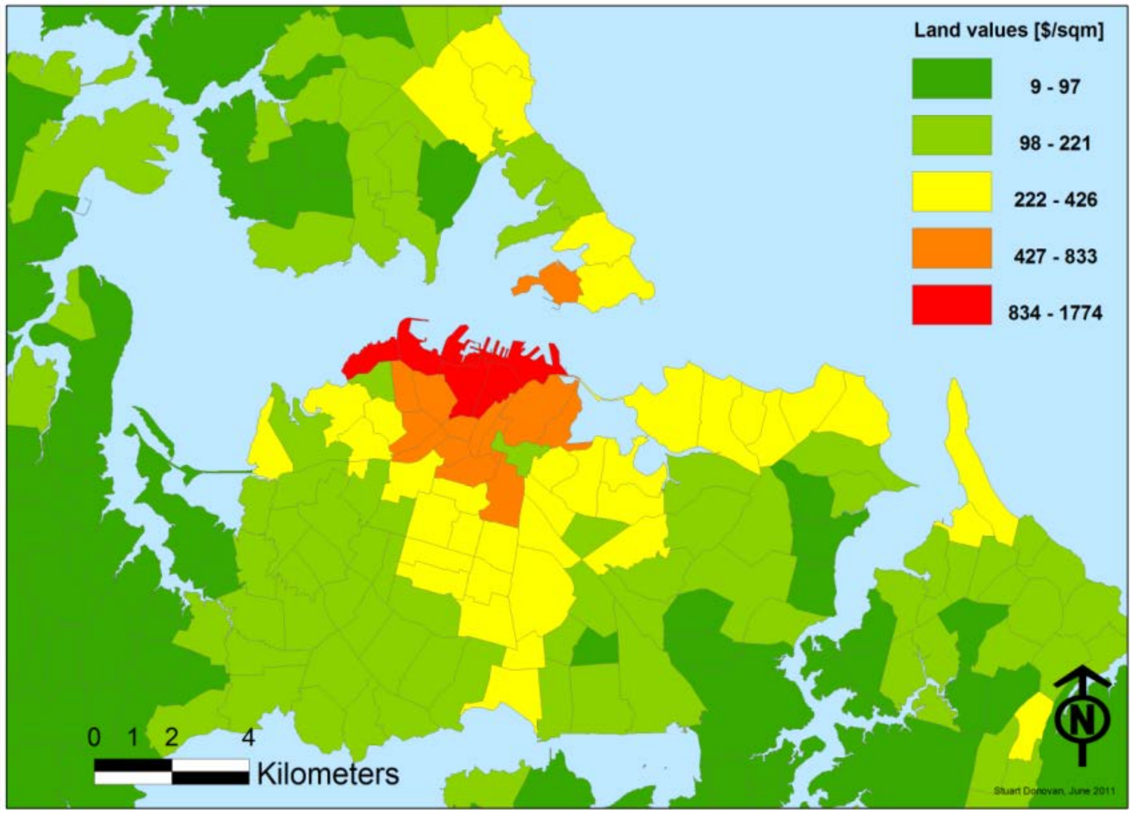
- *Recorded property sales in Auckland* – We used a database of approximately 113,000 property transactions in the Auckland region for the period 2001–05. The database included residential and commercial properties, such as sale prices, land values and location, as well as a range of property-specific attributes, such as floor area and views.
- *Census of population and dwellings 2006* – This is New Zealand's national census data on socio-economic characteristics at several levels of spatial aggregation (Statistics NZ 2006a). Our analysis is undertaken at the level of CAUs, of which there are 365 in the Auckland region. The mean population is approximately 2500 residents per CAU.
- *Business demographic statistics* – This is an annual snapshot of the structure and characteristics of New Zealand businesses. Statistics are collected for all economically significant enterprises that produce goods and services in New Zealand, which generally include all employing units and enterprises with GST turnover greater than NZ$30,000 per year (Statistics NZ 2006b).

Our methodology for estimating agglomeration economies involves two steps. In the first step a hedonic regression model is used to estimate land values, while controlling for a range of property attributes, such as floor area. In the second step we model how land values respond to the location of additional employment. The following sections discuss the two steps in our methodology in more detail.

3.2.1.1 Stage 1 – modelling land values in Auckland

In stage 1 we used a hedonic regression model to model property values in Auckland in the period 2001–06. The model assumes that the price people pay for properties reflects the value of their underlying physical attributes, namely the combined value of capital improvements, land area and attractiveness of the local neighbourhood. The model had an R-squared of approximately 88%, while all variables had the expected sign and most were statistically significant (more detailed results are available in appendix B). Results from this model can be used to estimate the price of land for each CAU, as illustrated in figure 3.1.

Figure 3.1 Stage 1 results – land values in Auckland (2001)



We see that land values are generally highest in the city centre and decline towards the urban periphery. Higher land values seem to extend along the coast from the city centre, and also south and east of the city towards Maungakiekie, Onehunga, and St Heliers, as well as north to Devonport and Takapuna on the North Shore. Lower values are observed in west and south Auckland.

3.2.1.2 Stage 2 – modelling agglomeration economies in Auckland

Having estimated how land values vary across the Auckland region we can now move to stage 2 of our analysis, where we estimate how land values respond to the distribution of employment.

First, we define density in terms of how far employees are, on average, from other employment opportunities in the wider Auckland region. What we are looking to do is define density not only in terms of an individual area unit, but also the density of surrounding area units. Of course, the further away an area unit is from where we are the less it matters; hence we need to include some form of 'spatial weighting' that reduces the contribution of a CAU to other CAUs' density as distance increases.

Graham (2007) defines the following equation for calculating what he terms 'effective density':

$$\delta_i = \frac{E_i}{\left(\sqrt{A_i/\pi}\right)^{\alpha}} + \sum_{j}^{i \neq j} \left(\frac{E_j}{\left(d_{ij}\right)^{\alpha}} \right) \quad [1] \qquad \text{(Equation 3.4)}$$

Where: δ_i, E_i, and A_i are the effective employment density, employment and area of spatial unit i respectively; d_{ij} is the distance between locations *i* and *j;* and α is a distance decay parameter.[5]

This equation thus considers not only the own density of individual CAUs (i) but also the density contributed by other CAUs (j), although the latter are weighted by the distance between i and j.

We now estimate how land values change in response to changes in effective employment density, with the following regression model:

$$ln(V_j) = \alpha + \varepsilon . ln(\delta_j) \qquad \text{(Equation 3.5)}$$

Where: V_j is the land price in CAU j in 2005; α is the constant of regression; ε is the price elasticity of land with respect to effective density; and δ_j is the effective density of area unit j. We refer to this simple model as the 'OLS' model.

Before proceeding, however, we note that using land values to model agglomeration economies is not straightforward for the following two reasons:

1 The first issue is that 'simultaneous causality' exists between land values and density; the latter affects the former and vice versa. To isolate the effects of effective density on land values we need to control for the effects of land values on density. We do this by using a technique known as instrumented variables and two-stage least squares.

2 The second issue is that land values are 'spatially auto-correlated'. This means that land values in one CAU are likely to be influenced by land values nearby. This spatial autocorrelation exists because factors that influence land values tend to extend across CAU boundaries, which are indeed somewhat arbitrary. This is problematic for our model because the variation in land values caused by these unobserved factors may be correlated with effective employment density. Failing to control for their effects will again tend to bias our results. To control for spatial autocorrelation we use a more sophisticated "spatial error" regression model.

Results for the OLS (ordinary least squares), IV (two-stage least squares), and SE (spatial error) models are summarised below. Results for the ordinary regression, while biased for the two reasons noted above, provide a useful benchmark for interpreting the results of more sophisticated models.

Table 3.3 Stage 2 results – estimating agglomeration elasticities in Auckland

Variable	OLS (ordinary)		IV (instrumented)		SE (spatial error)	
	δ	t-stat	δ	t-stat	δ	t-stat
Effective employment	0.896	11.93	0.201	1.49	0.360	2.51

Results for the OLS model suggest that a doubling in effective employment will cause an 89.6% increase in land values. This elasticity reduces to 20.1% once the effective density variables have been instrumented,

[5] The first term in the expression measures the contribution of a spatial unit to its own effective density, adjusted for the average internal distance (we assume that the CAU is a disk over which all jobs are evenly spread). The second term measures the contribution of employment in all other spatial units, adjusted for the distance between the two units.

which suggests that a large part of the relationship between land values and density runs from the former to the latter, as we would expect. And finally, controlling for spatial autocorrelation with the SE model the agglomeration elasticity increases to 36%.[6] Our best estimate is therefore that a doubling in effective employment density will cause a 36% increase in land values, holding other factors constant. Put simply, this relationship now allows us to determine the change in land values that can be expected to follow from changes in effective employment density. This change in land values captures the agglomeration economies associated with increased urban scale and density.

But how does this result help us to understand the impact of urban form on economic outcomes? Quite simply, it tells us how an increase in effective employment density in one part of Auckland will flow through into higher land values across the city, by virtue of agglomeration economies (and their spatial spillovers). This in turn can help us to understand the relative economic efficiency attached to various urban forms and the employment patterns they support; this is the topic of the following section.

Before we continue, we first need to derive an equation to estimate the impact of a change in effective density on land values. Let us define land values before and after by V_j^A and V_j^B, with similar notation used to define effective density. Land prices before and after the change are thus defined by

$$ln\left(V_j^A\right) = \alpha + \delta . ln\left(E_j^A\right) \qquad \text{(Equation 3.6)}$$

and

$$ln\left(V_j^B\right) = \alpha + \delta . ln\left(E_j^B\right). \qquad \text{(Equation 3.7)}$$

The change in land prices is thus equal to:

$$\Delta ln\left(V_j\right) = ln\left(V_j^B\right) - ln\left(V_j^A\right) \xrightarrow{yields} ln\left(\frac{V_j^B}{V_j^A}\right) = ln\left(\frac{E_j^B}{E_j^A}\right)^{\delta} \xrightarrow{yields} \frac{V_j^B}{V_j^A} = \left(\frac{E_j^B}{E_j^A}\right)^{\delta} = \left(\frac{E_j^B}{E_j^A}\right)^{0.360} \qquad \text{(Equation 3.8)}$$

This equation allows us to calculate the percentage change in land prices for each CAU given a change in effective density. Such a change could be brought about either one of two ways, namely an increase in employment or a reduction in the distance between CAUs. The following section will explore the former.

3.2.2 Case study

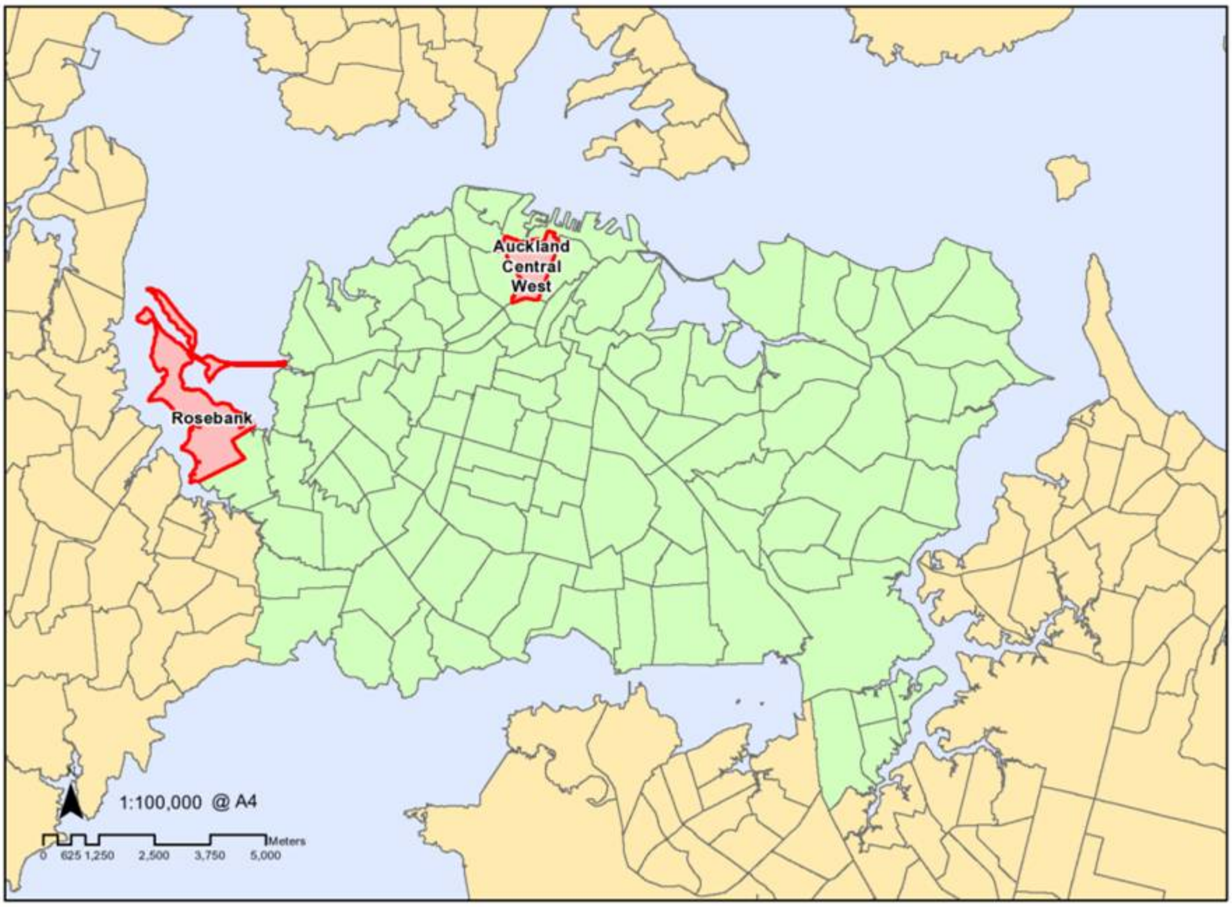
In this section we estimate the relative economic value of centralised versus dispersed employment patterns.

Let us simulate the effects of two hypothetical employment scenarios: scenario A involves a 'de-centralised' employment pattern that sees an additional 10,000 jobs located in the 'Rosebank' CAU, whereas scenario B is a centralised employment pattern that sees an additional 10,000 jobs being located the 'Auckland Central West' CAU.

[6] The higher elasticity that results using the SE model hints at two potential explanations: The first explanation is that estimates of agglomeration economies in the IV model may be biased due to omitted factors that are positively spatially correlated with effective density but negatively spatially correlated with land values. Examples of such factors might be infrastructure, such as ports, railways, and state highways, which tend to be located in areas of dense employment but which generate negative externalities. The second explanation is that the omitted factors are negatively spatially correlated with effective density, but positively spatially correlated with land values. Examples of such factors include parks, which will tend to reduce effective density but increase land values. These two effects are likely to explain why larger agglomeration economies are found when controlling for spatial autocorrelation.

The two affected CAUs are illustrated in figure 3.2.

