Light rail transit and residential density in mid-size cities

Working Paper 5

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Research Findings

In 2014 CURF completed Working Paper No 3, *Transport Oriented Urban Transformation: Contribution to urban futures* (Flannery et al., 2014). The paper cited some recent research and experience to provide a deeper understanding of the specific benefits of aligning the principles of land-use planning with a transport-oriented approach to urban transformation. The discussion and findings encompassed a wide range of economic, social and environmental benefits. It was noted that recent experience has been positive for inner urban communities, provided this triple bottom line approach is taken and there is a process for meaningful community engagement in sustainability solutions.

One of the key findings by Flannery et al. (2014) and recommended next steps was to initiate ongoing analysis and research to monitor and map the effects and the benefits of changes brought about by urban development decisions taken along Canberra’s initial stage light rail transit (LRT) corridor. This background paper contributes to a commencement of that process and focuses on the factor of population density adjacent to the light rail corridor with an examination of the changes in density due to light rail in cities comparative to Canberra.

To answer this, it identifies and discusses the following:

1. information on population density of light rail systems in mid-size cities (cities with populations smaller than 500,000 and thus of a size comparable to Canberra)
2. the original density prior to light rail and post light rail in the walkable corridor around the light rail and the nature of the planning policies along the corridor
3. some comparisons to Canberra and the potential impacts of Canberra’s proposed light rail
4. reports on the current density condition within the Northbourne corridor prior to commencement of the light rail in Canberra
5. a preliminary methodology that will enable a longitudinal study of land use changes in the Canberra light rail corridor.

The cities chosen for a closer examination here are Adelaide (South Australia), Edmonton (Canada), Bergen (Norway), and Freiburg (Germany). These have been selected for the reasons following.

Adelaide has been selected firstly because it is an Australian city and therefore population and density data collected through Australian Bureau of Statistics (ABS) data and mapping techniques are equivalent; and secondly, because the characteristics of the light rail corridor between Glenelg and the city are somewhat similar to the corridor from Gungahlin to the City.

Edmonton has been chosen as a case study city as its population was about 445,000 when the city launched the first stage of its light rail project. By comparison, the population of Canberra-Queanbeyan was about 435,000 in 2014.

Bergen has been included in this study as it is similar to Canberra in terms of its size and in terms of its dispersed physical form.

Freiburg has been selected because it is an international exemplar of the alignment of transit services with land development planning. The case study includes an examination of two interesting...
development precincts in the inner city, Vauban and Rieselfeld, which were established and constructed on brownfield sites as transit oriented developments.

This study establishes a walkable corridor of 1.5km either side of the light rail. Analysis has also been undertaken to compare this wide corridor with a smaller 400 metres either side of the light rail.

Research findings

The key research findings of the report follow.

Case studies on similarly sized cities—Adelaide, Edmonton, Bergen and Freiburg—have highlighted the potential impacts on urban density from light rail systems.

Case Study 1—Adelaide

• Population and dwelling densities have changed only marginally within Adelaide’s study areas between 2006 and 2011. The line has been in existence (albeit for other forms of vehicle) for over 140 years and more intense development is well established, particularly at the Glenelg end of the line. The urban realm for the Adelaide corridor was largely set when the tram was the primary mode along the corridor, and as such densities reflect these historical precedents rather than any change over the last couple of years.

• Since the completion of the first extension of the line through Adelaide city centre in 2007, however, there has been observed an increase in patronage along the full length of the Glenelg line during the peak hours in both directions; and total employment within 400 metres of the tram extension also increased significantly compared to the rest of the CBD.

• Population and dwelling density has also increased marginally in Hindmarsh at the northern extent of the light rail line in the last decade.

• Light rail is being used to set new policy to deliver urban renewal and transformation.

• The Glenelg line connects two specific destinations, the beach side resort of Glenelg, which is a popular recreational and entertainment destination for city residents, and the CBD employment node.

• The route traverses divergent socio-economic geographies and land use zonings with respective changes in permissible densities providing numerous stops to upload and discharge commuters.

• The high commuter areas of the CBD and Glenelg offer free travel; fares are charged only when commuting between these areas.

• The line is popular with tourists due to the connection with beachside, funfair, recreational and harbour destinations, and hotel accommodation and for the ease-of-commute to the city centre.

• The clear distinction between the destinations, each with a well-branded identity and uniquely differentiated focus, enhances the connectivity.

Case Study 2—Edmonton

• The urban design of Edmonton city is a similar ‘Y-Plan’ to that of Canberra, and Edmonton has a similar topography with development in town centres across a landscape that comprises valleys and a river.
• The successful continued patronage of the Edmonton light rail has encouraged the adjustment of land use policy to focus medium and higher density residential, retail and employment growth around LRT stations and transit centres. The city’s LRT Network Plan is directly linked to the broader strategic planning policy ‘City Vision’ which seeks further transit-oriented development, compact urban form and a shift in transportation modes.

• Wide community familiarisation and utilisation of the Edmonton light rail enables popular appreciation of the wider benefits of transit-oriented development.

• Use has steadily increased since the first stage, and the second stage is due to be opened April/May 2015, with a further four lines being planned to link the town centre nodes with downtown Edmonton in the near future.

Case Study 3–Bergen
• With a population of about 275,000 and with much of the city’s population concentrated in the valleys that spread outwards from the city centre, Bergen is similar to Canberra in size and in dispersed physical form.

• The Bergen local government has encouraged and legislated for denser development around light rail stations, where it seeks to facilitate the construction of most new housing and commercial property. Private developers have shown keenness to develop sites in the light rail corridor.

• The first stage of Bergen’s light rail system, covering 9.8km and 15 stations between Bergen centre and Nesttun, opened in 2010. By mid-2013 it transported over 31,000 passengers daily, attracting far more than was originally predicted.

• Future stages of the Bergen light rail are receiving increased popular support. Future extension of the existing light railway system is being planned. The existing network may be extended to Fyllingsdalen and Loddefjord in the west and Sandviken / Åsane in the north. A link between the primary regional hospital and the city centre is also being considered.

Case Study 4–Freiburg
• Freiburg has over several decades simultaneously made public transport, cycling, and walking viable alternatives to motor vehicle use, while increasing the cost of car travel. Improving quality and level of service of alternative modes of transport has made car-restrictive measures politically acceptable (Buehler and Pucher, 2011).

• Light rail and other deliberate sustainability policy initiatives in Freiburg have dramatically improved the image of the city, its reputation as a tourist destination and as an exemplar of compact urban environment.

• The development of Vauban and Rieselfeld from brownfield sites to very high population and dwelling density precincts, with all residences within close immediate proximity to light rail, exemplify the extraordinary capacity of transit oriented development to create desirable and successful urban precincts.

• Two office blocks in Freiburg that were built at the same time and have the same quality: the offices that have tram access have 15–20 per cent higher rents than the office block which has no tram access, even though it is closer to the city centre (Crampton 2003, p9).
A density analysis has highlighted that population and dwelling densities are correlated and already increasing along the Flemington–Northbourne corridor, particularly in already established population centres, as part of the ACT Government’s urban intensification planning strategy.

**Insights for Canberra**

- The review of the case study cities has highlighted that there must be to an *integrated approach to land use planning and light rail implementation* as part of a holistic urban planning and urban transformation process. This is critical, as relying on the private sector to rezone and redevelop without a precinct strategy to reinforce these outcomes makes it less likely for the best urban outcomes to occur. International experience has shown that the lack of an integrated planning framework is one of the key inhibitors to land use and transport integration.
- The international and interstate case studies include a range of populations demonstrating light rail can be beneficial for small–medium sized cities. The study found some evidence (Ginn, 1998) to support a quantifiable minimum population threshold of 200,000 for sustaining an urban light rail system which might facilitate urban renewal or patronage targets. Two of the case study cities and other international cities have both successful light rail systems and populations significantly less than that of Canberra.
- The case studies highlight evidence of change in land use activity over time including more intensive (more dense) residential developments and the development of mixed use. Activated density – density driven by strong, planned and deliberate land-use policy implementation - has been shown to be more highly effective in achieving better urban outcomes than a reliance solely on induced density –a density achieved ad hoc through a build-the-rail-and-density-will-come approach.
- Adopting explicit Transit Oriented Development (TOD) guidelines, as is the case with Edmonton, appears to be an important factor in density increases along with a wider city plan. Such guidelines are critical for the activation of the urban regeneration along the corridor.
- Community attitudes to the urban challenge of car-dependence have changed as exhibited clearly in the cases of Freiburg and Bergen. In Freiburg a shared understanding of city building and future-proofing the city against planning challenges was cultivated in all levels of government and with key stakeholders and professional groups. Community confidence increased as new stages of light rail were planned and delivered. In Bergen the funding mechanism of implementing a toll on an existing ring road gained popular acceptance. The present and future challenges of traffic congestion and peak car use in Australia, however, although they have been frequently and regularly identified by governments (BTRE, 2007; Infrastructure Australia, 2014) are less widely understood.
- The new light rail services examined showed that easy transfer between multi-modal systems needed to be provided. This included the integration of network design, timetables, ticketing and fare structures in most examples.
- A broader cost-benefit analysis undertaken as a potential future study would highlight the community (active travel and healthy cities) and environmental (climate change mitigation and biodiversity) benefits. The study team notes that transport economics cannot currently quantify these benefits, but if the implementation of light rail is integrated with land-use planning then at least some of the urban intensification benefits can be captured.
• The international case studies show that commercial and residential property values can be higher when the properties are constructed close to a light rail station, in part stimulated by a willingness of purchasers to pay for access to transit (McIntosh et al, 2014). Developers were aware of the investment opportunities associated with light rail to leverage the economic and also the social benefits.

• Public transportation patronage increases as light rail transit systems become operational.

• Although LRT systems can bring considerable financial, social and environmental benefits to a host city, research demonstrates that local conditions must be receptive if these systems are to have a measurable impact on urban transformation and land use change. Light rail transit cannot be a driver of new growth and land use change on its own, but as a component part (albeit a foundational part) in a long-term strategic urban planning effort to shape growth and revitalisation in the city (Higgins, 2014).