Figure 3.2 Location of Rosebank (scenario A) and Auckland Central West (scenario B) CAUs

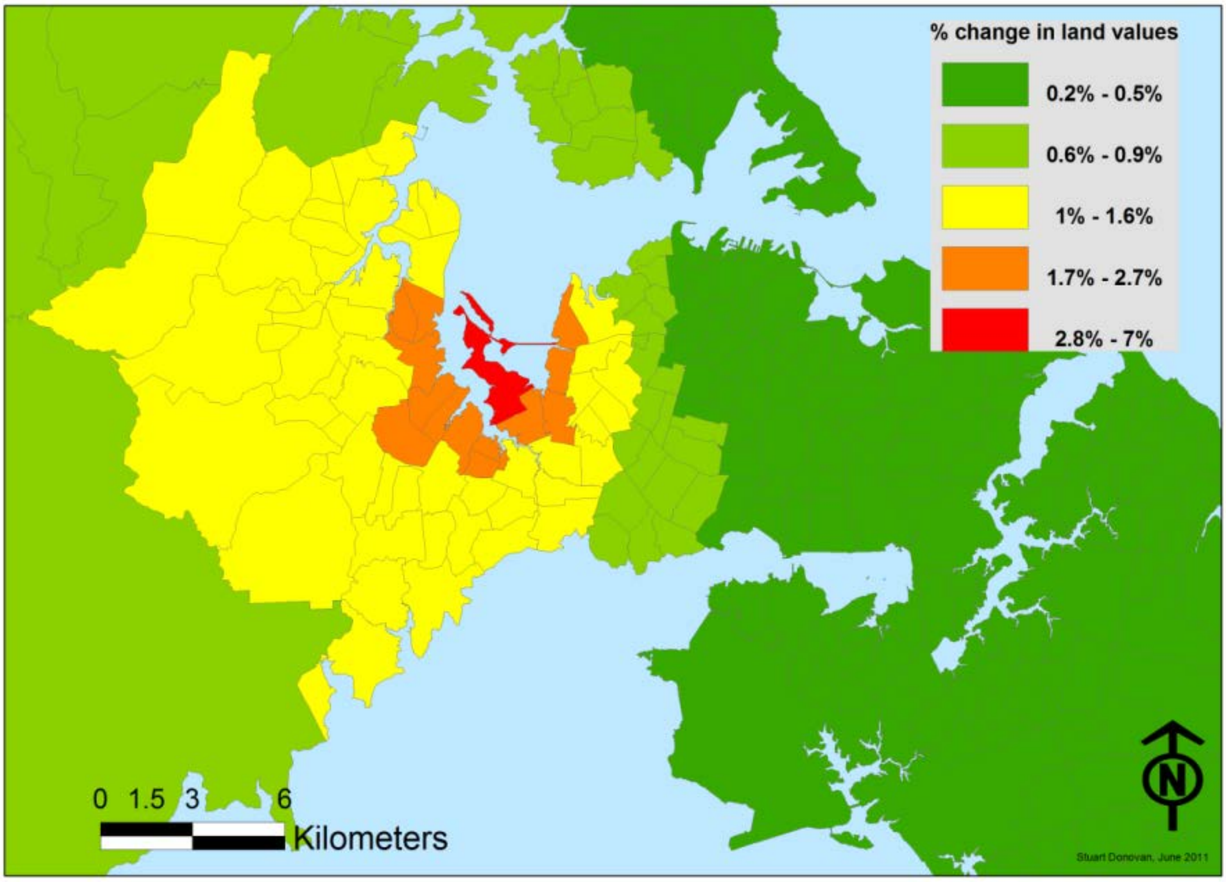


It is important to spell out precisely what we are trying to model here: we have taken two different parts of Auckland (namely Rosebank and the Auckland CBD) and added 10,000 jobs. We have then used the relationships established in the previous section to calculate and compare what the economic impacts of this change in employment density would be, assuming all other factors remain constant.

The key question we would like to answer then becomes: What are the relative economic benefits of each employment scenario?

In scenario A our model predicts a 7% increase in land values in Rosebank, with positive benefits spilling over to surrounding CAUs, especially to the west. This reflects the fact that areas to the west have lower effective densities to begin with; as such the relative impact of the increased employment in Rosebank is proportionally greater than other parts of Auckland to the east. Areas to the north and south are relatively remote from Rosebank and are therefore mostly unaffected by the additional employment opportunities.

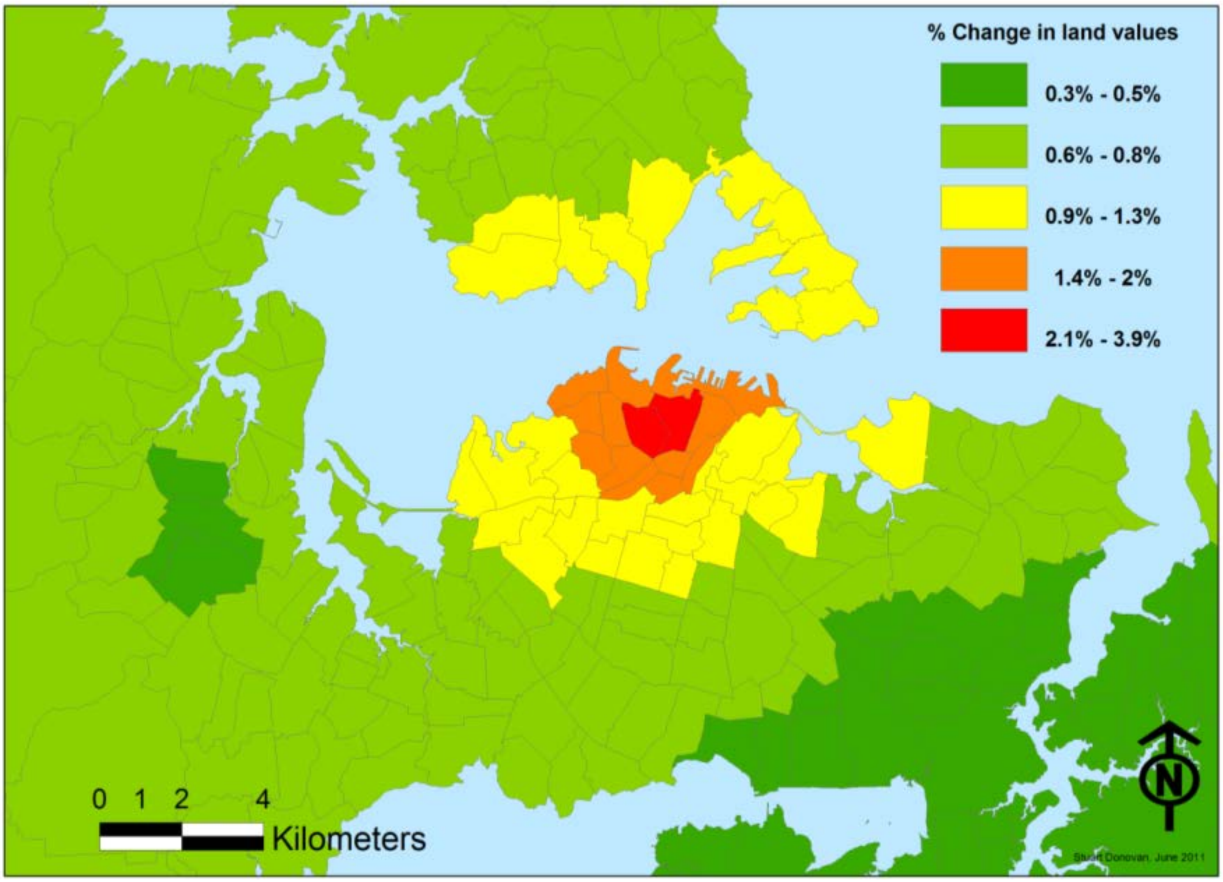
Figure 3.3 Impacts of employment (scenario A Rosebank) on land values in Auckland



In contrast, the percentage change in land values for scenario B is illustrated in figure 3.4. This shows a smaller increase in land values of only 3.9% in Auckland Central West (compared to 7% in Rosebank). This reflects the fact that Auckland Central West is starting from relatively high land values.

Nonetheless, the positive uplift in land values associated with the more centralised employment pattern in scenario B is more evenly spread across the city area than those associated with scenario A. This reflects the fact that additional employment in Auckland Central West causes more even spatial spillovers across a larger number of Auckland's central suburbs.

Figure 3.4 Impacts of employment (scenario B Auckland Central West) on land values in Auckland



The percentage change in land values does not tell us much about the net economic benefits associated with each employment scenario. We can, however, estimate this using the following process:

- Multiply the change in land values per CAU by the area of privately owned land in each CAU.
- Sum the net 'uplift' in land values across all CAUs.

Using this methodology we calculated the net agglomeration benefits associated with scenarios A and B of NZ$2.00 billion and $2.03 billion respectively (in 2005 values compared to the base situation). Thus, scenario B is found to generate additional economic benefits of $294.8 million, or approximately $30,000 per job compared with scenario A. We have strong evidence to suggest that more centralised employment patterns have external economic benefits compared with dispersed employment patterns.

3.2.3 Summary of results

In the previous sections we have:

- developed a methodology for estimating land values in Auckland, which in turn has been used to link changes in effective employment density to agglomeration economies
- used our model of agglomeration economies to investigate the relative merits of centralised versus dispersed employment patterns, as measured through land value uplift
- found that a more centralised employment pattern generates additional economic benefits in the order of $30,000 per job compared with the more dispersed employment scenario.

The case study is instructive for illustrating the relative economic benefits associated with centralised employment patterns in Auckland. We note that by ‘centralised’ we are effectively referring to employment patterns that are relatively ‘accessible’ to surrounding areas.

But observing economic benefits from centralised employment patterns is one thing, achieving them is quite another. Put another way, our analysis begs the question of how would one incentivise 10,000 new jobs to locate in the city centre or in Rosebank, what that public cost would be, and whether the net benefits would justify one decision over another. Those are valid questions, but they will of course vary greatly from place to place. Some general answers on how to achieve denser employment patterns lie outside the scope of this chapter, but are considered in more detail in chapter 4.

To finish, we note again that agglomeration economies represent the net benefits of higher density, ie they are net of the costs of density, such as congestion. This is consistent with how agglomeration economies are defined and empirically measured.

4 Improving New Zealand's urban form

Previous sections have helped us to understand 'how' urban form impacts on transport and land use in New Zealand. They have hinted at the types of transport and land use policies that regional and local councils could pursue to improve their urban form.

In this section we tackle this question more directly; the following sections are structured as follows:

- Section 4.1 highlights attributes of efficient and durable street networks.
- Section 4.2 discusses attributes of efficient public transport networks.
- Section 4.3 considers policies to support efficient land use outcomes.

We note that the links between the material in this section and those that precede it are implicit, rather than explicit. The material that follows is motivated by a combination of the results of our literature review, our subsequent analysis, and our professional experience with the types of policies that can support an efficient urban form. Readers are therefore likely to find the following sections more applied, albeit by necessity more subjective and selective.

Finally, in the interests of conciseness we have not touched on all the possible transport and land use policies that regional and local councils might pursue, instead we have chosen to focus on the 'low-hanging fruit'. We think there is merit in tackling these policies first, and with some urgency.

4.1 Street networks

Street networks are important not only because they impact on transport and economic outcomes, but also because very little can be done to change them once they have been defined; they are very durable urban form elements (although the allocation of space within the street network can be adjusted).

There is considerable opportunity for improvement within New Zealand's urban street networks – both in their design and in their use. Councils in New Zealand have hitherto tended to delegate final decisions on street networks to private developers, who have in turn pursued their narrow financial interests to the detriment of more strategic outcomes. This is most clearly seen in the newer suburbs of rapidly growing cities, such as Tauranga and Hamilton.

For inspiration New Zealand's policy makers would do well to look overseas, to cities such as Amsterdam, where a sustained emphasis on connected street networks and provision for all modes of transport has resulted in an urban form that supports efficient transport and economic outcomes.

4.1.1 Network structure

Street networks lie on a spectrum between 'tree-like' and 'connected' networks. Tree-like networks are common in New Zealand and focus on creating a hierarchical road network that meets peak demands. While tree-like networks are (superficially) efficient, they also have several disadvantages, namely:

- the segregation of urban space by high capacity roads (Engwicht 1993)
- limited capacity to adjust to changing development patterns, eg shifts in commuting flows
- vehicle volumes are concentrated to a level that may undermine adjacent land uses
- travel distances can increase, resulting in increased vehicle operating costs.

At the other end of our spectrum are connected street networks, which have higher intersection densities and tend to spread vehicle demands over multiple routes. This reduces the need for high-capacity road infrastructure, such as grade separation. Connected street networks tend to preserve access to land uses, which is often compromised by tree-like networks. Connected street networks are likely to reduce travel distances and facilitate walking/cycling, and are more flexible when confronted with changing traffic demands. Modelling in Portland, for example, found that improving the connectivity of the street network reduced traffic volumes on major streets and improved peak-hour travel times (Metro 2004). An example of both a tree-like and connected network is illustrated below.

Figure 4.1 Tree-like (Papamoa, Tauranga) and connected (Pt Chevalier, Auckland) street networks

4.1.1.1 Case study: Hamilton city centre connectivity and block size – Hamilton, Waikato

The existing road network in Hamilton city centre effectively operates (particularly along Victoria and Anglesea Streets) as a corridor rather than as a network, as illustrated in the following figure.

Figure 4.2 Street networks and block sizes in Hamilton city centre

This image overlays the connected street network from Newmarket in Auckland (red) on top of the tree street network in Hamilton (blue), at the same scale. Hamilton's street network is essentially reliant on just four major intersections (which are numbered 1–4) that must handle all the traffic in the city centre. In Newmarket a number of alternative routes are available that enables the network to accommodate more complex traffic flows. Moreover, Newmarket provides a smaller block size, which is considerably more conducive to pedestrians and cyclists. This in turn enables retail activity to spread back from the main streets, which serves to greatly expand the retail area.

Credit: Jim Higgs

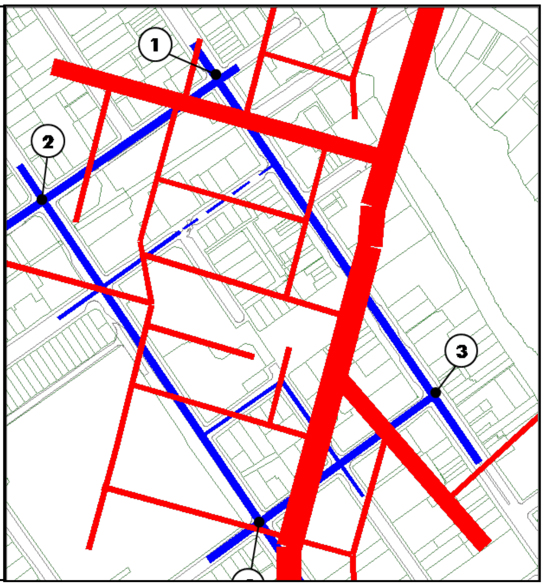
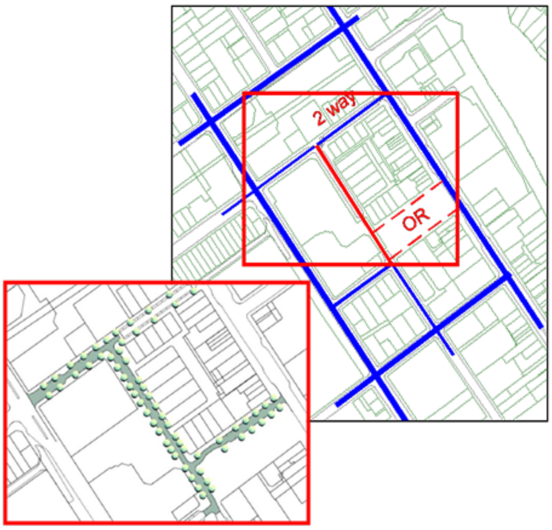


Figure 4.3 Improving street networks and block sizes – Hamilton city centre street connections



In response to the issues identified above, Hamilton City Council is considering changes to the existing street network that would add new connections and reduce the block size. The main change is to connect Worley and Alexandra Street, and provide a new Garden Place Lane (shown in red in the figure to the left). This would contribute to considerable benefits for pedestrians as well as motorists. Drivers, for example, could more easily park and walk to several destinations, rather than having to shift their vehicle.