A longitudinal study to identify changes to population and dwelling density as a result of the light rail and assess the indirect effects associated with land use changes would assist future planning and management of a light rail network in Canberra. The role of rezoning and precinct planning will be a critical aspect of this analysis.
1.0 Introduction

Canberra Urban and Regional Futures (CURF), based at the University of Canberra, had its origins in the realisation that the issues of urbanisation, population pressures, the impacts of climate change and an awareness of the environmental and social impacts of urban growth were all driving an increasing interest in research for evidence based decision making for cities and regions. The overall objective of CURF’s research partnerships is to build pathways towards sustainable futures for cities and regions.

During 2014 CURF completed Working Paper No 3, *Transport Oriented Urban Transformation: Contribution to urban futures* (Flannery *et al*., 2014). The paper discussed some of the key examples of transport-oriented development within Australia and internationally, and highlighted some of the key risks and opportunities to be considered in developing and implementing inner urban transformation that could be considered in the ACT context. Recent research and experience was cited to provide a deeper understanding of the specific benefits of aligning the principles of land-use planning with a transport-oriented approach to urban transformation. The discussion and findings encompassed a wide range of economic, social and environmental benefits. It was noted that recent experience has been positive for inner urban communities, provided this triple bottom line approach is taken and there is a process for meaningful community engagement in sustainability solutions. There are multi-dimensional impacts of light rail transport on adjacent land use, which in turn affects ease of accessibility and long-term economic, social and environmental benefits (Bardhan, 2013).

One of the strategic principles and desirable outcomes of contemporary urban planning is urban consolidation that strives for more compact cities. More specifically, this is being achieved in many cities through greater urban density, especially along transport corridors, to tackle the related challenges of urban sprawl, car dependence and reduction of greenhouse gases.

Public transport works best in higher density neighbourhoods where a critical mass of residents is located within an easy walk or cycle from transfer stations (Newman and Kenworthy, 1996). It facilitates the creation of more vibrant local communities with areas of medium to high density dwellings, opportunities for diverse and affordable housing and a greater area of public realm and more open space and parks.

Working Paper No 3 noted that the combined challenge of car dependence and traffic congestion is a regularly recurring theme observed in current literature and in the policy response in numerous international cities enabling public transport orientated urban growth and the creation of more compact and walkable neighbourhoods. The potential benefits stemming from increased productivity were also noted, as were the potential increases in value of land immediately adjacent to public transport corridors and node points.

With the transport sector accounting for approximately 25 per cent of greenhouse gas emissions in metropolitan areas worldwide, the paper also noted that the creation of less car dependent urban forms is an essential governance and policy response to climate change mitigation and adaptation. One of the key findings and recommended next steps was to initiate ongoing analysis and research to monitor and map the effects and the benefits of changes brought about by urban development.
decisions taken along Canberra’s initial stage light rail transit (LRT) corridor. It is seen as valuable to establish this research-based monitoring to review social, environmental and economic outcomes and performance targets of transport infrastructure and related transit-oriented development. Good baseline data and information is seen as essential so that the future benefits of any investment in fixed public transport systems can be quantified and assessed.

1.1 Scope

This background paper, therefore, contributes to a commencement of that process of review and, acknowledging the wider benefits stemming from urban consolidation, it focuses on the factor of population density adjacent to the light rail corridor with an examination of the changes in density due to light rail in other cities comparative to Canberra.

By focusing on Canberra and on urban density, this paper seeks to dispel some popularly held misconceptions namely that smaller cities of under 500,000 people and/or of low density cannot sustain LRT.

This paper identifies and discusses the following:

1. information on population density of light rail systems in mid-size cities (cities with populations smaller than 500,000 and thus of a size comparable to Canberra)
2. the original density prior to light rail and post light rail in the walkable corridor around the light rail;
3. some comparisons to Canberra and the potential impacts of Canberra’s proposed light rail;
4. reports on the current density condition within the Northbourne corridor prior to commencement of the light rail in Canberra; and
5. a preliminary methodology that will enable a longitudinal study of land use changes in the Canberra light rail corridor.

As this paper has been briefed to focus primarily on discussion and analysis of urban density, accordingly it does not deal with or consider:

1. A land and property market pricing analysis (measuring so-called uplift) to understand what people and businesses value and the implications to the proposed Canberra light rail.
2. An access strategy as increased urban will increase the need for appropriate pedestrian and cycling access and good connectivity to feeder buses.
3. A review of private and government parking supply and pricing for on and off street prior to and post LRT

These factors could be examined in the future as part of other studies related to Canberra’s proposed light rail.

1.2 Urban density

It has been acknowledged that when light rail is to be considered, it is necessary for a city to have a population base of 200,000 or more (Ginn, 1998). The critical issue is, moreover, not the population level, but rather how it is distributed along the light rail corridor. Urban density is expressed in a greater number of buildings, residences, retail outlets and services situated closer together for
connectivity and ease of walking; to enable an environmentally cleaner and more efficient use of services and resources; and to create a more enjoyable and convenient human habitat. Gordon (2011) states that density is one of three dimensions required for viability of light rail transit (the other two being cost and operating environment).

Cervero and Guerra (2011) compare both high cost heavy rail and light rail systems and note that both need higher levels of urban density to achieve a high cost-effectiveness rating. At an observed average cost per mile of $US231 million and $US53 million ($US136 million and $US33 million per km) for heavy rail and light rail respectively in 2011, the average heavy rail and light rail systems respectively need around 45 and 30 people per gross acre (18 and 12 people per gross hectare) near stations for cost-effectiveness (Cervero and Guerra, 2011). Similarly, Gordon (2011) reports that for light rail transit to be viable, around 2223 people per square kilometre (22 people per hectare) is an ideal density threshold. In addition, Cervero and Guerra (2011) note the crucial need to increase jobs around transit while keeping capital expenditure down and reducing operating costs.

By way of comparison and to set some context, some of Australia’s highest residential densities can be seen in Sydney with Pyrmont/Ultimo at 143 persons/hectare, Potts Point/Woolloomooloo 136, Darlinghurst 133 and Surry Hills 131; whilst in Melbourne the inner-city has 124 and Carlton 90; and New Farm and Kangaroo Point in Brisbane have 63 and 60 p/ha respectively (ABS, 2014).

Existing (2013) resident population densities in Canberra suburbs examined in the study area of this paper are Braddon 39 p/ha, Dickson 14, Downer 23, Hackett 15, Lyneham 9, O’Connor 11, Watson 16, Harrison 20, Mitchell 0 and Gungahlin 13 (ABS). (These ABS figures are based on ‘statistical areas level 2’ not within the pre-defined walking corridors widths used hereunder.)

Cervero and Guerra (2011) also note the distance of origins and destinations from transit stations has a strong influence on whether people use transit. Stated preference surveys and observed behaviour indicate that time spent walking is significantly more onerous than time spent in a car or transit vehicle. Thus reducing average walk times to transit can help increase transit ridership (Cervero and Guerra, 2011) hence the importance of higher density in the pedestrian catchments around transit stops. The location of stops is also critical to the success of light rail transit as ‘physical agglomerations’, which are clusters of development near transit stops (akin to clustered development in or around town centres or nodes), give rise to economies of scale (Chatman and Noland, 2014). This allows businesses and households to benefit from transit-induced densification, growth and increased productivity.

This study establishes a walkable corridor of 1.5km either side of the light rail. Analysis has also been undertaken to compare this wide corridor with a smaller 400 m either side of the light rail.

When understanding pedestrian catchments, people don’t think of distance, but rather time. Therefore, the catchments correspond to 5 and 20 minute walking catchments. Analysis shows that people don’t value the infrastructure outside an 800m walking catchment, and the urban development doesn’t change significantly outside a 400m catchment. Therefore the 400m -1.5km catchment used in this study is effectively a control catchment for purposes of comparison.

The location of the light rail and the defined study area for this paper is depicted in Figure 1.01.
Figure 1.01 – The location of the Capital Metro light rail, from Gungahlin to Civic in North Canberra, and the study area defined by a 400m light rail corridor and a 1.5km walkable corridor.
1.3 Measuring density

Two types of density are examined in this study: population density and dwelling density. The methodology for measuring population and dwelling densities is critical to the discussion in this analysis and, accordingly, two standard methods of measurement are used: gross density and net density. Gross density is the total population or number of dwellings in a given statistical precinct divided by the total area of the precinct. The advantage of this method is that it allows direct comparison with the way density is measured by the Australian Bureau of Statistics (ABS).

However, gross density calculations can provide unrepresentative quotients, particularly when a precinct contains significant zones for land uses other than for residential, e.g. commercial and industrial or community facilities. Accordingly, this paper expresses population and dwelling density also in terms of net density.

Net density is calculated by selecting only the residential land use zones within the study area (including roads), and dividing the population or dwellings by the residential area.

There are, however, some exceptions to this, where in the city and town centres there is a mix of development types (land use zones) such as ‘core’, ‘business’ or ‘services’ that may also include residential, for example where units are located above commercial premises. Parts of these zones where residential developments are known to exist have been selected as ‘residential’. This ensures residential developments extant in the urban centres have been included in the analysis. An advantage of this method of measurement is that it gives a truer snapshot of the residential density in the residential areas of the city.

Full details and further explanation of this methodology are provided in Section 4.0 of this paper.
2.0 The comparable cities

2.1 Smaller cities and light rail: insights

In reviewing population density of light rail systems in smaller than 500,000 population cities, this report identified four cities, which at the time of their first stage of light rail were of comparable size to Canberra.

The parameters for choosing the cities are as follows:

1. cities that had already installed light rail systems
2. cities of comparable size to Canberra at the time of installation of light rail systems
3. cities that had tracked the required data, being population density prior to light rail and post light rail in the walkable corridor around the corridor. (For the purposes of this study, the walkable corridor is taken to be 1.5km with comparative analysis undertaken also of any effects in a narrower 400m corridor).

The purpose of this working paper is to provide general insights into how the population density of other cities’ walkable corridors have changed, post light rail. It should be noted that the density information from the international case study examples is formative as it has been difficult to extract direct relationships of density because of the multiple drivers of inner urban transformation. For these reasons there is a strong case for the ACT Government to be tracking all these factors during the first stage of the Canberra light rail.

For completeness, cities in both Australia and overseas are discussed and include Adelaide (South Australia), Edmonton (Canada), Bergen (Norway) and Freiburg (Germany).

Adelaide has been selected firstly because it is an Australian city and therefore population and density data collected through ABS data and mapping techniques are equivalent; and secondly, because the characteristics of the light rail corridor between Glenelg and the city are somewhat similar to the corridor from Gungahlin to the City and so a comparison could be useful. We have focused all data analysis and discussion on a select corridor rather than the more expansive metropolitan area of Adelaide to allow a more direct comparison with Canberra and the other case study cities.

Edmonton has been chosen as a case-study city as its population was about 445,000 when the city launched the first stage of its light rail project. By comparison, the population of Canberra-Queanbeyan was about 435,000 in 2013. In addition, Edmonton has a similar ‘Y-Plan’ layout to that of Canberra, a similar topography and development in town centres across a landscape that comprises valleys and a river.

Bergen is the second largest city in Norway and has a population of about 275,000. Most of the city’s population is concentrated in the valleys that spread outwards from the city centre. It has been included in this study as it is similar to Canberra in terms of its size and in terms of its dispersed physical form. Canberra is a multi-nodal city connected by arterial road corridors. Canberra’s so-called ‘Y-Plan’ planned in the late 1960s by the National Capital Development Commission (NCDC)
and commenced throughout the 1970s created a city based on a series of town centres each with a separate suburban neighbourhood.

Freiburg has been selected because it is an international exemplar of the alignment of transit services with land development planning. This highly regarded environmentally aware city now has an extensive and well-integrated network of trams, buses, and commuter-rail lines. Each day 200,000 residents and visitors make use of the system of four tram lines and 26 bus lines. The case study includes an examination of two interesting development precincts in the inner city, Vauban and Rieselfeld, which were established and constructed on brownfield sites as transit oriented developments. Both new neighbourhoods are very high density, low car ownership developments with all dwellings in close proximity to light rail stations established concurrently with the residential area.

Other cities that were considered for inclusion include Grenoble in the south east of France (population over 660,000) and the American cities of Portland (610,000), Denver (650,000), Phoenix (1.5 million) and Dallas (1.2 million). Each of these cities has good published results on how developments have been attracted to LRT, however, their respective population sizes were considered too large to directly compare with Canberra.
2.2 Adelaide, South Australia

2.2.1 Overview

Adelaide is the capital of South Australia, and the fifth largest city in Australia (Figure 2.01). The City of Adelaide refers to the city centre, as distinct from the Adelaide metropolitan area, and Greater Adelaide. In 2013, the population of Greater Adelaide was 1.29 million people, which accounted for 77 per cent of the state’s total population (ABS, 2014). Whilst South Australia had a population density of only 0.02 people per hectare in June 2013, Greater Adelaide had a population density of four people per hectare. The most densely populated areas in Greater Adelaide in 2013 were Unley-Parkside, adjacent to the city centre, and Glenelg on the coast (both 29 p/ha).

Adelaide, known to some as the ‘20-minute city’, had light rail built upon its old tramway system in 2008. The light rail stretches from Hindmarsh in the north, through the city centre, past Unley to Glenelg in the south. Initially the Adelaide-Glenelg line was a steam rail line from 1873 until 1927, and in 1929 was electrified for trams (STA, 1979). A mixture of trams and trolleybuses serviced suburban Adelaide until 1950 when all but the Glenelg line were closed. Public transport since 1958 has relied primarily on buses (Radcliffe, 1974). Figure 2.02 shows the old tram and new light rail systems that operate concurrently today.

2.2.2 Geography, climate and governance

Adelaide is located on the Adelaide plains, north of the Fleurieu Peninsula between the Gulf St Vincent and the Mount Lofty Ranges. It has a Mediterranean climate, warm and temperate with long hot summers, short mild winters and low rainfall.

The city stretches 20km from the coast to the foothills, and 90km from Gawler in the north to Selleck Beach in the south. Whilst the Adelaide metropolitan region has a total land area of 870 sq km, Greater Adelaide covers a more expansive area of 3257 sq km. The Adelaide metropolitan area is divided between 18 local government areas (LGAs) (Local Government Association of SA). The State Government co-operates extensively with Adelaide City Council, and the state parliament’s Capital Council Committee is involved in the governance of the City of Adelaide, which is primarily concerned with the planning of Adelaide’s urban development and growth (Government of South Australia and Adelaide City Council, 2008).
2.2.3 Planning and rail

The light rail route was built in 1873 by a private company, the Adelaide, Glenelg & Suburban Railway Company Ltd—originally for stream trains though it was electrified for trams in 1929 as part of a wider tramway network. The Glenelg line is now approximately 15km long, having been extended from its initial 11km length to the Adelaide Entertainment Centre in 2008. It is the only light rail in South Australia and runs from Hindmarsh, through the CBD to Glenelg Beach. It runs on Adelaide's only remaining tram line. Until January 2006, 1929-vintage H-class cars were used on the Glenelg line, however these have been replaced by Flexity Classic and Citadis 302 trams.
The service is a mix of fare paying and free travel. The free ride is between the Adelaide Entertainment Centre in Hindmarsh and South Terrace in the city, and along the entire length of Jetty Road, Glenelg. Apart from short street-running sections in Adelaide city centre and Glenelg, the line has its own reservation, with minimal interference with road traffic. It is fenced off from adjoining land uses and roads with access via the tram stops within the reservation.

The line has been extended twice. The first extension of 1.6 km from Victoria Square along King William Street and North Terrace to Morphett Street opened on 14 October 2007. The second extension included a new bridge over South Road to replace the existing crossing opened on 15 March 2010 with a further 2.8km extension of the line along Port Road to the Entertainment Centre, which opened on 22 March 2010 (Figure 2.03). The first extension eliminated the need to transfer to a bus to connect to the Adelaide Railway Station and to the City West precinct within the City. This extension coupled with improved capacity and frequency of tram services and a free “Terrace to Terrace” tram service has improved accessibility to the core of the City. (Elaurant et al, 2014)

**System details**
- Length of network: approx. 15 km
- Frequency: every 5–10 minutes weekday peak, 15 minutes weekday non-peak, 20 minutes on nights and weekends.
Figure 2.03 – The Adelaide light rail line, from the Adelaide Entertainment Centre to Glenelg
Source: Adelaide Metro

### 2.2.4 Density data

Table 2.01 – Statistics for gross and net population and dwelling densities in Adelaide and the 1.5km walkable corridor and 400m light rail corridor, derived from 2006 and 2011 census data and land use zones
(Source: ABS and Government of South Australia).

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adelaide (gross)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>3.4 p/ha</td>
<td>3.8 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>1.5 dw/ha</td>
<td>1.6 dw/ha</td>
</tr>
<tr>
<td><strong>1.5km walkable corridor (gross)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>19.6 p/ha</td>
<td>21.6 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>10.0 dw/ha</td>
<td>10.0 dw/ha</td>
</tr>
<tr>
<td><strong>400m light rail corridor (gross)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>18.3 p/ha</td>
<td>19.6 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>9.4 dw/ha</td>
<td>10.0 dw/ha</td>
</tr>
<tr>
<td><strong>1.5km walkable corridor (net)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>25.6 p/ha</td>
<td>27.4 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>12.9 dw/ha</td>
<td>13.7 dw/ha</td>
</tr>
<tr>
<td><strong>400m light rail corridor (net)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>26 p/ha</td>
<td>27.3 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>13.5 dw/ha</td>
<td>13.9 dw/ha</td>
</tr>
</tbody>
</table>

*p = persons; dw = dwellings
2.2.5 Analysis

Gross and net population and dwelling densities, shown in Table 2.01 above, were derived using ABS census data on population and dwelling counts, and land use zones determined by the Government of South Australia. Thresholds for mapping net population and dwelling densities in the light rail and walkable corridors are provided in Table 2.02. Net population density thresholds were derived based on a dwelling occupancy of 2.4 (ABS, 2015). The methodology used to calculate and map densities for the Adelaide light rail is the same as that used to determine and map population and dwelling densities in Canberra, which is outlined in Section 4.2.

Table 2.02 – Net dwelling and population density thresholds for mapping densities around the Adelaide light rail.

<table>
<thead>
<tr>
<th>Net Dwelling Density</th>
<th>Net Population Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low density</td>
<td>&lt; 6 dw/ha</td>
</tr>
<tr>
<td>Low density</td>
<td>6-12 dw/ha</td>
</tr>
<tr>
<td>Medium density</td>
<td>12-17 dw/ha</td>
</tr>
<tr>
<td>High density</td>
<td>17-23 dw/ha</td>
</tr>
<tr>
<td>Very high density</td>
<td>&gt; 23 dw/ha</td>
</tr>
<tr>
<td></td>
<td>&lt; 14.4 p/ha</td>
</tr>
<tr>
<td></td>
<td>14.4-28.8 p/ha</td>
</tr>
<tr>
<td></td>
<td>28.8-40.8 p/ha</td>
</tr>
<tr>
<td></td>
<td>40.8-55.2 p/ha</td>
</tr>
<tr>
<td></td>
<td>&gt; 55.2 p/ha</td>
</tr>
</tbody>
</table>

Figures 2.04 and 2.05 highlight the spatial changes in net population and dwelling densities within the walkable 1.5km corridor and the light rail corridor of 400m, from 2006 prior to the light rail being constructed, to 2011 after the light rail was established. Population and dwelling densities have only marginally changed within both corridors over this five year period.

Of interest is that the gross and net densities increase only slightly between 2006 and 2011 and do not differ greatly between the 1.5km walkable corridor and the 400m light rail corridor (Table 2.01). The net population density increases from 26 p/ha in 2006 to 27.3 in 2011, and dwelling density increases from 13.5 to only 13.9 dw/ha over the five years. In some cases, the density is smaller where it would be expected to be larger (because density increases as area decreases for a given population or dwelling count). For example, the gross population density for the 1.5km corridor is 21.6 p/ha in 2011, whereas the gross population density is only 19.6 p/ha in the 400m corridor. This is largely due to the dominant urban and non-urban land use types in the northern extent of the corridors (Adelaide and North Adelaide), such that there is a reduced amount of residential development in this section of the 1.5km corridor, and little to none in the 400m corridor.