Credit: Jim Higgs

Inside Hamilton City Centre, the average block area was about 11 hectares. Typical street blocks in town centres are, on average, around two hectares. Large blocks and a limited secondary road network meant that vehicle turning movements were concentrated at fewer intersections. In response, signal cycle times were consequently very long (140 seconds in peak periods) and pedestrians were given low priority.

4.1.2 Street integration

Even with a sustained emphasis on connected street networks, it is inevitable that some roads will carry higher volumes of vehicle traffic.

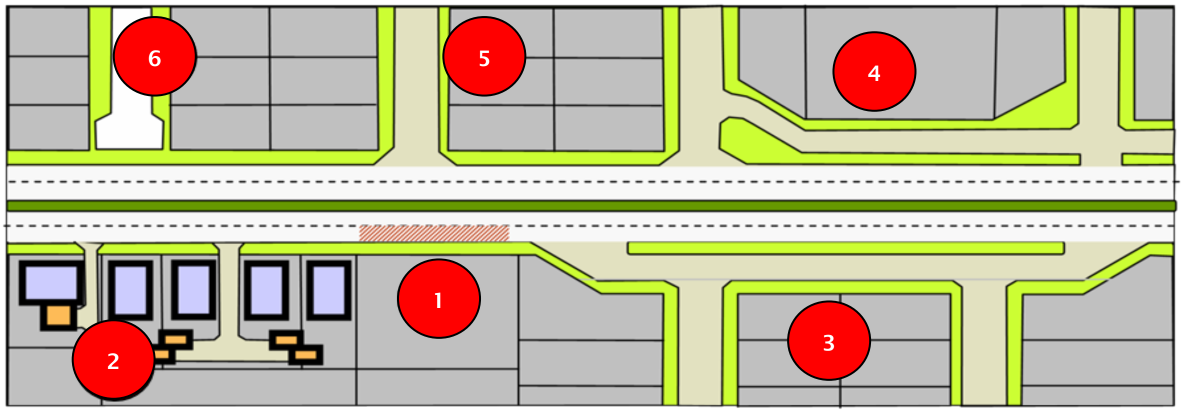
For these roads some important choices often need to be made on the degree to which they integrate and connect with the surrounding urban areas. A high level of integration provides full access for adjacent properties and streets, which would undoubtedly slow through-traffic and possibly give rise to safety issues. On the other hand, low levels of street integration can undermine adjacent land uses.

But the choice between integration (access) and segregation (no access) is not a binary one; there is in fact a spectrum of potential treatments that can ensure the major street operates safely and efficiently while maintaining accessibility for adjacent properties. Potential treatments include:

1. Normal property access with on-street parking, or with on-site parking (highest degree of integration)
2. Garages arranged so that cars access the side road before travelling onto the main road
3. Parallel slip lanes with direct access to the main corridor
4. Parallel slip lanes with access off the side street before connecting with the main corridor
5. Left in-left out of a side street with many 'side on' to the major corridor
6. Fronting onto the side street but no access to main corridor. Pedestrians and cyclists can however access the main street (lowest degree of vehicle integration).

Few of these treatments have been deployed in New Zealand, where cities and towns have too often imposed hard and inflexible 'road hierarchies' that are not responsive or conducive to diverse urban environments. Other parts of the world tend to be more creative in the way major street corridors are integrated into the urban form. Clever design and localised treatments are often used to improve mobility without compromising access to adjacent land uses. The range of treatments listed above is illustrated (and numbered) in figure 4.4.

Figure 4.4 Varying levels of street integration



4.1.2.1 Case study: Integrating arterial road corridors – Amsterdam, the Netherlands

The city of Amsterdam supports extraordinarily high rates of walking and cycling. While much of this may be attributed to the city's density and topography, it is also partly due to a sustained policy focus on creating a connected street network. This focus is perhaps most evident when examining modern arterial roads, which have been typically integrated in a way that allows for efficient vehicle movement, without undermining adjacent land uses, as shown in figure 4.5.

Figure 4.5 Integrating arterial roads into the urban form – Rooseveltlaan, Amsterdam

These figures show the configuration of Rooseveltlaan, which is located in the suburb of De Pijp. Rooseveltlaan has one-way slip lanes adjacent to the residential buildings that front both sides of the street. The slip lanes are separated from the arterial road by a wide tree-lined berm that provides footpaths and cycle paths, as well as gardens and street seats. The sole purpose of the slip lanes is to enable safe access to residential buildings without impeding through traffic.

The bottom figures show the street itself, which provides (additional) on-street parking, one lane for general traffic and a central lane for public transport. No properties have direct access to the main street – which greatly reduces friction for through movements. Access is by way of the slip lanes, which connect with side streets. At the same time, the green space and cycle paths contribute to amenity and help mitigate effects of high traffic volumes. This street is an example of the integration option 4 in figure 4.4, namely parallel slip lanes with access off a side street, before connecting with the main corridor.

4.1.3 Intersection design

Many intersections in New Zealand have been designed solely with vehicles in mind. This has created situations where the needs of pedestrians are unfairly sacrificed to increase vehicle capacity. Intersections need to be safe and efficient for all road users, not just drivers. In most places the key decision relates to the choice of intersection controls, namely roundabouts versus traffic signals.

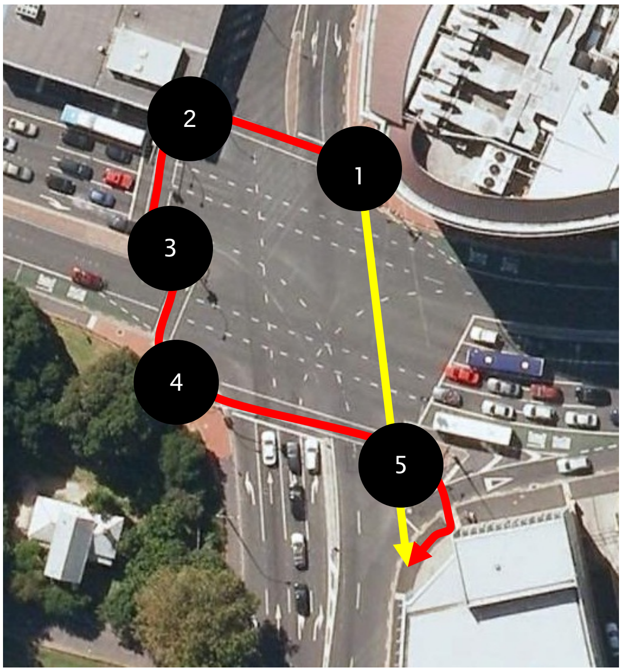
Roundabouts have a legitimate role in areas with low pedestrian volumes, and in areas peripheral to a centre where they can be used to signal a change in land use condition, such as a transition from a rural to an urban area. Roundabouts operate by having drivers wait for gaps in the traffic stream. This tends to 'smooth out' the traffic flow, which in turn reduces gaps for vehicles waiting downstream. Roundabouts tend to have a large footprint, especially when they need to cater for heavy vehicles.

However in denser urban environments, we suggest that roundabouts are avoided as they create barriers to pedestrian movement. Issues with roundabouts in urban areas tend to result in poor land use and transport integration, as with the Panmure roundabout in Auckland (figure 4.6, image on right).

Figure 4.6 Roundabouts often create major barriers to pedestrian movement

In developed urban areas with medium to high pedestrian volumes, traffic signals are nearly always preferred to roundabouts. While traffic signals are sometimes more expensive to install, when properly designed and managed they tend to provide a multi-modal intersection. Traffic signals can be used to maintain opportunities for pedestrians to cross, which also interrupts the traffic stream and provides opportunities for vehicles waiting downstream (eg vehicles that need to turn out of an uncontrolled side street). Notwithstanding these inherent advantages over roundabouts, many signalised intersections in New Zealand's urban areas suffer from serious design flaws, as illustrated in figure 4.7.

Figure 4.7 The configuration of signalised intersections can greatly compromise pedestrian movement



The intersection shown to the left is located on Fanshawe Street in Auckland city centre, close to the harbour front and adjacent to Victoria Park. A desired pedestrian path from location 1 to 5 is illustrated in yellow. The actual path that would need to be followed is illustrated in red. It is 125m (versus 50m) and involves waiting for four pedestrian crossings (note the staged crossing on the western approach to the intersection. Navigating this intersection via the yellow route would require only two to three minutes, but in the current configuration requires upwards of five minutes. Such intersections are all too common in New Zealand and greatly reduce pedestrian accessibility in order to achieve what are often marginal improvements in vehicle capacity.

Some of the most common issues with intersections in New Zealand's cities and towns include:

- Pedestrian crossings are not provided on some approaches, as shown above. This is extremely common even in busy pedestrian areas, such as Victoria Street in Auckland.
- Staged pedestrian crossings require pedestrians to cross one direction of traffic at a time. These greatly lengthen the time needed to cross, especially when combined with 'dropped' pedestrian crossings, such as those illustrated above.
- Extremely long cycle times can provide pedestrian green phases only at two-minute intervals. Given that most walking trips are 15 minutes or less, time spent waiting at traffic lights can act as a major impediment to pedestrian mobility.
- The provision of left-turn slip lanes at intersections facilitates higher vehicle speeds, while making pedestrian crossing more difficult.

Rectifying issues with intersection design would go a long way towards improving the pedestrian environment in New Zealand. This is especially important in central city locations where intersection designs that curtail pedestrian movements will effectively undermine the potential for localised agglomeration economies, such as knowledge spillovers.

This discussion highlights the tension between vehicle and pedestrian accessibility in downtown areas. The former might be expected to increase the supply of labour to the city centre and realise agglomeration economies (as per Venables 2007), whereas the latter might be expected to enhance knowledge spillovers (as per Arzaghi and Henderson 2009).

While these issues are complex, it seems apparent that there is a need for dense and diverse city centres to strike a balance between local and regional accessibility. In our opinion, most parts of New Zealand give the latter complete precedence, which in turn seems to undermine the economic, social and environmental performance of our cities and towns.

4.2 Public transport

This section discusses some specific ways in which urban form impacts on the effectiveness of public transport. In many ways it builds on the material presented in the previous section.

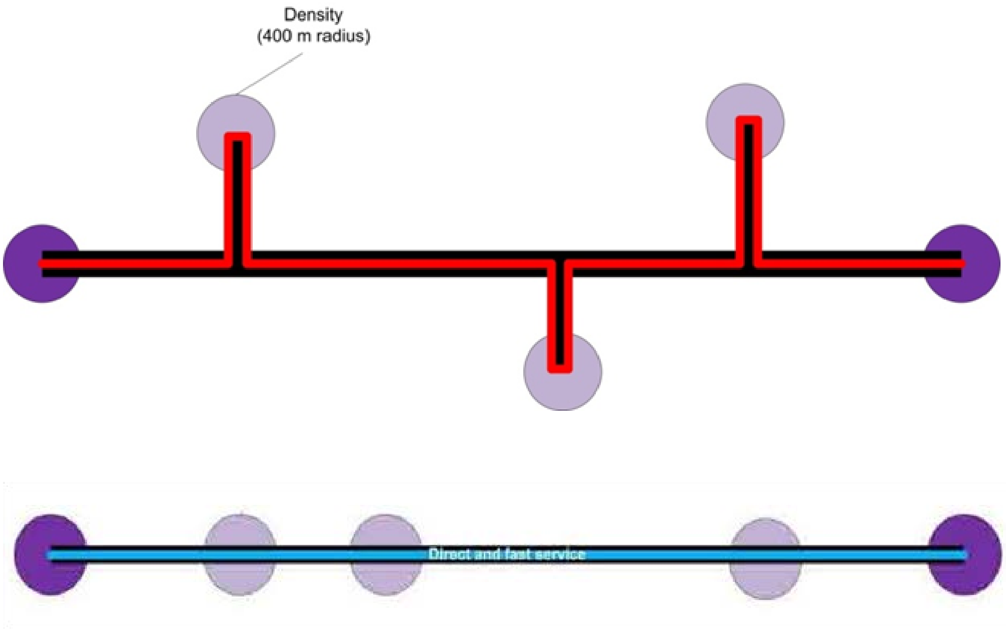
Our key message is this: Urban centres that aspire to have public transport services in the future should plan now to ensure that their urban form develops in a way that is conducive to public transport. In our experience, *the future viability of public transport in a community depends as much on urban form as it does on subsequent decisions about infrastructure and services.*

Once an urban area has developed in a way that is hostile to public transport, it is much more expensive to deliver an effective network. A focus on urban form can therefore lay the foundations for efficient public transport, even in areas where it does not currently operate. The following sub-sections highlight some key ways in which urban form can support effective public transport outcomes and vice versa.

4.2.1 Be on the way – land use planning for public transport

An efficient public transport corridor provides direct connections between important origins and destinations. While this sounds self-evident, the concept has not been well implemented in New Zealand's cities and towns over the last 50 years (an example is illustrated in figure 4.9). The following two figures, for example, show two superficially similar corridors.

Figure 4.8 Directness versus diversions – the benefits of 'being on the way'



The key difference is that any public transport service running on the first corridor must choose to either divert to serve the destination or stop on the major street and force passengers to walk, whereas intermediate stops in the second figure can be served without requiring diversions. This is a crucial feature because diversions incur delays for all passengers who are not travelling to that destination. The second corridor (where stops are aligned) is fast and direct for passengers riding to any destination.

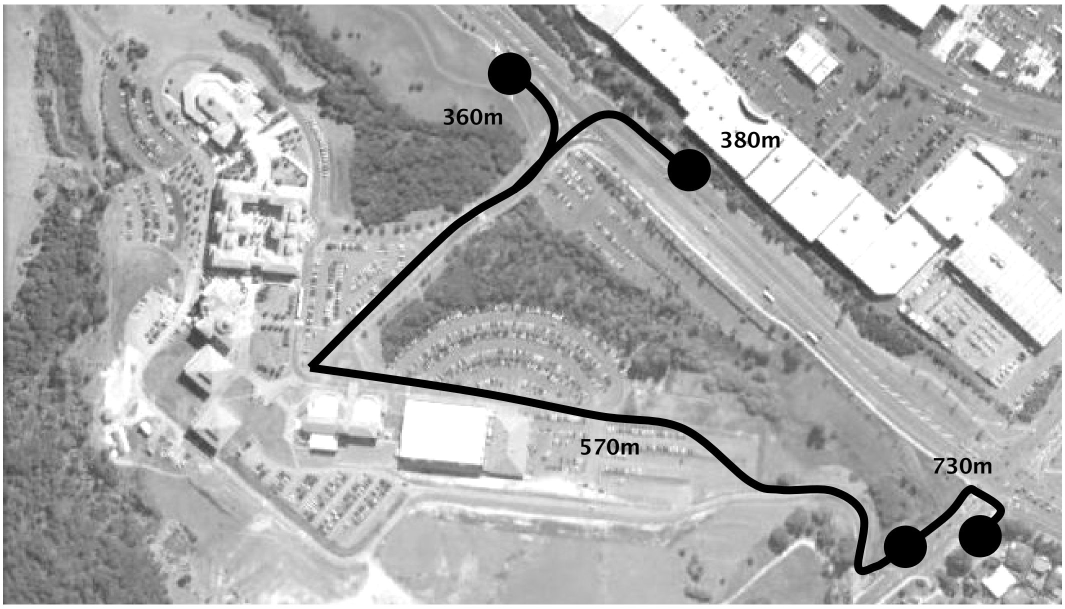
A typical rail line offers this efficiency because the only delay incurred is the time required to stop, ie it cannot divert and so provides a direct, fast, and highly legible service. In contrast, the efficiency of bus corridors is often compromised by diversions, largely because buses are assumed to be flexible. Buses are indeed flexible, but this does not get around the geometric inefficiencies introduced by an urban form where major destinations are not 'on the way'.