In 2006, the majority of residential land within the study area had low population density (14-28 p/ha), whereas in 2011 the proportion of residential lands that have medium population density (28-40 p/ha) increased. In general, low to medium population density is most prevalent throughout the study area over this time period, suggesting that the light rail has not had much impact on population density in the outer suburbs of Adelaide. There are only a few small pockets of high (40-55 p/ha) to very high (>55 p/ha) population density in the study area. Population density also increased between 2006 and 2011 in these areas, which are the most built up within the walkable corridor—the city of Adelaide, Glenelg in the south, Hindmarsh in the north and Everard Park/North Plympton around the centre of the light rail line.
Similarly, the predominant dwelling density increased from low (6-12 dw/ha) to medium (12-17 dw/ha) over the five years, distributed throughout the study area. There are pockets of high (17-23 dw/ha) and very high (>23 dw/ha) dwelling densities in the same areas (though more extensive) as high population density, i.e. the city centre, Glenelg, Everard Park/North Plympton and Hindmarsh. There is also high dwelling density around Unley. These results highlight that dwelling density appears to correspond to population density.

Whilst dwelling density tends to be higher in some areas within the 400m light rail corridor, this is not consistently so, and population density does not appear to increase with proximity to the light rail. Thus it cannot be deduced from this analysis whether the increased dwelling densities are primarily due to the light rail, as it has existed as a tram line since the 1920s, and further research is required to determine whether any correlations exist between light rail and density in Adelaide.

Elaurant et al claim that the first stage line extension was very successful in transport terms. They note that, since its completion in 2007 there has been observed an increase in patronage along the full length of the Glenelg line during the peak hours in both directions by 40% and patronage rising by 70% within the City compared to when the tram service terminated at Victoria Square and transferring to the free Bee Line bus connecting Victoria Square and City West. The Adelaide tram service now carries in excess of 20,000 trips per day. (Elaurant et al, 2014)

As part of their research Elaurant et al undertook a post-hoc analysis of evidence for wider economic benefits (WEBs) from the project was undertaken.

Data on property values and employment was obtained at city block level from before the tram extension was completed to four years after opening. Property values within 400 metres of the tram extension increased relative to the rest of the CBD, but the increase was not statistically significant. Total employment within 400 metres of the tram extension also increased compared to the rest of the CBD, and the difference was highly significant statistically. (Elaurant et al, 2015)

In the year to 2013, the population of Greater Adelaide increased by 13,100 people (1%) (ABS, 2014). The push for urban density increases (Dodson and Gleeson, 2007) is clearly located in the 30 year strategic planning for Adelaide that moves from 50:50 greenfield to infill development with a ratio of 30:70 by 2038 (Government of South Australia, 2010). The existing policy on density in South Australia provides a typical built form associated with each category of density.
Figure 2.04 – Net population density for residential land uses within the light rail and walkable corridors of the Adelaide light rail, based on 2006 and 2011 census data and land use zones. Source: ABS and Government of South Australia
Figure 2.05 – Net dwelling density for residential land uses within the light rail and walkable corridors of the Adelaide light rail, based on 2006 and 2011 census data and land use zones. Source: ABS and Government of South Australia
2.2.6 Adelaide insights

- Population and dwelling densities have changed only marginally within Adelaide’s study areas between 2006 and 2011. The line has been in existence (albeit for other forms of vehicle) for over 140 years and more intense development is well established, particularly at the Glenelg end of the line. The urban realm for the Adelaide corridor was largely set when the tram was the primary mode along the corridor, and as such densities reflect these historical precedents rather than any change over the last couple of years.
- Since the completion of the first extension of the line through Adelaide city centre in 2007, however, there has been observed an increase in patronage along the full length of the Glenelg line during the peak hours in both directions; and total employment within 400 metres of the tram extension also increased significantly compared to the rest of the CBD.
- Population and dwelling density has also increased marginally in Hindmarsh at the northern extent of the light rail line in the last decade.
- Light rail is being used to set new policy to deliver urban renewal and transformation.
- The Glenelg line connects two specific destinations, the beach side resort of Glenelg which is a popular recreational and entertainment destination for city residents, and the CBD employment node.
- The route traverses divergent socio-economic geographies and land use zonings with respective changes in permissible densities providing numerous stops to upload and discharge commuters.
- The high commuter areas of the CBD and Glenelg offer free travel; fares are charged only when commuting between these areas.
- The line is popular with tourists due to the connection with beachside, funfair, recreational and harbour destinations, and hotel accommodation and for the ease-of-commute to the city centre.
- The clear distinction between the destinations, each with a well-branded identity and uniquely differentiated focus, enhances the connectivity.
2.3 Edmonton, Canada

2.3.1 Overview

Edmonton is the capital city of the Alberta Province in Canada. It is built adjacent to the North Saskatchewan River and is the centre of the Edmonton Capital Region (Figure 2.06). The current population for Edmonton city is just over 875,000 people, a population which has grown steadily from 445,000 people in 1974 the year the city launched the first stage of its light rail project. Edmonton is located in the north of Canada and its metropolitan population is now just over one million people (Edmonton Census, 2014).

Figure 2.06 – Location of Edmonton, Canada.
Source: Google Maps

Edmonton has two light rail lines, the first stretching for 21 km from north east Edmonton and ending at the south end and is known as the Capital Line (Figure 2.08). The second is scheduled for completion and opening in early to mid-2015, linking to areas north of the downtown (main CBD). The first stage of Edmonton’s Light Rail Transit (LRT) was the first in North America for a metropolitan population of less than one million, with six stations from Central to Belvedere in 1978. This was followed by the Clareview extension in 1981; the Central to Corona extension (downtown) in 1983; the Grandin Government Centre in 1989; and the University extension in 1992. It operates as a blend of surface and underground stations (City of Edmonton Planning And Development, 2008; Edmonton Transit System, 2004). Between 2005 and 2010, another five stations were added from University further south to Century Park (Edmonton Transit System, 2004).
Figure 2.07 – Edmonton Capital Line.

Figure 2.08 – The Edmonton light rail system.
Source: Transportation Master Plan, p.44
In 2009, the Transportation Master Plan outlined two new LRT network lines, one linking the east of
the city to the west, and the other the downtown area. The ultimate plan is by year 2040 to have six
lines extending to the northwest, northeast, east, southeast, south and west, as demonstrated in
Figure 2.08.

2.3.2 Geography, climate and governance

Sitting at an elevation of 671 metres, Edmonton is a land that is flat to gently rolling, with some
deeper ravines and river valleys. It neighbours an area known as Aspen Parkland and other forest
areas and urban parklands. It has a temperate climate with average rainfall.

There are 24 municipalities in Alberta’s Capital Region, demonstrated below. This represents five
cities including Edmonton, four municipal districts, 11 towns and three villages (Capital Region
Board, 2013).

2.3.3 Planning and rail

Incorporated as a town in 1892 and then as a city in 1904, Edmonton grew very rapidly in the early
1900s and is no stranger to the importance of rail infrastructure. In 1885 the Canadian Pacific
Railway brought with it increased economic activity to Alberta, in 1891 rail linked Calgary to
Edmonton and in 1905 the Canadian Northern Railway commenced operation (Canadian Railway,
2004). These national railway systems helped pave the way for Edmonton to be built around its
transport systems. Edmonton City Centre airport was built in 1929 as the first in Canada, and since
the 1950s has seen increased growth in the retail, arts and cultural events, and tourism sectors.

Since the first stage of Light Rail Transit (LRT) in Edmonton in the 1970s, Edmonton abandoned the
use of the tramway to embrace the benefits of LRT, which runs on the surface of the outer suburbs
and underground in the central city area (Ginn, 1998). Originally funded due to oil and gas revenues
and promoted along with the 1978 Commonwealth Games, Edmonton LRT was an original 7km
downtown section (Ginn, 1998, page 21). By the 1990s, the patronage of the LRT system in
Edmonton was 36,000 journeys per day over a distance of 12.3 km (Ginn, 1998, page 19), and with
over 100,000 passenger trips per day in 2013 (Transport Planning, 2014).

In 2012 Edmonton City launched its suite of policy responses designed to provide a 30 year strategic
plan for the city. These policies are:

- The Way Ahead (strategic plan)
- The Way We Grow (Municipal Development Plan)
- The Way We Move (Transportation Plan)
- The Way We Green (Environmental Plan)
- The Way We Live (People Plan).

Together, these policies provide the framework for the long term planning agenda in Edmonton, and
are each designed to ‘talk to’ the other to ensure integration. Edmonton’s 30 year agenda (Figure
2.09) includes to shift transport modes and to transform urban form, as well as diversifying their
economy, improving liveability and sustaining the environment (The City of Edmonton Transit
The city’s *Transit Oriented Development Guidelines* (TOD) was approved by City Council in February 2012 under Policy C565. The *TOD Guidelines* set out Edmonton’s planning approach to building a city that is compact, sustainable and transit oriented—i.e. a city where people can walk, cycle and use public transport. TOD is a 30 year plan that aims to transform the neighbourhoods around LRT stations into ‘vibrant hubs of mixed use activity that bring people together’ (City of Edmonton, 2015) by focussing medium and higher density residential, retail and employment growth around LRT stations and transit centres. It emphasises public transit, pedestrians and cycling to connect people and places and increasing transit ridership with a view to reducing the number of car kilometres driven. The *TOD Guidelines* specify the zoning, planning and design requirements for the station areas and transit areas along the LRT corridors at a distance of 400m (5 minutes walking) with various zoning, design and planning guidelines (Page 4 and following, The City of Edmonton *Transit Oriented Development Guidelines*, 2012).

On the release of the concept plan, the City of Edmonton held a public competition to help name the lines. The chosen names of proposed and approved lines were made public in January 2013 (Kent, 2013). The Edmonton LRT system is a vibrant and interconnected transport system that is vital to the city’s long term transit oriented vision.

![Figure 2.09 – Edmonton Station Area Types; concept plan for 30 year plan.](http://www.edmonton.ca/city_government/documents/PDF/TOD_Station_Area_Types_Map.pdf)
2.3.4 Density

Gross population density = 12.8 p/ha

Gross dwelling density = 3.9 dw/ha

These statistics are based on a population of 877,926, dwelling count of 265,340 and an area of 684.4km².