A high-speed corridor where there is no trade-off between access and speed, such as the ideal corridor sketched out above, is rare. While public transport planners should certainly look for these rare opportunities and capitalise on them where they exist, it is the urban form that ultimately determines whether they are available. Achieving an efficient public transport network requires a commitment to an urban form where key destinations are 'on the way'.

This is not an argument for extreme soviet style centralised planning. Instead, it is a pragmatic observation that many major destinations, such as universities and hospitals, expect public transport service. While this expectation is a good thing that should be encouraged, it invokes a mutual responsibility – that is, the destinations involved needs to be located and configured in a way that is not unnecessarily hostile and inefficient for public transport.

In areas developed primarily around car travel, however, it is common to see key development configured in ways that are deeply problematic for public transport. These issues arise because for much of the late 20th century it was considered appropriate to set major destinations back from surrounding transport corridors. New Zealand's urban areas are peppered with examples of major developments that are set back from adjacent road corridors and hence unable to be effectively served. An example of this is Massey University's Albany Campus, which is illustrated below.

Figure 4.9 Massey University is not 'on the way'



Providing public transport services to major developments that are not 'on the way' can in the long run incur considerable costs. In the above example, for example, running buses into the Massey Albany campus incurs an additional 750m in travel distance and a two to three minute delay for every bus service, which equates to approximately $66,000 per year (assuming 20 buses per weekday; $2 per bus-km; $25 per bus-hour; and 250 weekdays per year). Thus, over a 20-year lifespan Massey University's decision to set their campus back from the adjacent streets has generated additional public sector costs of approximately NPV $1 million; that is $1 million that is not available to invest in services.

Because the costs of providing public transport are not incurred by the developer but are instead met by the council, there is a role for the latter to have input into the location and configuration of major developments. The simple message from regional and local councils should be that any new development that aspires to have a public transport service should resist the temptation of the cul-de-sac and the setback. Instead, new developments should be located 'on the way' between two destinations that already support public transport service(s), or where it can be serviced by a logical extension of an existing service.

In turn, this requires regional and local councils to set out their future public transport networks in advance, so that developers have certainty as to where public transport services can be provided.

4.2.2 Frequency is freedom!

A core mantra that underpins the development of many modern public transport systems is that 'frequency is freedom'. This observation arises from several ways in which frequency is able to positively influence public transport's usefulness, namely:

- **Waiting-time.** For many short trips (of, say, less than 5km) waiting time is a major component of overall travel time. If we assume 15 minute frequencies, for example, then the average user (assuming random arrivals) will be waiting for 7.5 minutes. If a person is only travelling a distance of 5km, an additional 7.5 minutes can represent a large part of their total journey time.
- **Simplicity.** High frequencies help reduce people's resistance to transfers, which in turn allows a much simpler public transport network. If connections are avoided, then lines must be provided between many more origins and destinations. If connections are accepted as necessary, but mitigated with high frequency, then fewer routes are required and the network is able to be greatly simplified.
- **Spontaneity.** High frequencies enable passengers to adopt a more spontaneous 'turn up and go' approach to using public transport. Rather than planning your trips around the schedule, you can relax in the knowledge that you never have to wait very long for the next service to come. Over time, the ability to travel spontaneously is a key feature of high-quality public transport networks.
- **Reliability.** On a related-point, frequency can help mitigate (although not solve) reliability issues. Frequency means that another service is always coming sooner rather than later, which reduces the need for any individual service to stay on schedule.

Figures 4.10 and 4.11 illustrate how the importance of frequency is increasingly being addressed in cities overseas. Figure 4.10 shows Brisbane's BUZ network, which consists of lines that run every 10 and 15 minutes in peak and off-peak periods respectively, all day, all week. Figure 4.11 shows an excerpt from the Vancouver transit map, which also communicates the benefits of a frequent service network. Here rail – and bus – rapid transit lines are clearly delineated as thick coloured lines, while the remaining frequent bus lines are also relatively visible. Less frequent all-day routes are marked with a simple solid line, while peak-only routes are dashed. At a glance the grid of frequent all-day lines is immediately visible and clearly distinct from less regular services.

Figure 4.10 Map of Brisbane's BUZ network

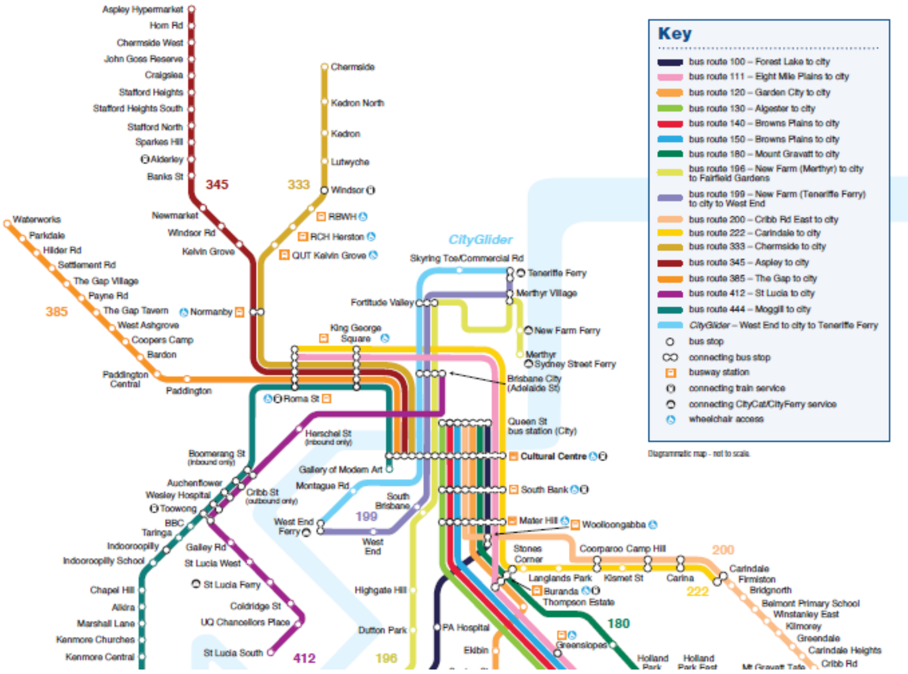


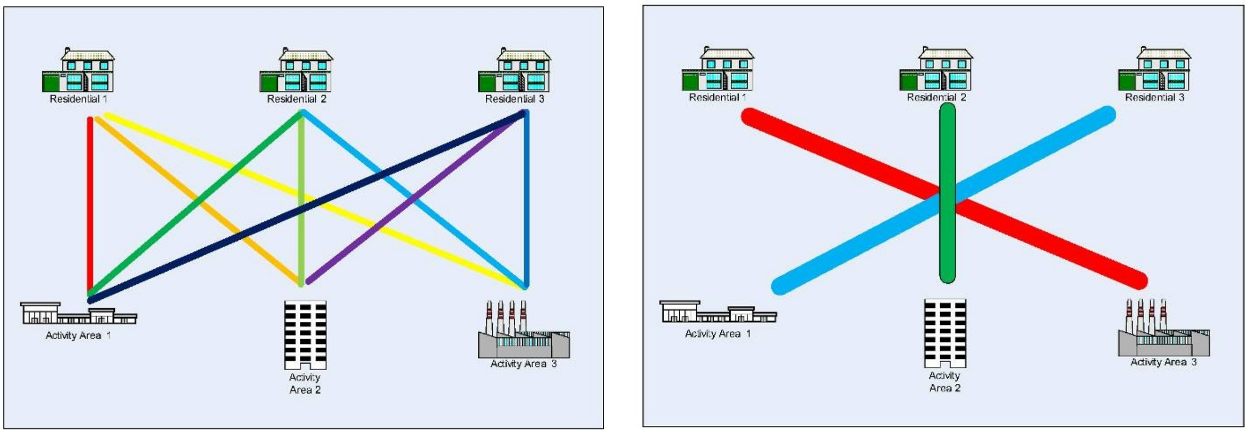
Figure 4.11 Excerpt of Vancouver's transit network

In both maps the suggestion is the same: if you can get to one of these lines then you can be assured that service is coming sometime soon. And by extension, with a frequent network map people can navigate to most of the major parts of the city, even if they have to connect. Bear in mind that both Brisbane and Vancouver have far more extensive public transport systems than are illustrated here; the key point is that they have developed a network of high frequency lines they can promote as their 'core product'.

4.2.3 The benefits of a connected network

One of the key benefits of increased frequency is reduced waiting time. This in turn allows public transport planners to design a connected network that relies on relatively few, high frequency lines. To highlight this point first consider a hypothetical city consisting of three origins and three destinations.

Figure 4.12 Comparing possible network structures in a hypothetical city



The network on the left has lines operating between every origin and every destination, which results in a total of nine lines. Assume for the moment that each line can be run every 30 minutes. The network on the right, in contrast, consists of only three lines, which are designed to intersect at a single point, where passengers can connect with all other services. Because the network on the right has three lines instead of nine, it can run each line at three times the frequency for the same budget: Every 10 minutes instead of every 30 minutes (NB: The difference in frequency is indicated by the thickness of the lines).

Most crucially, the increased frequency can actually save (or at the very least not increase) overall travel-time even for people who must now connect to complete their trip. For example:

- **Direct-only network** – average travel time from 'Residential 1' to 'Activity area 2' consists of waiting time (30 minutes/2 = 15 minutes)[7] plus in-vehicle time of 15 minutes = *30 minute journey*.
- **Connected network** – average travel time from 'Residential 1' to 'Activity area 2' consists of initial waiting time (10minutes/2 = 5 minutes), plus second waiting time of 5 minutes, plus in-vehicle time of 15 minutes = *25 minute journey*.

Travellers who do not have to connect to complete their trip (which the network design can seek to minimise to some degree) will benefit from vastly improved frequency, with all its associated benefits.

Thus, by creating a connected network consisting of high frequency lines we have in this case been able to improve total journey time. We have also greatly simplified the network and in the process made it far more legible for all users. Finally, the point at which the lines intersect obviously becomes an additional opportunity for urban intensification, because from this location people can access high frequency public transport service to an unusually wide range of destinations.

[7] Of course, at lower frequencies passengers will time their arrival so as to reduce waiting time. Nonetheless, there is still a convenience penalty associated with having to time ones arrival, which may even result in time spent 'waiting' at home. Thus while uniform arrivals is likely to over-state the actual waiting-time at lower frequencies, we think that it is a useful first-order approximately of the time and inconvenience associated with low frequency services.

In the long run connected networks have another key advantage: lines in the network tend to leverage off, or indirectly benefit from, improvements (in terms of frequency or otherwise) that occur elsewhere on the network. Consider, for example, a situation where frequency on the red line in figure 4.12 was increased. This would not only directly benefit users of that line, but also any users of the blue and green lines that connected with the red line for part of their journey. The so-called 'network effect' (credited to Dr Paul Mees and often found in other disciplines, such as telecommunications) observes that connected networks tend to have synergistic, or complementary, effects.

The primary downside of moving to a connected network is that when a journey requires a connection, the quality of the environment where connections occur is also important. Experience suggests that in high-quality environments people will connect readily. For this reason, embracing a connected network requires a change in the way that New Zealand's cities and towns design new stops and intersections. Current traffic engineering practice, for example, is to build slip lanes into intersection footprints. This will need to be avoided in situations where it prevents buses from stopping close to the intersection, because this is where connections between lines will typically need to occur. Additional supporting infrastructure, such as pedestrian facilities, may also be required.

4.3 Land use policies

In this section we examine how the land use policies pursued by regional and local councils can contribute to improved urban form. The following sections are structured as follows:

- Section 4.3.1 considers how to *remove impediments to* a more efficient and durable urban form.
- Section 4.3.2 discusses how to *incentivise* a more efficient and durable urban form.
- Section 4.3.3 summarises how councils might *manage* urban expansion.

4.3.1 Removing impediments

Rectifying regional and local council policies that act as impediments to efficient urban form should be a priority. Feedback from the private sector confirms our own professional experience (ARC 2006, p14):

> *Developers express a desire to produce better quality higher density developments but believe this is hindered by delays in the consent process as well as existing planning rules. A vast majority of developers indicate that planning rules are a constraint to intensification. In general, the main issues for developers with planning rules surround their rigid application. These rules may not apply well to specific site conditions and the application of them is found to be counter to achieving the benefits of a more compact and liveable city. Excessive parking requirements and limits on height restrictions were the two examples used. Both developers and planning consultants consider that planning rules do not reward innovation and the pursuit of quality development. Where developers are interested in varying design and height, they say that certainty of consent becomes almost negligible.*

In this section we present and discuss three land use policies that act as impediments to urban intensification, namely land use zoning, building height limits and minimum parking requirements.

4.3.1.1 Land use zoning

Land use zoning originally emerged during the nineteenth and twentieth centuries as a way of managing negative effects between residential, commercial and industrial activities.

But their application has become stricter and resulted in an increasingly hard and large separation between living and employment areas. As our literature review and subsequent analyses have shown, a separation of living and employment activities tends to increase the need for mobility, with all its associated economic costs.

In an economic sense, land use zoning effectively prevents land from being used for its highest and most productive use. Usually zoning will prevent the development of commercial activities in residential areas, notwithstanding the fact that many of these activities could service people in the surrounding community. This reduces land values and in turn undermines the density of land uses that can be supported.

Mixed urban environments typically offer a range of activities, such as housing, shopping, community facilities and employment, which not only reduce the need for mobility but also create opportunities for sharing of infrastructure. This suggests more relaxed land use zoning would provide greater opportunities for firms and households to co-locate, increasing non-car travel.

4.3.1.2 Building height limits

'Building height limits' are a regulatory intervention that seeks to constrain the height of new developments so as to avoid perceived adverse effects, such as shadows, on adjacent properties. While tall buildings no doubt do have negative impacts, we have not found any evidence to suggest that the economic costs imposed by building height limits outweigh the economic benefits of increased density.

Stated differently, the negative effects of tall buildings, such as shadow effects and visual impacts, need to be weighed up against the positive economic benefits associated with higher density, namely agglomeration economies. We suggest that comparisons of the costs and benefits of high buildings are an important pre-requisite for the imposition of more informed building height limits.

In our experience, building height limits are often set at levels that are so low they make further development uneconomic. Often natural economies of scale in more intensive development cannot be achieved in the presence of building height limits, especially those that are set at low levels. In particular, multi-level buildings tend to incur fixed costs that are somewhat decoupled from height, such as elevators and fire safety systems. In our experience, building height limits that constrain development to less than four to five storeys are likely to be a major impediment to urban intensification.

Another related issue is that building height limits often become a tool through which local residents seek to block new development. In these cases building height limits effectively get hijacked by pecuniary local interests (ie homeowners) who have a vested interest in constraining the supply of new development in their surrounding areas because of negative localised effects (perceived or real). In the US there is some evidence to suggest that areas with higher incomes are more successful in blocking new developments, which in turn serves to preserve local exclusivity (Glaeser et al 2005).

Ultimately, building height limits are a potential constraint on the degree to which urban areas can develop vertically, in which case greater horizontal expansion becomes more likely. As such, we suggest that building height limits may, on balance, undermine the efficiency of New Zealand's urban form.

4.3.1.3 Minimum parking requirements

Minimum parking requirements are the single most significant impediment to a more efficient and durable urban form. In many of New Zealand's newer town centres parking is the single largest land use.

By way of background, minimum parking requirements were first applied in Los Angeles in the 1950s, as a means of shifting responsibility for providing parking onto private developers. At the time, rapid growth in car ownership was placing pressure on public parking and creating congestion.

The idea behind minimum parking requirements seems simple enough – they ensure new developments provide sufficient parking to meet their own demand for parking. And at least initially they seemed to work: by ensuring lots of parking was provided at every destination, drivers were able to park quickly and conveniently wherever and whenever they desired. As a result, many places around the world followed Los Angeles' lead and enacted minimum parking requirements in their respective jurisdictions.

Hindsight shows that minimum parking requirements have had hugely negative consequences. In the long run minimum parking requirements have generated more congestion, because they have increased the supply (and hence lowered the cost) of parking. This has subsidised vehicle ownership and travel and undermined uptake of other transport modes. Travel behaviour studies show a strong link between the availability and cost of parking and people's tendency to drive. Because minimum parking requirements effectively create a subsidy for drivers, people end up driving more and creating more, not less, congestion.

Minimum parking requirements also lower the density of land use activities, as illustrated in the following figures, which highlight land used for parking in Manukau City Centre and Albany Town Centre.

Figure 4.13 Land used for car-parking – Manukau and Albany Centres, Auckland

These aerial images show that in these town centres parking has become the single largest land use. While approximately 40 years separate the development of the town centres at Manukau and Albany, both appear to be following similar development patterns, especially with respect to parking. The negative consequences of minimum parking requirements have also been widely documented elsewhere (see, for example, Cervero (1985), Donovan and Genter (2008), Litman (2006), and Shoup (1999; 2005)).

Many cities and towns in New Zealand require approximately one car-park for approximately 30m^2 of gross floor area (GFA). Every individual car-park typically requires 30m^2 (once space for access and manoeuvring is considered), so these requirements mean that 30m^2 of parking needs to be provided to support 30m^2 of GFA, ie a 1:1 ratio between space used for parking and floor area. In this situation parking will take up as much space as the development itself – hence giving rise to the development outcomes illustrated above.

On the bright side, more urban areas are electing to remove minimum parking requirements. Auckland City Council, for example, removed minimum parking requirements in the city centre in 1999. Since that time the city centre has undergone something of a renaissance, as new development has increased density and land values in the city centre, relative to other areas of Auckland (Grimes and Liang 2007). Similarly, Rotorua District Council has recently proposed to remove minimum parking requirements in their city centre. Other cities and towns in New Zealand would do well to follow this lead.

4.3.2 Providing incentives

While the previous section considered impediments to a more efficient and durable urban form, this section will consider more positive topics. Here we examine how regional and local council policies could make intensive development more attractive.

In our experience, regional and local councils have not fully explored opportunities to incentivise better urban form. This view seems to be shared by the development community, which made the following comments during interviews with the Auckland Regional Council (ARC 2006):

> *There are too many sticks and not enough carrots. You won't get the development you want without some incentive.*
>
> *There is a need for outcomes driven process; incentives for doing right thing & rewards for new things.*

The value of incentives is that they help to align the interests of the public and private sector. They also tend to operate at the margin – that is, they provide continued impetus for more efficient urban development outcomes. The following sections focus on two opportunities for incentives, namely development contributions and transport rates.

4.3.2.1 Development contributions

Regional and local councils require new developments to make contributions so as to meet their share of growth and in some instances to mitigate specific effects, such as congestion. In most parts of New Zealand, the growth component is calculated based on standard units of transport demand.

In the former Auckland city, for example, the council levied developments based on household unit equivalents (HUEs) as outlined in table 4.1.

Table 4.1 Commercial and retail definitions of HUEs

Type of development	Trips (per 100m^2 per day)	Assessment factor
Commercial	11	1.22 HUEs per 100m2 GFA
Retail	34	3.78 HUEs per 100m2 GFA

The former Auckland City Council's development contributions policy set a charge of $2232 per HUE (excluding GST) for non-residential development consents.[8] This rate is multiplied by the HUE of the development to determine the baseline development contribution. For example, a 500m^2 commercial development would be charged transport contributions of 1.22*(500/100)*2232 = $13,615.

This methodology used to calculate development contributions is relatively blunt. It does not, for example, give consideration to the location of the development and whether it integrates with surrounding land uses. More intensive developments located in existing town centres and close to public transport facilities pay the same rate as if the development were located in car-dependent suburbs on the urban periphery.

Other councils have taken a different approach. In setting their development contributions, North Shore City Council (NSCC), for example, mapped the city in detail; established infrastructure capacity and service capacity by area; set out 10-year plans for future infrastructure; and set development contributions accordingly for each area. The nexus between need, user and allocation of costs is a legislative

[8] This rate applied to developments occurring within the financial year 1 July 2010 –30 June 2011.

requirement and we suggest that NSCC's approach is considerably more nuanced in this respect than that previously used by Auckland City Council (although there are other advantages of the latter's approach).

Regional and local councils could support intensification by tailoring their development contributions in ways to deliver the types of strategic urban form outcomes they want. Some factors that should figure in the calculation of development contributions include:

- proximity to high-quality public transport
- density and diversity of activities supported on site
- integration with surrounding activities, eg pedestrian connectivity
- provision of car parking.

We emphasise that these attributes are relatively local. They consider not just where the development is located in a broad sense, but also how it is configured in response to the surrounding environs.

We are not the first to identify weaknesses in the current approach to development contributions. For example, a joint report by the Local Government Forum and Property Council New Zealand (2010) identified significant problems with development contributions, including the high costs being passed on to consumers and the lack of transparency surrounding the calculations. They recommended the use of direct user charges as an alternative. While direct user charges (with appropriate safeguards to ensure equitable outcomes) are something to work towards, they will require sustained political support over several years or even decades. We suggest that in the interim, regional and local councils may wish to shape development contributions so as to incentivise efficient and durable urban form outcomes.

4.3.2.2 Transport rates

We now consider how regional and local authorities fund the provision of transport infrastructure and services. Typically, regional and local authorities use property rates to fund the development of transportation improvements.

Property rates are a relatively blunt instrument with which to fund transport infrastructure and services. Basing transport rates on property values tends to penalise high-value properties located in central locations. Property values are usually just an indicator of density, which (all other factors being equal) tends to generate less demand for vehicle travel. Thus, basing transport rates on property values effectively discourages more intensive development, which tends to be less dependent on private vehicles, and in the process penalises accessible development in central locations.

So how can transport rates be adjusted to support better transport outcomes? We see two broad options. One is to 'tailor' transport rates so they are based not on property values but instead linked more directly to the degree with which certain areas generate vehicle travel that leads to congestion. In this case, the additional costs of travel demands generated by a particular part of the city could be estimated using strategic regional transport models, where the traffic generated by each zone is iteratively reduced. The reduction in total congestion costs attributed to the removal of traffic from a particular zone would provide an indication of the costs of serving that particular zone. Targeted transport rates could then be levied based on the relative contributions of each zone to total network congestion, in much the same way that public transport rates are often targeted, eg in Auckland.

A second, less data intensive approach would be to base transport rates for commercial properties not on property values, but instead on the number of on-site car-parks that they provide. The number of on-site car-parks is likely to be a reasonably accurate indication of a development's actual traffic-generating potential. While a parking levy could be designed to be fiscally neutral in aggregate, the effect of the parking levy would be to raise more rates from those properties that provide less parking. We note that parking levies are currently applied in several Australian cities, specifically in central areas in Sydney, Melbourne and Perth. In Australian cities parking levies vary from $200 in Perth to $2000 in central Sydney. In Sydney parking levies raise approximately AU$100 million per year, which is hypothecated to transport improvements. Nottingham, UK has also recently introduced a workplace parking levy. Parking levies work best in areas where minimum parking requirements have been removed (as per our earlier recommendations), so that affected developments are able to re-develop existing parking to reduce their financial liability.[9] The primary motivation for replacing transport rates with an annual parking levy is that it creates a direct incentive for developments – both existing and new – to provide less off-street parking.[10] Further work could seek to establish whether such a levy is possible under existing legislation, or whether further legislative amendments are required (Donovan and Genter 2008).

On balance, it is clear that the way general transport rates are currently levied has the potential to have adverse (and somewhat perverse) impacts on urban form. Instead of linking transport rates to property values we have identified two possible alternatives, namely a zone-based rate based on external costs of congestion, or an annual parking levy linked to the number of on-site car-parks. A key advantage of these types of changes is that they apply to both existing and new developments. In this way, these changes create a broad-based incentive for more efficient and durable urban form.[11]

4.3.2.3 Allocation of street space

Finally, we note that many central city areas in New Zealand are starting to recognise the benefits of 'place-based' development patterns that are conducive to the exchange of ideas, such as streets that engage actively with adjacent cafes and other spaces. Research suggests it is these kinds of urban environments that attract people and firms and create conditions for property investment and more intensive employment opportunities that seem to underpin agglomeration economies.

A place-based city tends to rely on tight and dynamic land uses that weave density, design and originality into the fabric of its neighbourhoods and public spaces, including in particular street networks. High-quality pedestrian amenity is part of this process. Barcelona and Portland are prime examples of this approach to urban development.

One of the easiest ways for regional and local councils to influence their existing urban form is through changing the allocation of street space in areas that might support these types of activities. We emphasise this is not a universal panacea, but when carefully targeted to particular streets it can help households and businesses to spatially self-sort in areas that are better suited to their tastes.

[9] Naturally, if the total number of off-street car-parks decreases, then revenue from the levy will also decline, unless it is accompanied by a commensurate increase in the levy. This suggests that the parking levy (per car-park) would need to increase over time, until such point as the parking supply reaches some form of equilibrium where people are prepared to pay cost of the levy. The net effect of the parking levy on public finances is likely to be positive because it will over time support less vehicle dependent, centrally located development patterns and increase uptake of public transport. The additional fare revenues and lower operating subsidies should reduce the need for operating subsidies. Stated differently, the annual parking levy would contribute to a more financially sustainable public transport system.

[10] A parking levy will also fall disproportionately on low density, vehicle dependent developments on the urban periphery and reduce the burden on high-value centrally located properties. Thus in one enlightened swoop councils could create an incentive for more compact developments (ie that have less parking) while also encouraging development more central locations (ie where they can be accessed by a variety of transport modes).

[11] One final comment is also warranted – where rates are applied to the value of capital improvements, they may serve to discourage more intensive development (Brueckner 2009). Rather than considering the value of capital improvements, council rates should, as much as possible, be calculated based on the value of land.

4.3.3 Managing urban expansion

Some cities and towns in New Zealand are growing and grappling with urban expansion.

Debates on urban expansion are highly polarised. On one side are the 'free marketeers' who lament controls on urban expansion, such as Auckland's metropolitan urban limits, because they reduce the supply of land and thereby push up the direct cost of development. On the other side of the debate are the 'smart growthers' who argue that unfettered urban expansion has negative external effects, such as traffic congestion, which public policies need to manage. We see merit on both sides of the debate. It seems clear that a limit on urban expansion will increase land values. On the other hand, there also seems little doubt that development on the urban periphery is likely to generate external economic costs that are borne neither by developers nor the future occupants of that development.

The key economic issue discussions on urban expansion have not yet been able to answer is this: how much is society willing to pay in order to reduce urban expansion? Some recent studies have suggested that the productivity benefits of a more compact urban form are equivalent to the macroeconomic reforms of the 1980s and 1990s (MfE 2006). Many of these benefits are associated not only with efficiencies in infrastructure provision, but also the productivity enhancing benefits of density.[12] Reducing urban expansion may benefit existing residents by preserving their access to rural open space, which for many people (especially in New Zealand) seems to have aesthetic value. Urban expansion makes it more difficult for many people to access rural open space and thus imposes a negative externality on existing city residents, who must now travel further to escape the city. Indeed, aesthetic values feature prominently in many documents that advocate for controls on urban expansion.

We believe a more pragmatic and informed debate on the merits of urban expansion is required.

The position of the free marketeers tends to ignore the fact that land use and transport markets are currently highly distorted and thereby unlikely to deliver efficient outcomes, at least when left to their own devices. Subsidies for car travel can mean that urban growth expands horizontally beyond what is economically efficient, ie they result in too much urban expansion. And because housing is a durable good, it is simply not plausible to suggest that we can reverse the expansion at a later stage. The very existence of sub-economic urban expansion in the past may even make 'first best' pricing measures, such as time-of-use road pricing and parking reforms, all the more difficult to implement. Put simply, once the urban expansion horse has bolted it is likely to be relatively difficult to get it back in the stable. For these reasons, a free marketeer approach to urban expansion would right now be likely to result in sub-optimal levels of urban sprawl, which in the long run act as barriers to efficient outcomes.

For their part, the smart growthers need to recognise that the presence of distortions in transport and land use markets provides only limited support for government intervention. And the best solution is, of course, to address the transport and land use distortions directly through the implementation of accurate pricing signals, such as parking pricing and time-of-use road pricing. So in responding to transport and land use distortions the smart growthers need to clearly link policies to the negative effect that they are trying to rectify, and support their policies by detailed analysis showing that they are the most effective way to achieve that outcome. The presence of market failure is a necessary but insufficient premise for policy intervention.

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[12] Although it should be noted that while managing urban expansion can contribute to an increase in urban density, it may do so as the expense of urban scale. Stated differently, if policies contributed to higher housing costs then they may cause potential residents to migrate elsewhere, which will in turn reduce the size of the city and potentially undermine its ability to realise agglomeration economies.

For example, if more compact development delivers infrastructure cost savings, then can these cost savings be reflected in development contribution policies, rather than in a hard restriction on urban development? More accurately priced development contributions would ensure development on the urban periphery paid the full marginal costs of infrastructure provision. This links in with our previous discussion on how to make intensification more attractive though the use of incentives. Similarly, external effects of urban expansion, such as traffic congestion and aesthetic/conservation impacts, may be better managed by way of so-called 'Pigouvian taxes' or transferable development instruments that effectively seek to internalise the external social economic costs of urban expansion.

Thus, through the use of more tailored development contributions and targeted taxes, regional and local councils may be able to manage urban expansion while avoiding many of the pitfalls associated with 'hard' regulations. This is not to say that economic instruments should or can completely replace planning instruments – in some cases regulations may be the most efficient way to achieve a certain outcome. But it is to say that councils should try to avoid creating large distortions in land use development, which can lead to a variety of unintended and undesirable consequences, most notably distorted land values.

The debate on managing urban expansion is far from settled and considerable further research is needed to assess the relative effectiveness of different policies. This research needs to carefully distinguish potential costs (such as higher land prices) with the potential benefits of a more compact urban form, many of which have been discussed in earlier sections of this report.