2.3.5 Analysis

In 1985 a study of both Calgary and Edmonton found modest changes to densities, residential construction and mixed use development due to LRT, though costs per passenger had steadily risen. (Cervero, 1985). An additional study was completed that used the 1.5km walkable distance, to measure changes in density around the LRT. The research found that transit use was greatest in highest density (apartments) and lowest for office employees.

The wider benefits of LRT are also appreciated by residents of Edmonton having lived with and grown accustomed to their light rail systems for over 40 years. The Alberta Urban Municipalities Association (which represents also the city of Calgary) stated the following in 2007:

Albertans cannot afford to continue to carry the costs of congestion, emissions and sprawl which have become associated with its “car culture”. Instead they must be provided with viable options. LRT has proven to be an attractive alternative to single vehicle use. Daily LRT boardings are 260,000 in Calgary and 40,000 in Edmonton. It therefore contributes to reductions in congestion and vehicle emissions, and is a central feature of good quality, higher density, mixed use development. It also enhances economic prosperity by meeting workforce transportation needs as well as being a major mode of transport for special sporting and cultural events which Edmonton and Calgary are increasingly hosting. The benefits of LRT are not restricted to Edmonton and Calgary as residents of surrounding areas and beyond use the LRT to access services, educational and work related opportunities, and tourist attractions.

These benefits make funding LRT a quality of life issue. It has become a global expectation that any major city will have attractive alternatives for getting to work, school, and leisure activities. If Alberta is going to increase its edge in the global competition for business and labour, it must invest adequate resources to operate and expand light rail transit systems. Investment beyond a onetime injection is necessary. A long term financial assurance is required to plan the expansion of LRT over the next decades. (AUMA)

2.3.6 Edmonton insights

- The urban design of Edmonton city is a similar ‘Y-Plan’ to that of Canberra and Edmonton has a similar topography with development in town centres across a landscape that comprises valleys and a river.
- The successful continued patronage of the Edmonton light rail has encouraged the adjustment of land use policy to focus medium and higher density residential, retail and employment growth around LRT stations and transit centres. The City’s LRT Network Plan is
directly linked to the broader strategic planning policy ‘City Vision’ which seeks further transit oriented development, compact urban form and a shift in transportation modes.

- Wide community familiarisation and utilisation of the Edmonton light rail enables popular appreciation of the wider benefits of transit oriented development.
- Use has steadily increased since the first stage, and the second stage is due to be opened April/May 2015, with a further four lines being planned to link the town centre nodes with downtown Edmonton in the near future.
2.4 Bergen, Norway

2.4.1 Overview

Bergen is a city on the west coast of Norway and is located in the Hordaland region (Figure 2.10), for which it is the administrative centre.

Figure 2.10 – Location of Bergen, Norway.
Source: Google Maps

In January 2015, the population of Bergen was 275,112, making it Norway’s second largest city after Oslo, the national capital (Statistics Norway, 2015). The population of the greater Bergen region is 410,300 (by comparison, the population of the Canberra–Queanbeyan region in 2014 was about 435,000. Table 2.03 shows Bergen’s population growth throughout its history. Bergen is considered Norway’s most international city (ECM 27, 2012), with non-Norwegians migrating from a diverse range of cultures, including German, Dutch and Scottish.
Table 2.03 – Bergen’s population growth through history.

<table>
<thead>
<tr>
<th>Date</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500</td>
<td>5,500</td>
</tr>
<tr>
<td>1769</td>
<td>18,827</td>
</tr>
<tr>
<td>1855</td>
<td>37,015</td>
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<tr>
<td>1900</td>
<td>94,485</td>
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<tr>
<td>1910</td>
<td>104,224</td>
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<tr>
<td>1920</td>
<td>118,490</td>
</tr>
<tr>
<td>1930</td>
<td>129,118</td>
</tr>
<tr>
<td>1940</td>
<td>Not available</td>
</tr>
<tr>
<td>1950</td>
<td>162,381</td>
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<td>1960</td>
<td>185,822</td>
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<td>1970</td>
<td>209,066</td>
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<td>2000</td>
<td>229,496</td>
</tr>
<tr>
<td>2010</td>
<td>256,580</td>
</tr>
<tr>
<td>2014</td>
<td>271,949</td>
</tr>
<tr>
<td>2015</td>
<td>275,112</td>
</tr>
</tbody>
</table>

Source: Statistics Norway

Today Bergen is an international centre for shipping; Bergen port is situated in one of Europe’s largest and busiest harbours, servicing the oil export industry and the Norwegian Navy (ECM 27, 2012). It is also a national centre for finance, tourism and education (ECM 27, 2013). The first two stages of the Bergen light rail cover 20 stations over 13.4 km between the city centre and Lagunen Storsenter, opened in 2010, and from Nesttun to Lagunen, opened in June 2013.

2.4.2 Geography, climate and governance

Bergen is located along Norway’s mountainous and deeply indented North Atlantic coast, famous for its spectacular fjords. The city centre and the northern precincts are located along the shoreline of Byfjorden (‘The Village Fjord’). Because of its mountainous topography, Bergen is sometimes known as ‘the city between the seven mountains’ (ECM 27, 2012). The urban form is largely determined by the mountainous landscape and the coastline of the fjord.

With its location on the Norwegian west coast adjacent to the mild waters of the Gulf Stream, Bergen has a temperate oceanic climate with cool winter, mild summers and a large amount of rainfall due to the orographic effects of the surrounding mountains. On average Bergen receives 2250 mm of precipitation (by comparison, Canberra’s average annual rainfall is about 625 mm).

Climate change is already affecting Bergen’s environment. Increases in precipitation and winds in recent years (with evidence that these trends are linked to climate change) have increased the incidence of flooding and landslides, with some fatalities and much property damage. Sea-level rise is a big concern. Even now the city’s historic wharf (‘Bryggen’) is regularly flooded at extreme tides. As sea level rise further, increasing numbers of historical sites and infrastructure, such as the rail line to Oslo, are vulnerable to flooding. A sea wall outside of the harbour has been proposed to protect the city.
The area covered by the municipality of Bergen is 465 km$^2$ and the city consists of eight boroughs (Figure 2.11). The city centre lies in Bergenhus, located on the shores of Byfjorden, with urban areas radiating out to the north, west and south. A large mountain blocks extension of the urban area to the east. Parts of Fana, Ytrebygda, Åsane and Arna boroughs are rural and not part of the greater Bergen urban area.


### 2.4.3 Planning and rail

The first stage of the Bergen Light Rail System was approved by the city administration in 2000. The project was part of a larger transport package that included investments in the road system and was funded by the tolls from the existing ring road. The project received widespread political support across most political parties, and was justified on the basis of environmental benefits, urban development and alleviation of road congestion. Criticisms came primarily from residents of the northern and western suburbs, as the first stage was a single line that served the southern suburbs in Fana out to the airport.

Initial works began in 2007 and construction of the light rail itself began in January 2008. The line was officially opened on 22 June 2010 by Queen Sonja of Norway with five of the eight train units available.

The initial 9.8 km route runs from the city centre to the southern suburb of Nesttun. The city terminus is in the centre of the city at a transit hub with good connections to the bus network. The route to Nesttun passes Brann Stadion, the city’s largest football stadium, as well as the campuses of the University of Bergen and Bergen University College.

Once completed, the southwards extension of the line to Rådal was begun almost immediately, in January 2011, on its own right-of-way, parallel to the road. The track was completed in October 2012 and the line was opened to the public on 22 June 2013. A further extension from Rådal to the airport...
is underway and is scheduled to be opened in 2015. This extension, in addition to serving the airport, will also serve a large corporate centre with many of Bergen’s largest employers as well as areas of rapidly increasing population.

The proposed northward extension of the line will either replace the current bus services, with many stops, or run as an express service with only a few stops at major points, such as the Norwegian School of Economics. The third line will run from the city centre southwards, east of the City-Nesttun line, and is designed to serve the Haukeland University Hospital, which is western Norway’s largest workplace.

The line is operated with a five-minute headway (interval between trains) during rush hour, a 10-minute headway in off-peak times and a one-hour headway at night. Because of the large number of stations (15) on the 9.8 km line, the average speed is slow—28 km/hr. In 2010 the price of a single ticket was NOK 25 (approximately $A 4.00 at current exchange rates) and the tickets are integrated with the bus system. One ticket allows transfers between the modes.

The train units have five articulated sections, measuring 32.18 metres in length and 2.65 metres in width. Each unit weights 35.7 tonnes. The units are expandable to 42 metres by adding another two modules. All stations are built to handle the extended trains. Eight motors provide a total of 360 kW for three bogies. Maximum speed is 70-80 km/hr, and they are capable of operating on a 7 per cent gradient. Current is delivered via overhead wires.

Passenger capacity is 212, of which 84 can sit abreast. The entire light rail system is step-free, providing access for mobility-impaired passengers. There is wheelchair and pram access throughout the cars. All trains have wireless internet access.

The tracks and train widths are standard gauge, and the line is double track. Tracks in city streets are laid with a rubber jacket to reduce noise. The light rail, when running on city streets, has priority at traffic lights to improve speed. The first stage (9.8 km) has 15 stations and the second stage (3.6 km) has an additional five stations. The municipal government has encouraged denser development around the stations, where it aims to have most residential and commercial development. There has, however, been opposition by residents when developers propose projects that change the character of the neighbourhood. The light rail system is shown in Figure 2.12.
Figure 2.12 – The route of the first stage of the Bergen Light rail system, showing the extension to the airport.
Source: http://www.urbanrail.net/eu/no/bergen/bergen.htm

System details
Number of stations: 20
System length: 13.4 km
Daily ridership: 31,000
Interval between trains: 5–10 minutes
Began operation: 22 June 2010

2.4.4 Density data
Gross population density = 5.9 p/ha
Gross dwelling density = 2.6 dw/ha

These statistics are based on Bergen’s population of 275,112 (in 2015), dwelling count of 122,871 (in 2011) and an area of 465.6 km².
2.4.5 Analysis

Less than 30 per cent of dwellings in Bergen are detached houses, however it has a high proportion of two-dwelling houses and other compact housing, with the majority of housing in the central urban areas of Bergen being units (Statistics Norway, 2013b). Whilst Bergen has the second largest portion (42%) of dwellings that are units in Norway, more than 20 per cent of suburban dwellings in the areas surrounding the city have been built since 2001 (Statistics Norway, 2013b). The suburbs outside the Bergen municipality grew rapidly in the 1950s and 1960s with a much lower density suburban form than in the urban centre. After these surrounding municipalities were merged with Bergen in 1972, low density population expansion has continued. These outer suburbs are connected to the urban centre of Bergen by several roads and train tunnels (ECM 27, 2012).

The inner part of the city is densely populated but the majority of the population of the greater Bergen region live in sparsely populated residential areas that have been built since the 1950s. The inner city has been redeveloped several times, often after extensive fires, much of the development being carefully planned for high population density. The population within the ‘urban settlement’ of Bergen increased by 4 per cent, from 247,731 in 2012 to 257,364 in 2013 (Statistics Norway, 2014). Some of this growth can be attributed to the installation of the new light rail in 2008. The now larger municipality of Bergen (incorporating surrounding areas) is encouraging higher density population areas around commercial centres and the Bergen Light rail stations.

2.4.6 Bergen insights

- With a population of about 275,000 and with much of the city's population concentrated in the valleys that spread outwards from the city centre, Bergen is similar to Canberra in size and in dispersed physical form.
- The Bergen local government has encouraged and legislated for denser development around light rail stations, where it seeks to facilitate the construction of most new housing and commercial property. Private developers have shown keenness to develop sites in the light rail corridor.
- The first stage of Bergen's light rail system, covering 9.8km and 15 stations between Bergen centre and Nesttun, opened in 2010. By mid-2013 it transported over 31,000 passengers daily, attracting far more than was originally predicted.
- Future stages of the Bergen light rail are receiving increased popular support. Future extensions of the existing light railway system are being planned. The existing network may be extended to Fyllingsdalen and Loddefjord in the west and Sandviken / Åsane in the north. A link between the primary regional hospital and the city centre is also being considered.
2.5 Freiburg im Breisgau, Germany

2.5.1 Overview

Freiburg im Breisgau (Freiburg) is a city in the south-west of Germany (Figure 2.13). It is located between Dreisam River and the Black Forest, and in close proximity to the borders of both France and Switzerland. Freiburg’s economy is based on tourism, university teaching and research, government and church administration, and a broad range of services provided to the surrounding region (City of Freiburg, 2009). In 2013 the population of Freiburg was 218,043 (UNData).

![Figure 2.13 – Location of Freiburg, Germany](source: Google Maps)

In 1972 the Freiburg City Council also decided to expand the light rail network (referred to as ‘Stadtbahn’) construction for which commenced in 1978. The Second Transport Plan (Generalverkehrsplan) of 1979 emphasised ‘changed’ political and environmental circumstances, the connection of transport planning and land use planning, and favoured the so-called ‘green modes’ of transport (walking, cycling, and transport) over the motor vehicle. Priorities for land-use policies shifted accordingly. The land-use plan of 1981 prescribed that new development was to be concentrated along public transport corridors, especially the city’s expanding light rail system, whose first new line opened in 1983 (Blatter, 1995; City of Freiburg, 2008; Hilliard, 2006). In 2002, the Transport Development Plan sought to adjust the primary goals of the integrated transport system, and focus on population growth and spatial development.
The city is regarded as having advanced environmental practices (Kemp and Stephani, 2015, p102) particularly due to its success at encouraging sustainable alternatives to car use, or at least to keeping the modal split between cars and reliance on the train to a minimum (Beim and Haag, 2010). Urban planning in Freiburg over the last 40 years has emphasised cycling, walking and public transport, traffic calming and mixed-use developments to encourage the development of a highly accessible city and well integrated city (Beim and Haag, 2010). A wide range of green building initiatives including regional heating, low energy buildings and recycling have been established. The city mandates a fairly stringent energy standard for all new homes. (Newman et al., p60). Planning in the region has confined development within urban containment boundaries preventing urban sprawl (IMCL, accessed 2015).

The Freiburg *Transport Development Plan 2020* seeks a continuing trend to a sustainable modal split, with 24 per cent of the population walking, 27 per cent on bicycles, 20 per cent on public transport, 24 per cent as car drivers and five per cent passengers (Beim and Haag, 2010, p286). While much of the success of the rail network has previously been attributed to the low cost travel pass that was issued in 1984 (FritzRoy and Smith, 1998), that has been but one aspect of a highly integrated network (Beim and Haag, 2010).

### 2.5.2 Geography, climate and governance

Freiburg sits at an elevation of 581 metres above sea level and its topography consists of hills and valleys which sit either side of the main river (Sarine River). It has a relatively temperate climate with slightly above average rainfall with an extended rainfall season ([http://en.climate-data.org/location/2134/](http://en.climate-data.org/location/2134/)).

### 2.5.3 Planning and rail

After two decades of cutting streetcar services only 14 km of old streetcar lines were still in operation in Freiburg in 1970 (Nahverkehr Breisgau, 2008; Schroeder, 2009). Services were slow and infrequent and the infrastructure and rolling stock outdated—and public transport patronage had been continuously declining.

Expanding and upgrading the light rail system was at the centre of Freiburg’s multi-faceted strategy to integrate public transport and land-use planning. Since the opening of the first new light rail line in 1983, Freiburg has added four new lines with a total extent of 36.4 km in 2008 (City of Freiburg, 2009). During the same period, the supply of light rail services has almost tripled (from 1.1 to 3.2 million vehicle km). In 2006, 65 per cent of Freiburg’s residents and 70 per cent of all jobs were located within easy walking distance (300 m) from a light rail stop (City of Freiburg, 2008b).

Freiburg now has an extensive and well-integrated network of trams, buses, and commuter-rail lines. Each day 200,000 residents and visitors make use of the system of four tram lines and 26 bus lines. The region’s 17 transportation companies work in partnership to create a common ticketing system. Over the past 10 years there has been a 100 per cent increase in public transportation use. The city has the lowest motor vehicle density of any city in Germany with 423 cars per 1000 people. The increase in car trips in Freiburg over the last 15 years was only 1.3 per cent. Public transport passengers have increased 53 per cent and bicycle trips have risen 96 per cent since 1976 (Kemp and Stephani, 2015, p102).
Freiburg is an international exemplar of the alignment of transit services with land development planning. Occupancy permits for new residences are not granted until light rail transit services have begun operations in the block. Newcomers, therefore, are discouraged from using cars for commuting and the road-building requirements in developments are thus kept to a minimum (Suzuki et al., p83).

Figure 2.14 – Freiburg’s Streetcar Network as of March 2014.  
Source http://www.livablecities.org/articles/amazing-possibilities-streetcars

System details

Length of network: approximately 36 km
Number of Lines: 4
Frequency: line 1 every 5 min, lines 2, 3 and 5 every 7.5 min.  
(Source: Urbarail.net)
2.5.4 Analysis

Vauban

Vauban is a recently established and constructed neighbourhood for 5000 inhabitants and 600 jobs three to four km to the south of the Freiburg town centre. Construction commenced in 1998 and was completed in 2010. It was built as a sustainable model district on the site of a former French military base. It is a car-reduced brownfield redevelopment with parking-free residential streets: car ownership and use are exceptionally low—160 cars per 1000 residents with parking spaces provided less than 0.5 vehicles per residence (Field, accessed 9 March 2015).

This relatively new area of Freiburg is a good example of a deliberate Transport Oriented Development strategy leading to higher density. Given its former use as a military base, the urban density at commencement in 1998 was very low or negligible.

Figure 2.15 – New development areas Freiburg V=Vauban  R=Rieselfeld (shown in blue) (Source: EEI)
Figure 2.16 – Vauban aerial view looking west
(Source: EEI)

Vauban indicators—achieved values 2006
Total land: 32 ha
Total population: 4588
Total number of dwellings: 1991 at 2.3 people/ha
Gross population density: 143 people/ha
Gross dwelling density: 62 dwellings/ha
Net population density: 232 people/ha
Net dwelling density: 104 dwellings/ha
(Source: EEI)

Rieselfeld

Rieselfeld is the second district of Freiburg founded in 1992. Pilot projects commenced in the 1980s while full development started in 1993 and continued for the next two decades. The site is a former sewage treatment facility at the western edge of the Freiburg city centre. A 250-hectare natural reserve area was created together with a 78-hectare housing development with about 4500 homes designed (by means of several architectural design competitions) to accommodate 10,000–12,000 people. One section of the village is car-free with residents agreeing to not own a vehicle (Gauzin-Müller, 2002).
Figure 2.17 – Rieselfeld, Freiburg,
Aerial view from the west showing central light rail corridor (Source: EEI)

Rieselfeld indicators—achieved values 2008
Total land: 70 ha
Total population: 8200
Total number of dwellings: 3200 at 2.56 people/dwelling
Gross population density: 117 people/ha
Gross dwelling density: 45 dwellings/ha
Net population density: 195 people/ha
Net dwelling density: 76 dwellings/ha
(Source: EEI)
2.5.5 Freiburg insights

- Freiburg has over several decades simultaneously made public transport, cycling, and walking viable alternatives to motor vehicle use, while increasing the cost of car travel. Improving quality and level of service of alternative modes of transport has made car-restrictive measures politically acceptable (Buehler and Pucher, 2011).
- Light rail and other deliberate sustainability policy initiatives in Freiburg have dramatically improved the image of the city, its reputation as a tourist destination and as an exemplar of compact urban environment.
- The development of Vauban and Rieselfeld from brownfield sites to very high population and dwelling density precincts, with all residences within close immediate proximity to light rail, exemplifies the extraordinary capacity of transit oriented development to create desirable and successful urban precincts.
- Two office blocks in Freiburg were built at the same time and have the same quality: the offices that have tram access have 15–20 per cent higher rents than the office block which has no tram access, even though it is closer to the city centre (Crampton, 2003, p9).
3.0 Analysis and comparisons to Canberra

3.1 City location

Canberra, the National Capital, is located in southeast Australia. It is a planned city, created as the seat of national government in 1909. The Australian Constitution, enacted at Federation in 1901, determined that ‘the seat of the Commonwealth ... be within New South Wales, and be distant not less than one hundred miles (160 km) from Sydney.’ The site for the city chosen after much political wrangling was known as the Limestone Plains located on the Molonglo River. Canberra is approximately 300 km from Sydney and 500 km from Melbourne in an almost direct alignment to fulfil the requirements of the Constitution (Pegrum, 2008).