5 Conclusions and recommendations

5.1 Conclusions

We conclude that urban form matters, insofar as it impacts on transport and economic outcomes:

- While the impacts of individual urban form attributes on transport outcomes are relatively modest, their cumulative impacts may be quite significant. By extension, urban form can have large impacts on the use of public transport and walking/cycling.
- Evidence suggests that urban transport corridors that balance mobility and amenity deliver more optimal economic outcomes. Residential and commercial land use activities seeming willing to pay more (by way of rents) to locate close to transport corridors that deliver both amenity and mobility.
- The supply of road infrastructure is positively related to the demand for vehicle travel; expansions in road capacity tend to be largely offset by higher demand. In the long run this suggests the primary impacts of transport projects are on urban form, rather than on mobility outcomes.
- Agglomeration economies suggest that the scale and density of urban areas impact on their economic productivity. Some types of agglomeration economies, such as knowledge spillovers, attenuate rapidly with distance, whereas others extend over a wide area, such as labour market effects. There is some evidence to suggest that agglomeration economies are strengthening over time.
- Insofar as changes to the urban form are able to reduce the demand for vehicle travel and/or increase demand for alternative modes, then it may be expected to have positive benefits for social and environmental outcomes, such as vehicle accident rates, physical activity, population health and energy efficiency. Improved street lighting seems to be particularly effective at improving the safety and security of urban areas.
- When quantifying the impacts on urban form on social and environmental outcomes, it is important to account for differences in underlying population preferences, ie self-selection. Longitudinal micro-data is useful in this respect, because it allows researchers to track the same individuals over time and thereby control (at least partially) for unobserved population characteristics, eg the types of people who like to live in dense urban environments are also those that prefer to walk and cycle.

5.2 Recommendations and opportunities for further research

Regional and local councils in New Zealand have a number of opportunities to improve their urban form. We identified opportunities to improve:

- Street networks – through a focus on connectivity and integration. Because of their durability, we suggest that street networks are an especially critical area for improvement.
- The effectiveness of public transport networks – by ensuring major destinations are located ‘on the way’ and supported by a network of frequent, simple lines.
- Land use policies – by removing impediments to efficient and durable urban forms, such as minimum parking requirements; incentivising good urban form outcomes, through for example targeted transport rates; and developing more targeted policies to manage urban expansion.

We suggest that a concerted, multi-pronged focus on improving policy outcomes in these areas will over time support significant improvements in New Zealand's prevailing urban form.

Several opportunities for future research emerge from this study, namely:

- How urban form impacts on New Zealand's ability to retain and/or attract mobile people and businesses.[13] This might consider whether migrants' origins impact on their travel patterns here, and whether this makes particular urban forms more likely and/or achievable.
- Improved input data, such as:
  - analysis of a wider suite of urban form variables, such as the supply of transport infrastructure and services, so as to better understand the full impacts of urban form
  - investigation of alternative transport data sets, such as Google Transit Feeds on public transport service levels
  - research into the impacts of urban form on transport and economic outcomes at finer spatial resolutions, such as census meshblock
  - identifying longitudinal micro-data sets that can be used to analyse the impacts of urban form at the level of individual people, businesses and households
  - inclusion of more recent data, such as the 2013 census results, when available.
- Case studies of situations where an efficient and durable urban form has resulted in transport and economic outcomes.
- Investigation of how wider technological and demographic trends might impact on transport outcomes, such as developments in telecommunications and an ageing population.
- Potential impacts of urban form on the economic efficiency of the public sector, such as costs of health, education and emergency services.

[13] This relationship was hinted at by our regression results, which found a negative relationship between proportion of the population with postgraduate degrees and levels of vehicle ownership/drive mode share.

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Appendix A: Types of agglomeration economies

The following sections provide a general background to agglomeration economies.

A1 Learning spillovers

Learning spillovers describe how proximity enables the informal transmission of ideas between people that positively affects their productivity effects. Because cities bring people into closer proximity, they are supposedly more conducive to learning spillovers. Detecting learning spillovers is problematic because they leave no paper trail; they are neither priced nor usually recorded. Most studies use proxies for spillovers, such as patent registrations or business formation (Jaffe et al 1993). Audretsch and Feldman (1996) found that industries in which leaning spillovers were expected to be important (ie research intensive industries) were more highly concentrated. Arzaghi and Henderson (2008) found strong evidence of learning spillovers among advertising agencies in Manhattan, where benefits were capitalised into land rents (as opposed to wages) and decayed to zero after 750 metres. The rapid spatial decay (or attenuation) of learning spillovers was confirmed by Rosenthal and Strange (2008), who also found that agglomeration economies were almost entirely attributed to the proximity to college educated workers, rather than lesser educated workers, which suggests that agglomeration economies are amplified by the presence of human capital. Proximity thus seems to be the primary lever through which society can extract ‘social returns’ from human capital (Moretti 2004). It also seems most relevant in industries in which face-to-face contact remains relatively important.

A2 Home market effects

Home market effects describe how a combination of transport costs and increasing returns to scale mean that firms can increase their profits by locating in larger regions. These profits in turn create real wage differentials that attract mobile labour to the region where the firm is located. Home market effects form the basis for models of new economic geography, in which so-called core regions create self-reinforcing growth, at the expense of peripheral regions (Krugman 1991). Davis and Weinstein (1999 and 2003) studied regional and national industrial location in Japan and the OECD respectively; they found some evidence to support the importance of home market effects. Sarvimäki et al (2009) examined the effects of Finnish re-settlement policies post-WWII, when 10% of the population were moved from areas ceded to the Soviet Union. They found that a 10% increase in population in the period 1939–49 was associated with a 15% increase from 1949–2000, mainly due to inward migration. Theory and evidence suggests that home market effects operate nationally and regionally, rather than locally.

A3 Labour market pooling

Labour market pooling describes the benefits to firms and employees from having access to larger labour markets. A large labour pool can enable more productive matches between workers and jobs. Second, a large labour pool affords greater flexibility (and hence lowers risk) in the face of uncertainty. For example, in a large labour market, workers who find themselves unemployed are more easily able to find alternative employment without having to change their place of residence. At the same time, firms can more easily adjust their workforce size by hiring and firing as and when needed, because there is an external pool of firms and workers that can respond to the changes. Diamond and Simon (1990) found that returns to labour were higher in more specialised cities, implying that wages are sensitive to unemployment risks. Costa and Kahn (2000) presented evidence to suggest that highly educated couples were able to solve their co-location problem by living in larger cities where they could access specialised labour markets. Put simply, larger urban areas are able to reduce the risks and increase the returns for workers. We would expect the benefits of labour markets to operate within urban areas where reasonable commuting times are possible.

A4 Consumer benefits

Consumer benefits describe how urban areas can deliver benefits to consumers through, for example, providing access to a more diverse range of consumer goods. Tabuchi and Yoshida (2000) investigated agglomeration economies in Japan within an empirical framework that allowed them to estimate both nominal and real wages.[14] They found that a doubling in city size was associated with nominal wages that were 10% higher, which s consistent with the productivity enhancing effects of agglomeration discussed above. On the other hand, high costs of living (mainly associated with higher rents) mean that real wages are 7% to 12% lower than elsewhere. This suggests that the productivity enhancing benefits of agglomeration economies do not flow through to the consumer, but are actually captured in rents. Because real wages are actually lower in larger cities, Tabuchi and Yoshida inferred that consumers did not benefit from agglomeration economies in production, but instead had to enjoy some other compensating benefits in consumption. Glaeser et al (2001) presented a number of stylised facts pointing towards the increasing importance of consumption, such as the rise of reverse commuting, the success of high amenity cities, increasing demand for urban amenity and increasing wealth in inner-city areas.[15]

A5 Fiscal externalities

Fiscal externalities describe how increased scale and/or density enables public goods, such as street lighting, to be delivered more efficiently.[16] Fiscal externalities reflect true scale economies, whereby every additional person and firm that chooses to locate in a particular urban area reduces the fiscal burden associated with providing public goods to everyone else (Roos 2004). The presence of fiscal externalities in the provision of public goods and infrastructure is a major reason why many regional and local authorities implement policies to manage urban growth. This topic is discussed in more detail in section 4.3.3.

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[14] Nominal wages are what the employer pays, ie before tax and other deductions. Real wages are what is received by the employee, ie after tax, but adjusted for the cost of living, which is particularly important in larger cities where rents are considerably higher than elsewhere.

[15] Some of the stylised facts identified by Glaeser et al (2001) are not only explained by consumer benefits from agglomeration. Le Roy and Sonstelie (1983), for example, explained re-gentrification of inner-city suburbs (which may in turn explain growth in reverse commuting and increased wealth in inner-city areas) in terms of interactions between the uptake of new transport technologies and residential location. According to LeRoy and Sonstelie's model, the re-gentrification of inner-city suburbs reflects how increased vehicle ownership has enabled low-income households to outbid high-income households on the urban fringe. Re-gentrification of the inner city is here cast not as a new economic phenomenon, but instead a return to a historical economic equilibrium.

[16] We use the term 'public goods' in to loosely describe goods and services delivered by government authorities, rather than the strict economic definition that refers to goods/services that are non-rivalrous and non-excludable.

Appendix B: Estimating agglomeration economies

The following sections provide a detailed explanation of the methodology by which we have estimated agglomeration economies.

B1 Stage 1 – estimating land values

Our preferred hedonic regression model has the following specification:

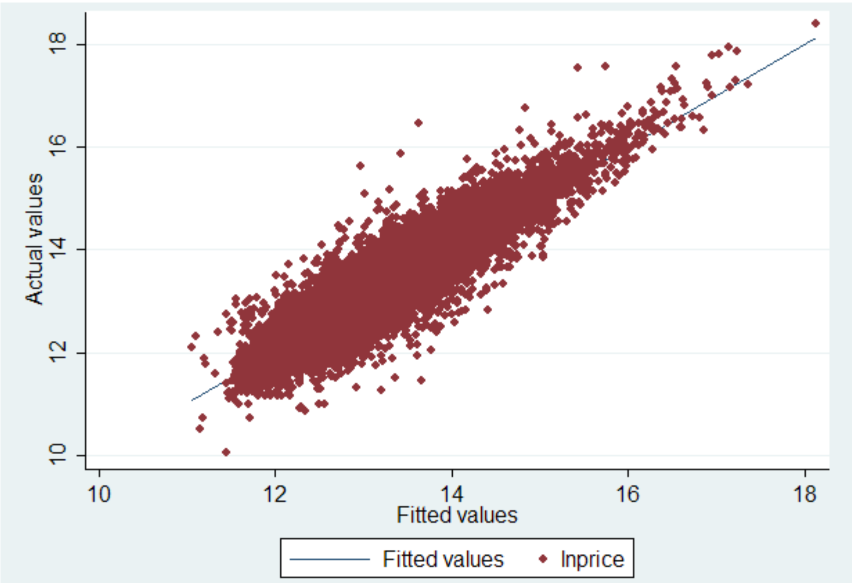
$$\ln(\mathrm{P_i}) = \alpha + r_j.\ln(\mathrm{L_i}) + f_j.\ln(\mathrm{F_i}) + f_j^C.\mathrm{D_i}.\ln(\mathrm{F_i}) + t_{qT}.\ln(\mathrm{L_i}).\mathrm{T_i} + \sum_{k \in K} \gamma_k.\mathrm{A_{ik}}$$

Where:

- $\mathrm{P_i}$ is the sales price for property transaction i and α is the constant of regression
- r_j is the price elasticity wrt land area (L) in CAU j, while $\mathrm{L_i}$ is the land area of property transaction i
- f_j is the price elasticity wrt floor space (F) in CAU j, while $\mathrm{F_i}$ is the floor space of property transaction i
- f_j^C is the price elasticity 'premium' wrt commercial floor space in CAU j. $\mathrm{D_i}$ is a dummy variable where $\mathrm{D_i}$= 1 when property transaction i is a commercial property, and $\mathrm{D_i}$= 0 otherwise
- t_{qT} is the time fixed effect for land in local council q in time period T, which is a dummy that defines the year and quarter when the property transaction occurred
- γ_k is the price elasticity wrt property specific attributes, A, including building/roof conditions and views.

Predicted versus actual values for our hedonic regression model are illustrated below. This shows how the predicted model fits the data well and is reasonably well-behaved (ie few outliers are evident).

Figure B.1 Actual versus fitted property values



We estimated the model with 112,943 observations. The final model estimated coefficients for approximately 1000 variables and had an R-squared of 0.8799, with a root mean-square error of 0.1982.

An expression for the marginal value of land is then found by taking the total derivative of the hedonic regression model and rearranging as follows (NB: A conditional derivative is used because the marginal value of land varies by property transaction i and CAU j:

$$\frac{1}{P_i}.dP = \frac{r_j}{L_i}.dL \rightarrow \left.\frac{dP}{dL}\right|_{i,j} = r_j.\left(\frac{P_i}{L_i}\right)$$

Once we have calculated the marginal value of land for each property transaction, it is then straight-forward to estimate the weighted-average marginal value of land in each CAU.

Due to the large number of variables it is not possible to report comprehensive regression results. Instead we here report only the coefficients for the price elasticity of land in each CAU. The table below summarises coefficients, standard errors, p-values, and confidence intervals for the r_j coefficients. All coefficients have the expected sign and are statistically significant. Statistically insignificant coefficients are associated with CAUs that had small data sample and/or exhibited high degrees of heterogeneity.

Table B.1 Elasticities of price with respect to land area by census area unit

CAU	r_j	S.E.	P>|t|	[95% CI]		CAU	r_j	S.E.	P>|t|	[95% CI]	
505300	0.1926	0.0305	0	0.1329	0.2523	516301	0.2612	0.0331	0	0.1963	0.3261
505400	0.3043	0.0454	0	0.2153	0.3933	516302	0.1597	0.0148	0	0.1308	0.1887
505500	0.1762	0.0221	0	0.1328	0.2196	516400	0.2656	0.0264	0	0.2140	0.3173
505600	0.1898	0.0290	0	0.1330	0.2467	516500	0.2505	0.0383	0	0.1755	0.3256
505700	0.5280	0.1192	0	0.2944	0.7615	516601	0.2170	0.0296	0	0.1589	0.2750
505802	0.1915	0.0210	0	0.1504	0.2326	516602	0.2159	0.0379	0	0.1416	0.2903
505803	0.1842	0.0960	0.055	-0.0039	0.3723	516700	0.2938	0.0354	0	0.2244	0.3633
505804	0.2085	0.0247	0	0.1601	0.2569	516800	0.4393	0.0568	0	0.3280	0.5506
505805	0.1941	0.0200	0	0.1548	0.2334	516900	0.1416	0.0161	0	0.1100	0.1731
505902	0.2739	0.0151	0	0.2443	0.3036	517001	0.2142	0.0413	0	0.1332	0.2952
505904	0.1588	0.0177	0	0.1241	0.1935	517002	0.2166	0.0566	0	0.1056	0.3276
505906	0.2306	0.0356	0	0.1608	0.3003	517100	0.0882	0.1431	0.538	-0.1924	0.3687
505907	0.2522	0.0273	0	0.1986	0.3057	517200	0.2738	0.0440	0	0.1876	0.3601
505908	0.2054	0.0211	0	0.1641	0.2467	517400	0.0693	0.0252	0.006	0.0198	0.1187
505909	0.2071	0.0200	0	0.1679	0.2462	517500	0.3353	0.0439	0	0.2492	0.4213
505910	0.1376	0.0123	0	0.1134	0.1617	517600	0.2174	0.0462	0	0.1268	0.3080
506000	0.2730	0.0215	0	0.2309	0.3152	517701	0.2394	0.0253	0	0.1898	0.2890
506200	0.1956	0.0303	0	0.1362	0.2550	517702	0.2358	0.0178	0	0.2009	0.2708
506300	0.0904	0.0316	0.004	0.0285	0.1524	517703	0.1909	0.0707	0.007	0.0524	0.3294
506613	0.2086	0.0644	0.001	0.0824	0.3348	517800	0.2842	0.0246	0	0.2359	0.3325
506614	0.2304	0.0223	0	0.1867	0.2741	517901	0.3422	0.0265	0	0.2902	0.3941
506616	0.3303	0.0492	0	0.2339	0.4266	517902	0.3352	0.0597	0	0.2181	0.4522
506620	0.2708	0.0563	0	0.1605	0.3811	517903	0.1729	0.0402	0	0.0941	0.2517
506631	0.2524	0.0158	0	0.2215	0.2833	518101	0.3910	0.0680	0	0.2577	0.5243
506632	0.3994	0.0362	0	0.3285	0.4703	518102	0.3297	0.0444	0	0.2427	0.4166
506641	0.2060	0.0261	0	0.1548	0.2572	518201	0.3578	0.0340	0	0.2911	0.4244
506642	0.3285	0.0452	0	0.2400	0.4170	518202	0.3400	0.0387	0	0.2641	0.4159