As the National Capital, Canberra is home to the Federal Parliament (see Figure 3.01) and hosts the major national institutions including the National Library, National Museum, National Gallery, High Court, and the Australian War Memorial.

Figure 3.01 – Parliament House Canberra
Source: David Flannery
The distinctive characteristic of Canberra is its landscape setting, which has earned it the name as a ‘bush capital’. Canberra’s location is strategically placed between the Australian Alps and the south coast NSW providing a magnificent surrounding region, particularly the magnificent backdrop of the Brindabella Range to the south-west of the city (Figure 3.02).

Figure 3.02 – A snow-capped Brindabella Range as the south-western backdrop to suburban Canberra
Source: David Flannery

3.2 History

Canberra was named as the new national capital on 12 March 1913. After an international design competition, in May 1912, Walter Burley Griffin was selected as the architect with the winning design entry.

Griffin’s winning design showed a chain of lakes along the Molonglo Valley and a triangular framework for a central national area laid out along major vistas from Mount Ainslie and Black Mountain. On the southern side of the central lake, Griffin proposed a terraced group of government offices leading to the ‘Capitol’, his place of the people (now the site of Parliament House). Lower hills in the valley were reserved for other government and national institutions, a university, military college and municipal buildings, including a city hall (Fact Sheet, NCA 2015).
Figure 3.03 – Walter Burley Griffin’s early plans for Canberra included rail and light rail.

Image source: http://urbanplanning.library.cornell.edu/DOCS/griffin.htm, ‘Plan of City and Environs, one frame. Rendered on cambric in monotone to indicate graphically the dominant topographical features and the relation thereto of the proposed, and indefinitely proposed public architecture, and landscape treatment. Also the communication lines including rail and train ways and the local residential and industrial plots together with their resistance in future times.’ [From Engineering News, July 1912].
3.3 Population

The Australian Capital Territory is just over 2,400 square kilometres in area but it is its urban and suburban areas that are generally referred to as Canberra. After the founding of Canberra, it grew relatively slowly.

Initially growth was hindered by the Great War between 1914–18, however, it was seen as a national imperative to make a substantial start on the construction of the new capital throughout the 1920s. In 1927, Parliament was transferred from its temporary location in Melbourne to the Provisional Parliament House and a small population of mainly public servants occupied some of the new first suburbs on both sides of the Molonglo River.

Little progress occurred following the Great Depression which commenced in 1928 and which continued into the 1930s and through the years of the WW2 1939–45.

The National Capital then grew very quickly from the late 1950s and particularly during the 1960s under the patronage of then Prime Minister Robert Menzies. The population of Canberra grew from about 39,000 in 1957 to a thriving capital with a current population of approximately 385,000 (385,996, 2014 for ACT) and 434,982 including the adjoining border city of Queanbeyan (2013 for Canberra–Queanbeyan).

3.4 Transport in Canberra

The transport network for Canberra was designed in the original Griffin Plan to be based on active travel including trams (referred to as ‘street cars’ in his drawings and associated documents, the American term for trams). However, the tram network was never established and the polycentric city grew around town centres linked by an arterial road network. Today Canberra is a very car-based city supported by a bus system (ACTION) that feeds the town centres and surrounding suburbs.
3.5 Light rail in Canberra

During 2012, the ACT Government announced its commitment to building a light rail with the first stage to be between Civic and Gungahlin. Capital Metro was established to manage the project, with a physical commencement to construction in 2016 and a projected completion of 2019–20. ‘Current estimates for daily light rail boardings in the City to Gungahlin corridor are forecast to grow to over 13,000 by 2021 and over 20,000 by 2031’ (Capital Metro, 2015).
Figure 3.05 – Canberra’s Light Rail Project, Stage 1 Route map.
Source Capital Metro, 2015
Capital Metro is currently managing a comprehensive tendering process for the first stage of the light rail between Gungahlin and the city centre. Following this process the ACT Government will announce the winning tender and the next phase of construction. Concurrent with this, studies are proceeding to examine potential future extensions of the network to other town centres and key residential and commercial node points in the city.

![Canberra’s Light Rail Project, Stage 1 route map and possible future extensions.](image)

Source: Capital Metro, 2015

Below is a discussion of the case studies outlined earlier in this report, some comparison to Canberra and a discussion of key implications for the planning of the corridor.

### 3.6 Comparative analysis of case studies with Canberra

<table>
<thead>
<tr>
<th></th>
<th>Freiburg</th>
<th>Bergen</th>
<th>Edmonton</th>
<th>Adelaide</th>
<th>Canberra</th>
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<tr>
<td></td>
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<td>light rail</td>
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<td></td>
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<td>877,926 (2014)</td>
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<tr>
<td>Light rail</td>
<td>New light rail</td>
<td>New light rail</td>
<td>First light rail</td>
<td>Glenelg line established</td>
<td>Proposed commence-</td>
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<tr>
<td>Freiburg (1929)</td>
<td>Bergen</td>
<td>Edmonton</td>
<td>Adelaide</td>
<td>Canberra</td>
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<td></td>
<td>New light rail 2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross population density</td>
<td>143 p/ha Vauban</td>
<td>5.9 p/ha (city)</td>
<td>12.8 p/ha (city)</td>
<td>21.6 p/ha (1.5 km corr*)</td>
<td>13.1 p/ha (1.5 km corr)</td>
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<tr>
<td></td>
<td>117 p/ha Rieselfeld</td>
<td></td>
<td></td>
<td>19.6 p/ha (400 m corr)</td>
<td>26.0 p/ha (400 m corr)</td>
</tr>
<tr>
<td>Net population density</td>
<td>232 p/ha Vauban</td>
<td>Unknown</td>
<td>Unknown</td>
<td>27.4 p/ha (1.5 km corr)</td>
<td>18.4 p/ha (1.5 km corr)</td>
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<td></td>
<td>195 p/ha Rieselfeld</td>
<td></td>
<td></td>
<td>27.3 p/ha (400 m corr)</td>
<td>55.0 p/ha (400 m corr)</td>
</tr>
<tr>
<td>Net dwelling density</td>
<td>104 dw/ha Vauban</td>
<td>Unknown</td>
<td>Unknown</td>
<td>13.7 dw/ha (1.5 km corr)</td>
<td>8.1 dw/ha (1.5 km corr)</td>
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<tr>
<td></td>
<td>76 dw/ha Rieselfeld</td>
<td></td>
<td></td>
<td>13.9 dw/ha (400 m corr)</td>
<td>23.0 dw/ha (400 m corr)</td>
</tr>
<tr>
<td>Significant features</td>
<td>In 2006, 65% of Freiburg’s residents and 70% of all jobs were located within easy walking distance (300 metres) from a light rail stop</td>
<td>The route to Nesttun passes Brann Stadion, the city’s largest football stadium, as well as the campuses of the University of Bergen and Bergen University College.</td>
<td>The TOD guidelines set out Edmonton’s planning approach to building a city that is compact, sustainable and transit oriented, i.e., a city where people can walk, cycle and use public transport.</td>
<td>Extended in 2008 due to high demand, which improved access to entertainment &amp; health facilities &amp; encouraged urban regeneration in surrounding areas. Potential to extend to airport.</td>
<td>Polycentric city based on town centres with spaces in between green; car based city since major extension of road network during the 1960s.</td>
</tr>
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</table>

*corr = corridor

Above is a summary of the key characteristics of the four case studies with some comparison to Canberra. As can be seen from the table, the selected cities have introduced light rail since the 1970s.

Importantly, population size varies significantly from that well below Canberra to above the size of the Australian Capital Region. So, depending on how large the proposed system will grow over time, there is possibly scope for a wider integrated light rail/ rail network for the Australian Capital Region (ACR). An illustration of what might be possible is shown below. While only schematic, it highlights that the introduction of light rail needs to be seen as part of an integrated transport network (Norman & Steffen, 2014). The case studies involve a mix of transport modes that extend the rail network including buses and a strong focus on ‘active’ travel. Any plan for the Northbourne–Gungahlin corridor should consider these aspects and the wider system.
3.7 Summary

- The review of the case study cities has highlighted that there must be to an integrated approach to land use planning and light rail implementation as part of a holistic urban planning and urban transformation process. This is critical, as relying on the private sector to rezone and redevelop without a precinct strategy to reinforce these outcomes makes it less likely for the best urban outcomes to occur. International experience has shown that the lack of an integrated planning framework is one of the key inhibitors to land use and transport integration.

- The international and interstate case studies include a range of populations demonstrating light rail can be beneficial for small–medium sized cities. The study found some evidence (Ginn, 1998) to support a quantifiable minimum population threshold of 200,000 for sustaining an urban light rail system which might facilitate urban renewal or patronage targets. Two of the case study cities and other international cities have both successful light rail systems and populations significantly less than that of Canberra.

- The case studies highlight evidence of change in land use activity over time including more intensive (more dense) residential developments and the development of mixed use. Activated density – density driven by strong, planned and deliberate land-use policy implementation - has been shown to be more highly effective in achieving better urban
outcomes than a reliance solely on induced density—a density achieved ad hoc through a build-the-rail-and-density-will-come approach.

- Adopting explicit Transit Oriented Development (TOD) guidelines, as is the case with Edmonton, appears to be an important factor in density increases along with a wider city plan. Such guidelines are critical for the activation of the urban regeneration along the corridor.

- Community attitudes to the urban challenge of car-dependence have changed as exhibited clearly in the cases of Freiburg and Bergen. In Freiburg a shared understanding of city building and future-proofing the city against planning challenges was cultivated in all levels of government and with key stakeholders and professional groups. Community confidence increased as new stages of light rail were planned and delivered. In Bergen the funding mechanism of implementing a toll on an existing ring road gained popular acceptance. The present and future challenges of traffic congestion and peak car use in Australia, however, although they have been frequently and regularly identified by governments (BTRE, 2007; Infrastructure Australia, 2014) are less widely understood.

- The new light rail services examined showed that easy transfer between multi-modal systems needed to be provided. This included the integration of network design, timetables, ticketing and fare structures in most examples.