CAU	r_j	S.E.	P>|t|	[95% CI]		CAU	r_j	S.E.	P>|t|	[95% CI]	
506643	0.2526	0.0175	0	0.2183	0.2868	518301	0.2755	0.0271	0	0.2223	0.3287
506651	0.2751	0.0284	0	0.2194	0.3308	518302	0.2986	0.0271	0	0.2454	0.3517
506652	0.3052	0.0577	0	0.1921	0.4184	518500	0.1542	0.0214	0	0.1124	0.1961
506653	0.1884	0.1219	0.122	-0.0504	0.4272	518600	0.2973	0.0178	0	0.2624	0.3322
506800	0.1518	0.0190	0	0.1145	0.1890	518701	0.2473	0.0143	0	0.2193	0.2754
506901	0.2248	0.0253	0	0.1752	0.2745	518702	0.2267	0.0243	0	0.1791	0.2743
506902	0.2789	0.0407	0	0.1991	0.3588	518801	0.2535	0.0324	0	0.1900	0.3170
506903	0.1506	0.0234	0	0.1048	0.1964	518802	0.2222	0.0381	0	0.1476	0.2967
507000	0.2009	0.0245	0	0.1528	0.2490	518803	0.2393	0.0297	0	0.1811	0.2975
507101	0.1635	0.0363	0	0.0922	0.2347	518901	0.2504	0.0218	0	0.2077	0.2931
507102	0.2180	0.0154	0	0.1878	0.2483	518902	0.2147	0.0208	0	0.1739	0.2556
507200	0.2052	0.0282	0	0.1500	0.2604	519001	0.2637	0.0233	0	0.2180	0.3094
507300	0.1367	0.0260	0	0.0858	0.1877	519002	0.2899	0.0269	0	0.2372	0.3427
507400	0.2211	0.0270	0	0.1681	0.2741	519200	0.2280	0.0333	0	0.1628	0.2932
507500	0.2072	0.0451	0	0.1188	0.2956	519300	0.3535	0.0625	0	0.2310	0.4761
507710	0.1606	0.0363	0	0.0894	0.2318	519400	0.1561	0.0246	0	0.1079	0.2043
507720	0.1905	0.0230	0	0.1454	0.2357	519500	0.4160	0.0748	0	0.2695	0.5626
507800	0.1832	0.0586	0.002	0.0683	0.2982	519710	0.2929	0.0288	0	0.2365	0.3493
507900	0.3601	0.0442	0	0.2734	0.4468	519720	0.1849	0.0269	0	0.1322	0.2376
508010	0.1669	0.0476	0	0.0735	0.2603	519810	0.3414	0.0280	0	0.2866	0.3962
508020	0.1905	0.0448	0	0.1027	0.2784	519820	0.2164	0.0361	0	0.1456	0.2872
508110	0.1743	0.0817	0.033	0.0142	0.3343	519900	0.1460	0.0245	0	0.0979	0.1940
508120	0.1551	0.0338	0	0.0888	0.2214	520000	0.3388	0.0364	0	0.2674	0.4102
508210	0.2702	0.0252	0	0.2209	0.3195	520201	0.2166	0.0297	0	0.1584	0.2747
508220	0.2433	0.0195	0	0.2051	0.2814	520202	0.2252	0.0519	0	0.1235	0.3270
508310	0.2775	0.0175	0	0.2432	0.3118	520300	0.2656	0.0277	0	0.2112	0.3199
508320	0.2706	0.0308	0	0.2102	0.3310	520401	0.1128	0.0167	0	0.0800	0.1455
508411	0.2641	0.0221	0	0.2208	0.3074	520402	0.1891	0.0201	0	0.1497	0.2286
508412	0.2482	0.0197	0	0.2097	0.2867	520500	0.0977	0.0292	0.001	0.0404	0.1549
508420	0.1736	0.0221	0	0.1304	0.2168	520601	0.1200	0.0345	0.001	0.0524	0.1876
508510	0.2827	0.0143	0	0.2547	0.3107	520602	0.1833	0.0435	0	0.0980	0.2685
508520	0.1868	0.0176	0	0.1523	0.2213	520801	0.2040	0.0144	0	0.1757	0.2323
508610	0.3430	0.0159	0	0.3119	0.3742	521000	0.1680	0.0544	0.002	0.0614	0.2745
508620	0.2862	0.0355	0	0.2167	0.3557	521111	0.2625	0.0615	0	0.1420	0.3830
508701	0.1313	0.0310	0	0.0705	0.1920	521112	0.3044	0.1068	0.004	0.0951	0.5138
508703	0.2111	0.0205	0	0.1709	0.2512	521121	0.2014	0.0444	0	0.1144	0.2883
508704	0.1253	0.0458	0.006	0.0356	0.2151	521122	0.2453	0.0372	0	0.1724	0.3183
508803	0.1969	0.0322	0	0.1339	0.2600	521132	0.3295	0.0448	0	0.2416	0.4174
508804	0.1265	0.0208	0	0.0858	0.1673	521151	0.3213	0.0529	0	0.2177	0.4249

CAU	r_j	S.E.	P>|t|	[95% CI]		CAU	r_j	S.E.	P>|t|	[95% CI]	
508805	0.1037	0.0675	0.125	-0.0286	0.2360	521152	0.2361	0.0571	0	0.1241	0.3481
508806	0.1644	0.0321	0	0.1016	0.2273	521160	0.1339	0.0917	0.144	-0.0459	0.3136
508807	0.1379	0.0562	0.014	0.0278	0.2480	521201	0.3598	0.0667	0	0.2291	0.4905
508900	0.2779	0.0273	0	0.2243	0.3315	521202	0.5596	0.0039	0	0.5519	0.5674
509000	0.2258	0.0308	0	0.1655	0.2860	521203	0.5462	0.0039	0	0.5385	0.5538
509100	0.2237	0.0109	0	0.2022	0.2451	521301	0.2144	0.0412	0	0.1336	0.2951
509300	0.3224	0.0267	0	0.2701	0.3746	521302	0.5299	0.0041	0	0.5219	0.5379
509400	0.2390	0.0246	0	0.1909	0.2872	521501	0.2856	0.0516	0	0.1845	0.3867
509500	0.4300	0.0372	0	0.3572	0.5028	521502	0.2470	0.0378	0	0.1729	0.3211
509701	0.2585	0.0190	0	0.2213	0.2958	521601	0.2810	0.0197	0	0.2424	0.3196
509702	0.1371	0.0311	0	0.0761	0.1981	521602	0.2582	0.0250	0	0.2092	0.3072
509800	0.2375	0.0304	0	0.1779	0.2970	521801	0.1151	0.0363	0.002	0.0440	0.1862
510010	0.2413	0.0221	0	0.1980	0.2846	521802	0.2163	0.0516	0	0.1153	0.3174
510020	0.1448	0.0161	0	0.1132	0.1764	521803	0.2074	0.0339	0	0.1409	0.2739
510210	0.3210	0.0165	0	0.2886	0.3534	521901	0.1065	0.0293	0	0.0490	0.1640
510220	0.2294	0.0214	0	0.1874	0.2714	522100	0.1895	0.0149	0	0.1603	0.2187
510401	0.1817	0.0162	0	0.1500	0.2134	522201	0.1945	0.0295	0	0.1367	0.2522
510402	0.2900	0.0233	0	0.2443	0.3358	522202	0.2938	0.0571	0	0.1818	0.4057
510500	0.2389	0.0328	0	0.1747	0.3031	522301	0.3005	0.0370	0	0.2279	0.3731
510700	0.1010	0.0385	0.009	0.0255	0.1765	522302	0.1854	0.0196	0	0.1468	0.2239
510800	0.1483	0.0335	0	0.0825	0.2140	522400	0.1850	0.0229	0	0.1401	0.2299
511001	0.2226	0.0220	0	0.1795	0.2657	522601	0.2835	0.0315	0	0.2218	0.3453
511002	0.1397	0.0164	0	0.1075	0.1719	522603	0.3010	0.0588	0	0.1857	0.4164
511100	0.2321	0.0146	0	0.2035	0.2607	522604	0.3087	0.0470	0	0.2166	0.4008
511301	0.1740	0.0244	0	0.1261	0.2218	522711	0.1799	0.0141	0	0.1522	0.2075
511302	0.1823	0.0194	0	0.1443	0.2203	522712	0.2940	0.0175	0	0.2598	0.3283
511303	0.2923	0.0599	0	0.1749	0.4097	522721	0.2082	0.0388	0	0.1321	0.2844
511401	0.1505	0.0130	0	0.1250	0.1760	522722	0.2200	0.0180	0	0.1848	0.2553
511402	0.2399	0.0249	0	0.1911	0.2888	522723	0.3161	0.0172	0	0.2824	0.3498
511601	0.1769	0.0150	0	0.1475	0.2064	522730	0.1744	0.0290	0	0.1176	0.2312
511602	0.2590	0.0311	0	0.1981	0.3199	522810	0.2638	0.0253	0	0.2142	0.3135
511700	0.1755	0.0242	0	0.1280	0.2229	522820	0.1076	0.0276	0	0.0536	0.1616
511800	0.1602	0.0112	0	0.1383	0.1822	522910	0.2110	0.0192	0	0.1734	0.2486
511901	0.1782	0.0167	0	0.1455	0.2110	522920	0.2149	0.0163	0	0.1830	0.2469
511902	0.2151	0.0132	0	0.1892	0.2409	523000	0.3467	0.0144	0	0.3184	0.3750
512000	0.2221	0.0151	0	0.1925	0.2517	523101	0.3308	0.0312	0	0.2697	0.3919
512100	0.2717	0.0400	0	0.1933	0.3501	523102	0.1457	0.0617	0.018	0.0247	0.2667
512201	0.2699	0.0203	0	0.2301	0.3098	523105	0.1052	0.0143	0	0.0772	0.1332
512202	0.1289	0.0118	0	0.1059	0.1520	523106	0.0664	0.0168	0	0.0335	0.0994

CAU	r_j	S.E.	P>|t|	[95% CI]		CAU	r_j	S.E.	P>|t|	[95% CI]	
512300	0.1357	0.0081	0	0.1199	0.1516	523107	0.3242	0.0372	0	0.2513	0.3971
512401	0.2273	0.0169	0	0.1941	0.2605	523108	0.1315	0.0245	0	0.0836	0.1794
512402	0.2392	0.0147	0	0.2104	0.2679	523109	0.3031	0.1230	0.014	0.0620	0.5441
512500	0.2085	0.0124	0	0.1841	0.2329	523110	0.5381	0.0283	0	0.4827	0.5935
512600	0.2110	0.0195	0	0.1729	0.2492	523111	0.2194	0.0314	0	0.1578	0.2810
512700	0.2270	0.0293	0	0.1696	0.2844	523201	0.2407	0.0321	0	0.1779	0.3035
512801	0.2037	0.0157	0	0.1729	0.2344	523202	0.2417	0.0478	0	0.1481	0.3353
512802	0.1487	0.0543	0.006	0.0423	0.2552	523300	0.2681	0.0113	0	0.2461	0.2902
512901	0.0786	0.0082	0	0.0625	0.0947	523401	0.1445	0.0363	0	0.0734	0.2157
512902	0.2249	0.0174	0	0.1908	0.2589	523402	0.2364	0.0881	0.007	0.0638	0.4090
513011	0.1894	0.0155	0	0.1590	0.2198	523501	0.3301	0.1252	0.008	0.0846	0.5756
513012	0.1422	0.0439	0.001	0.0562	0.2282	523502	0.2294	0.0402	0	0.1507	0.3082
513013	0.1824	0.0251	0	0.1332	0.2316	523601	0.2151	0.0353	0	0.1459	0.2842
513020	0.1782	0.0162	0	0.1464	0.2100	523602	0.2759	0.0751	0	0.1287	0.4232
513100	0.1952	0.0201	0	0.1557	0.2346	523711	0.1630	0.0349	0	0.0946	0.2314
513211	0.1266	0.0377	0.001	0.0527	0.2004	523712	0.1124	0.0373	0.003	0.0393	0.1854
513212	0.1346	0.0189	0	0.0975	0.1718	523713	0.1261	0.0574	0.028	0.0136	0.2386
513213	0.1256	0.0319	0	0.0631	0.1881	523721	0.1186	0.0392	0.003	0.0417	0.1955
513214	0.1412	0.0148	0	0.1123	0.1701	523722	0.0977	0.0177	0	0.0630	0.1324
513220	0.2067	0.0119	0	0.1833	0.2300	523813	0.3934	0.0979	0	0.2015	0.5853
513301	0.2788	0.0627	0	0.1559	0.4018	523814	0.1813	0.0424	0	0.0983	0.2644
513302	0.1470	0.0109	0	0.1256	0.1684	523815	0.1950	0.0762	0.011	0.0456	0.3443
513410	0.2530	0.0228	0	0.2084	0.2977	523816	0.0740	0.0606	0.222	-0.0447	0.1927
513420	0.2612	0.0297	0	0.2031	0.3193	523817	0.0454	0.0714	0.525	-0.0945	0.1852
513430	0.1923	0.0252	0	0.1429	0.2416	523820	0.1176	0.0097	0	0.0986	0.1365
513511	0.2050	0.0499	0	0.1072	0.3028	523911	0.1117	0.0359	0.002	0.0413	0.1821
513512	0.1238	0.0159	0	0.0927	0.1549	523912	0.0678	0.0640	0.289	-0.0576	0.1932
513521	0.1384	0.0118	0	0.1152	0.1615	523920	0.1335	0.0245	0	0.0854	0.1815
513522	0.0862	0.0148	0	0.0572	0.1152	524001	0.2436	0.0216	0	0.2013	0.2860
513530	0.1528	0.0117	0	0.1298	0.1757	524002	0.1522	0.0307	0	0.0920	0.2124
513610	0.1841	0.0252	0	0.1347	0.2335	524111	0.2630	0.1080	0.015	0.0513	0.4748
513620	0.1692	0.0293	0	0.1118	0.2267	524112	0.2781	0.0437	0	0.1925	0.3637
513631	0.0983	0.0118	0	0.0751	0.1215	524121	0.2719	0.1070	0.011	0.0622	0.4817
513632	0.1793	0.0130	0	0.1539	0.2048	524122	0.0784	0.0778	0.314	-0.0741	0.2310
513701	0.3087	0.0940	0.001	0.1245	0.4929	524200	0.1541	0.0984	0.117	-0.0387	0.3469
513702	0.2331	0.0309	0	0.1726	0.2936	524301	0.1483	0.0216	0	0.1059	0.1906
513800	0.2657	0.0219	0	0.2228	0.3086	524302	0.1787	0.0325	0	0.1151	0.2423
514000	0.3324	0.0536	0	0.2273	0.4375	524303	0.1447	0.0213	0	0.1030	0.1864
514101	0.1417	0.0598	0.018	0.0245	0.2589	524402	0.2410	0.0401	0	0.1623	0.3197

CAU	r_j	S.E.	P>|t|	[95% CI]		CAU	r_j	S.E.	P>|t|	[95% CI]	
514102	0.2337	0.0672	0.001	0.1020	0.3655	524403	0.0694	0.0763	0.363	-0.0800	0.2189
514103	0.2309	0.1032	0.025	0.0287	0.4332	524404	0.1542	0.0799	0.053	-0.0023	0.3107
514200	0.2718	0.0625	0	0.1493	0.3943	524405	0.1473	0.0654	0.024	0.0191	0.2755
514301	0.1503	0.1041	0.149	-0.0538	0.3544	524510	0.2527	0.0461	0	0.1623	0.3431
514302	0.3818	0.0620	0	0.2604	0.5033	524520	0.1185	0.0539	0.028	0.0128	0.2242
514401	0.2940	0.0323	0	0.2307	0.3573	524530	0.2542	0.0512	0	0.1538	0.3546
514402	0.2221	0.0150	0	0.1926	0.2516	524601	0.1720	0.0325	0	0.1083	0.2357
514500	0.2912	0.0227	0	0.2467	0.3358	524602	0.2295	0.0631	0	0.1059	0.3531
514600	0.2046	0.0157	0	0.1739	0.2354	524711	0.1816	0.0254	0	0.1318	0.2314
514700	0.3162	0.0216	0	0.2739	0.3586	524712	0.2173	0.0400	0	0.1389	0.2956
514801	0.1910	0.0179	0	0.1559	0.2261	524713	0.0768	0.0523	0.142	-0.0256	0.1792
514802	0.1768	0.0158	0	0.1459	0.2077	524720	0.1324	0.0162	0	0.1007	0.1640
514900	0.2918	0.0273	0	0.2383	0.3454	524811	0.2466	0.0711	0.001	0.1073	0.3858
515001	0.2746	0.0347	0	0.2066	0.3425	524812	0.1302	0.0207	0	0.0897	0.1707
515002	0.2586	0.0232	0	0.2131	0.3041	524821	0.2187	0.0348	0	0.1505	0.2869
515003	0.2567	0.0350	0	0.1881	0.3254	524822	0.0826	0.0551	0.134	-0.0254	0.1906
515100	0.2261	0.0257	0	0.1758	0.2765	524901	0.2103	0.0145	0	0.1819	0.2387
515201	0.4374	0.0662	0	0.3077	0.5671	524902	0.1981	0.0194	0	0.1600	0.2361
515202	0.4942	0.0718	0	0.3534	0.6349	525001	0.1938	0.0366	0	0.1220	0.2656
515301	0.1296	0.0361	0	0.0589	0.2002	525002	0.2794	0.0367	0	0.2074	0.3513
515302	0.3284	0.0349	0	0.2600	0.3968	525101	0.2695	0.0485	0	0.1744	0.3645
515410	0.3072	0.0691	0	0.1717	0.4426	525102	0.1965	0.0459	0	0.1065	0.2866
515420	0.3883	0.0350	0	0.3197	0.4569	525201	0.3893	0.0344	0	0.3218	0.4568
515431	0.2631	0.1106	0.017	0.0464	0.4798	525202	0.2692	0.0300	0	0.2104	0.3279
515432	0.3730	0.0381	0	0.2983	0.4476	525410	0.1332	0.0544	0.014	0.0266	0.2399
515500	0.3796	0.0455	0	0.2905	0.4688	525420	0.2070	0.0387	0	0.1311	0.2829
515600	0.3718	0.0452	0	0.2832	0.4604	525510	0.1944	0.0653	0.003	0.0665	0.3224
515700	0.4329	0.0414	0	0.3517	0.5140	525520	0.2131	0.0182	0	0.1773	0.2488
515801	0.3632	0.0288	0	0.3068	0.4196	525530	0.1169	0.0250	0	0.0678	0.1660
515802	0.2469	0.0247	0	0.1986	0.2952	525540	0.2277	0.0179	0	0.1927	0.2627
515901	0.2877	0.0491	0	0.1914	0.3841	525610	0.0937	0.0293	0.001	0.0363	0.1512
515902	0.2240	0.0304	0	0.1644	0.2837	525620	0.2055	0.0276	0	0.1514	0.2596
516001	0.1936	0.0453	0	0.1048	0.2825	525630	0.2770	0.0605	0	0.1584	0.3956
516002	0.1850	0.0297	0	0.1268	0.2432	525700	0.1010	0.0230	0	0.0558	0.1462
516003	0.2728	0.0261	0	0.2217	0.3240	525910	0.1734	0.0220	0	0.1302	0.2165
516101	0.2434	0.0300	0	0.1846	0.3023	525921	0.2070	0.0211	0	0.1657	0.2484
516102	0.2595	0.0442	0	0.1728	0.3462	525922	0.2069	0.0417	0	0.1253	0.2886
516201	0.2175	0.0312	0	0.1564	0.2786	526101	0.1344	0.0169	0	0.1012	0.1676
516202	0.2508	0.0312	0	0.1896	0.3120						

B2 Stage 2 – estimating agglomeration economies

From the outset it is worth noting that our estimates of agglomeration economies are likely to be larger than those found in the literature for several reasons. The first reason is related to context – Auckland is relatively low density and as such probably has more to gain from agglomeration than cities elsewhere. The second reason is that Auckland, as New Zealand's only urban area of international scale, is likely to be home to a larger proportion of the types of industries that benefit the most from agglomeration. Third, our empirical design – especially our choice of land values as an indicator – is likely to result in larger agglomeration economies because land values capture benefits to both consumers and producers. Land is also immobile and in fixed supply; this supply-side invariance means changes in price result solely from shifts in demand.

The two technical issues encountered in estimating agglomeration economies were related to simultaneous causation and spatial auto-correlation. In terms of simultaneous causality, we used instrumented variables and two-stage least squares to control for the effects of land values on density. We expect to find smaller estimates of agglomeration elasticities when using instrumented variables, because the observed positive correlation between effective density and land values combines positive causal effects that operate in both directions. This is evident from the following two scatter plots, where we have plotted land values versus effective density, where the latter is in both in raw and instrumented. Results confirm our expectations – a less positive relationship exists between land values and effective density when the latter is instrumented.

Figure B.1 Scatter plot of land values versus effective densities for each census area unit

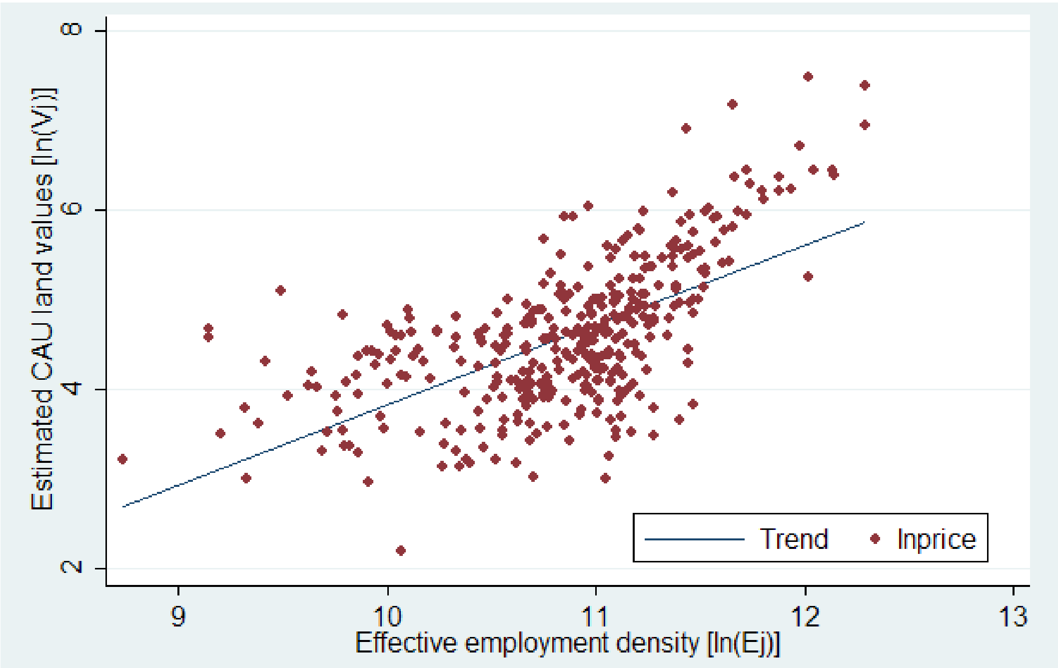
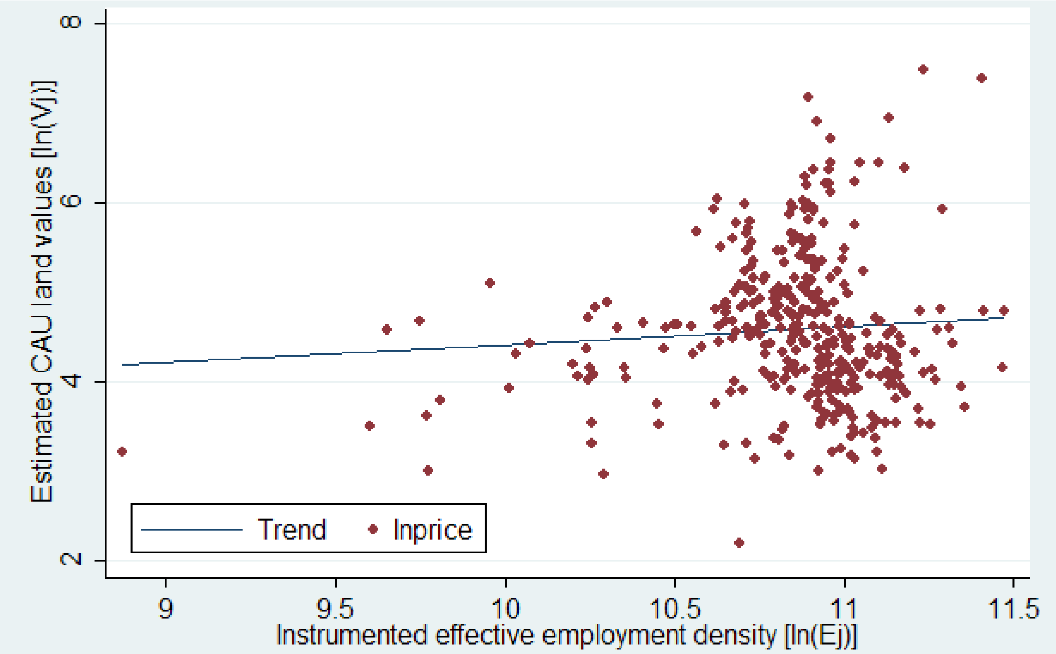


Figure B.3 Scatter plot of land values versus instrumented effective densities for each census area unit



We refer to the instrumented model as the 'IV' model. A number of instruments were investigated but most were very weak or invalid (ie not exogenous). Our preferred instrument was the effective density of the agriculture, forestry and fishing sectors, which we found to be correlated with overall effective density but independent of land values. Because this industry sector is relatively small (on average only 1% of the CAU workforce), removing it from our analysis was found to have negligible impacts on our estimates of effective density. We suspect that the nature of these activities would be highly correlated with total effective density but not strongly correlated with land values, and so it proved.

The table below summarises the cross-correlation matrix for land values $\ln(V_j)$, total effective density $\ln(E_j)$, our instrument $\ln(E_j^1)$, and the resulting instrumented effective density $\ln(\bar{E}_j)$.

Table B.2 Cross correlation matrix for variables in the IV1 model

	$\ln(V_j)$	$\ln(E_j)$	$\ln(E_j^1)$	$\ln(\bar{E}_j)$
$\ln(V_j)$	1.0000	-	-	-
$\ln(E_j)$	0.6197	1.0000	-	-
$\ln(E_j^1)$	0.0615	0.5166	1.0000	-
$\ln(\bar{E}_j)$	0.0725	0.5215	0.9906	1.0000

This shows how the instrument is only weakly correlated with price (0.0615) but strongly correlated with effective employment density (0.6197). The instrumented effective density variable is much less strongly correlated with price (0.0725). The IV1 model was then estimated using two-stage least squares (2SLS). Subsequent diagnostic tests on the strength (ie the instrument is relevant) and validity (ie the instrument is exogenous) are summarised in the following table.

Table B.3 Diagnostic tests on the strength and validity of our selected instruments

Strength (Wald test)	Validity[17] (Sargan Chi)
H0: Instruments are weak. F-statistic = 57, p-value < 0.000. *Reject H0 instruments are weak.*	H0: Instruments are valid. Chi2(1) = 2.18816, p-value = 0.1391. *Accept H0 instruments are valid.*

Results were robust to our choice of effective density (ie we used both a total effective employment density, as well as industry specific effective density). We tested the effects of excluding the contribution to effective density from the industry sector used as an instrument, but only negligible differences in results were observed. Further research could consider the use of spatially and temporally lagged variables to better control for endogeneity, which is a technique that is reasonably common in the literature.

The second technical issue we had to overcome when estimating agglomeration issues was related to spatial autocorrelation. The Moran's I statistic calculates the degree of spatial autocorrelation in our estimated land values. Our estimates of land values had a Moran's I = 0.219, which is indicative of reasonable spatial autocorrelation.

Diagnostic tests on the results of the IV model indicated that the spatial error (SE) model was preferred to the spatial lag model (ie robust Lagrange multipliers of 57.4 and 29.7 respectively). This is consistent with the presence of omitted spatial variables rather than spatial spillovers, which is not surprising given that our model includes only instrumented variables for effective density and no other independent controls on land values. Regression results for the SE model are summarised in table B.4.

Table B.4 Regression results for the SD1 model

Dependant variable: $\ln(V_j)$	**Obs.**	365	**Sigma**	0.65	
	Var. ratio	0.017	**Log-like.**	-363.9	
	Sq. corr	0.005	**Lambda**	0.988	
Variable	**Coef.**	**Std. Err.**	**P**	**[95% C. I.]**	
$\ln(\bar{E}_j)$	0.360	0.143	0.012	0.079	0.640
constant	-6.611	7.574	0.383	-21.46	8.234
lambda	0.988	0.012	0.000	0.965	1.011

The coefficient on our (instrumented) effective density variable jumps from 0.201 (IV model) to 0.360 (SE model) when controlling for spatial dependencies.

This suggests the omitted variables could be positively correlated with effective density and negatively correlated with land values, or vice versa. The first case would indicate there are local factors to support density, such as highways and railways, which generate localised negative externalities and reduce land values in the immediately affected area. Alternatively, the second case would indicate there may be local factors that reduce density, such as parks, which generate localised positive externalities and increase land values in the surrounding area. While the truth is likely to be a combination of both effects, the key observation is that controlling for spatial dependencies increases our estimated agglomeration elasticity.

[17] The test of over-identifying restrictions requires two exogenous instruments for one endogenous regressor. We included as a second instrument the natural log of the number of roads in each CAU. This instrument was very weak, but not endogenous and so allowed us to test the validity of the preferred instrument, $\ln(E_j^1)$. We also note that results reported in earlier sections are associated with the use of only one instrument, not both.