- A broader cost-benefit analysis undertaken as a potential future study would highlight the community (active travel and healthy cities) and environmental (climate change mitigation and biodiversity) benefits. The study team notes that transport economics cannot currently quantify these benefits, but if the implementation of light rail is integrated with land-use planning then at least some of the urban intensification benefits can be captured.

- The international case studies show that commercial and residential property values can be higher when the properties are constructed close to a light rail station, in part stimulated by a willingness of purchasers to pay for access to transit (McIntosh et al, 2014). Developers were aware of the investment opportunities associated with light rail to leverage the economic and also the social benefits.

- Public transportation patronage increases as light rail transit systems become operational.

- Although LRT systems can bring considerable financial, social and environmental benefits to a host city, research demonstrates that local conditions must be receptive if these systems are to have a measurable impact on urban transformation and land use change. Light rail transit cannot be a driver of new growth and land use change on its own, but as a component part (albeit a foundational part) in a long-term strategic urban planning effort to shape growth and revitalisation in the city (Higgins, 2014).
4.0 Density for the Northbourne corridor

4.1 GIS mapping overview

The case studies discussed provide some national and international evidence of successful urban transformations and revitalisation of urban corridors, cores and neighbourhoods. Benefits include increased mobility and access to and within city centres whilst reducing car dependence, traffic congestion and carbon emissions. The Capital Metro light rail in Canberra is expected to bring many of these environmental, social and economic benefits to the growing city (Flannery et al., 2014).

Spatial planning of urban growth within the walkable corridor, using population and dwelling densities as indicators, highlights some of the opportunities and constraints of the light rail development project. Accordingly, a Geographic Information System (GIS) analysis of trends using Australian Bureau of Statistics (ABS) census data and ACT Planning Authority land use zoning is being used to enable and facilitate the examination of residential development patterns and their impacts on the pre- and post-light rail condition for the Northbourne Avenue and Flemington Road corridor.

4.2 Data analysis

Study Area

The defined study area captures land within a 1.5km walkable corridor, i.e. 1.5km either side, of the Northbourne Avenue and Flemington Road light rail transit route, from Gungahlin in the north to the city centre, Civic (Figure 4.01). The boundary of the study has been established to align with physical and administrative boundaries rather than an arbitrary geometric shape. Based on this premise, a 1.5 km buffer was created to help determine the outer limits of the corridor; however, road, parcel and land use zone boundaries were used to delineate the study area boundary.

Analysis has also been undertaken to compare this wide corridor with a smaller 400 m corridor either side of the light rail. The boundary of the 400 m corridor has been delineated in the same manner as the 1.5km corridor boundary. The 1.5 km corridor is referred to as the ‘walkable corridor’, whereas the 400 m corridor is referred to as the ‘light rail corridor’.

It is noted that the 1.5 km corridor is wider than other corridors currently being examined for different purposes by the ACT Environment and Planning Directorate and other studies, which are commonly set at a distance of 400 m or 800 m from the light rail. Establishing a 1.5km walkable corridor for this study seeks to ensure the capture of any ‘edge effects’ on the outer limits of the study area where light rail might affect population and dwelling density.
The study area consists of a 400 m corridor around the light rail route and a 1.5 km walkable corridor, which have been delineated using 400 m and 1.5 km buffers as a guide.
Gross and net density measures

Population and dwelling densities were calculated for the ACT region and study area corridors using ABS census data. Density was determined by dividing the number of people or dwellings by land area, i.e. people per hectare (p/ha) and dwellings per hectare (dw/ha). Population density can also be calculated by multiplying residential density by occupancy rate (Landcom, 2011), calculating a simple average of population densities for all land parcels, or using a population weighted density measure, whereby the weighted average of the density of all parcels of land is determined, with each parcel weighted by the size of its population (Charting Transport, 2013). However, for the purpose of this study, density was derived from land area as this approach aligns with the ABS method of calculating density. This allows for ease of analysis and comparison against reported density figures.

In addition, two types of population and dwelling density were derived: gross density and net density. Gross density is calculated over the whole land area within a region or census unit, such as statistical area or collection district, and does not take into account local land uses that are zoned for residential development (Landcom, 2011; ACT Government, 2011; Pafka, 2013). Net density is measured for land that is occupied by residential uses only, and does not include areas that are zoned for other types of land use, such as commercial, industrial and parklands (Landcom, 2011; ACT Government, 2011).

Whilst gross density is a useful way of determining population and dwelling densities for an overall area, it is a generalised estimation. Net density is a more accurate measure as it provides population and dwelling densities within their residential context. Net density is used to examine the potential impacts of light rail within the 400 and 1.5km corridors in this study. These results are compared with gross population and dwelling densities for the study area and the ACT region.

Extracting residential areas

The ACT Territory Plan was used to extract residential land use zones for deriving net population and dwelling densities. Land use zones were assigned to one of three types of land use (Table 4.01). The land use types were defined as follows:

- residential—all suburban and urban types of residential development, including some urban land uses that have residential uses, such as urban core, mixed use, business and services zones
- urban—non-residential urban land uses including commercial and industrial development, community facilities, local centres and transport infrastructure
- non-urban—rural land, environmentally protected areas and open and green spaces.

The Territory Plan land use zones are shown in Figure 4.02 and the land use types derived from these zones for calculating net densities within the study area are presented in Figure 4.03.

Table 4.01 – The Territory Plan land use zones.

The Territory Plan land use zones assigned to residential, urban and non-urban land use types for determining net population and dwelling densities in this study.
<table>
<thead>
<tr>
<th>Residential</th>
<th>Urban (non-residential)</th>
<th>Non-urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>High density residential</td>
<td>Business</td>
<td>Broadacre</td>
</tr>
<tr>
<td>Medium density residential</td>
<td>Community facilities</td>
<td>Designated*</td>
</tr>
<tr>
<td>Suburban</td>
<td>Core</td>
<td>Hills, ridges &amp; buffer areas</td>
</tr>
<tr>
<td>Suburban core</td>
<td>Designated*</td>
<td>River corridor</td>
</tr>
<tr>
<td>Urban residential</td>
<td>General industry</td>
<td>Urban open space</td>
</tr>
<tr>
<td>Core/services/business**</td>
<td>Industrial mixed use</td>
<td></td>
</tr>
<tr>
<td>Leisure &amp; accommodation</td>
<td>Local centres</td>
<td></td>
</tr>
<tr>
<td>Mixed use</td>
<td>Restricted access recreation</td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* some (NCA) designated zones were classified as ‘urban’, such as the Australian National University and areas surrounding the city centre, whilst other designated zones would be classified as ‘non-urban’, such as nature reserves (though these are situated outside the study area).

** some core, services and business zones were included where there is residential (and potential future residential) development in urban centres.
Figure 4.02 – Current Land use zones in the Territory Plan
Source: ACT Government
Figure 4.03 – Residential, urban (non-residential) and non-urban land uses in the study area, based on the Territory Plan land use zones
Source: ACT Government
Mapping population and dwelling densities

In addition to reporting on the gross and net densities for population and dwellings, maps provide a visual depiction of how these densities are distributed throughout the study area, and how the density of populations and dwellings is changing both spatially and temporally. The net population and dwelling densities were mapped for 2006 and 2011 time frames using ABS census data for total population and number of dwellings. This provides a snapshot of residential density for the study area in recent times and a foundation for assessing future urban density changes post light rail construction.

The geographical units for the population and dwelling census data that were used in this analysis were Collection Districts (CDs) for 2006 and Statistical Areas Level 1 (SA1s) for 2011. These geographical units, which contain population and dwelling census data, were extracted for residential land uses within the study area in order to calculate and map net population and dwelling densities. For CDs and SA1s that were ‘cut off’ by the study area or residential land use boundaries, proportional population and number of dwellings were used in the density calculations to provide an accurate depiction of population and dwelling densities within the study area.

In order to map population and dwelling densities, threshold categories were determined for five categories of density: very low, low, medium, high and very high. Thresholds of dwelling densities were derived using values depicted in SA and NSW residential density guides published by Government of South Australia (2006) and Landcom (2011a) as a guide (Tables 4.02 and 4.03). The values used to map net dwelling density for this study are noticeably lower than the net densities in these guides and were selected for adequately representing density within the corridor, based on residential density in the ACT region, which is comparatively lower than its NSW and SA counterparts (Table 4.04).

Note: residential density is a measure of dwelling density in these guides.

Table 4.02 – Gross and net residential densities as defined in the Planning Strategy for Metropolitan Adelaide
(Source: Government of South Australia, 2006).

<table>
<thead>
<tr>
<th>Approximate Gross Density</th>
<th>Approximate Net Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low density</td>
<td>Less than 11 dw/ha</td>
</tr>
<tr>
<td>Low density</td>
<td>11-22 dw/ha</td>
</tr>
<tr>
<td>Medium density</td>
<td>23-45 dw/ha</td>
</tr>
<tr>
<td>High density</td>
<td>Greater than 45 dw/ha</td>
</tr>
</tbody>
</table>

Table 4.03 – Gross and net residential densities as defined in the Residential Density Guide and associated reference charts
(Source: Landcom, 2011a & 2011b).

<table>
<thead>
<tr>
<th>Gross Density</th>
<th>Net Density (based on Growth Centres Commission in NSW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low density (rural)</td>
<td>Less than 6 dw/ha</td>
</tr>
<tr>
<td>Medium density (edge suburban &amp; suburban)</td>
<td>6-17 dw/ha</td>
</tr>
<tr>
<td>High density (village &amp; village centre)</td>
<td>17-30 dw/ha</td>
</tr>
</tbody>
</table>
Mixed use density (urban & town centre)  
Greater than 30 dw/ha  
Greater than 66 dw/ha

Table 4.04 – Assigned net residential density thresholds for mapping dwelling density in the study area

<table>
<thead>
<tr>
<th>Net Dwelling Density</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low density</td>
<td>&lt; 6 dw/ha</td>
</tr>
<tr>
<td>Low density</td>
<td>6-12 dw/ha</td>
</tr>
<tr>
<td>Medium density</td>
<td>12-17 dw/ha</td>
</tr>
<tr>
<td>High density</td>
<td>17-23 dw/ha</td>
</tr>
<tr>
<td>Very high density</td>
<td>&gt; 23 dw/ha</td>
</tr>
</tbody>
</table>

No equivalent guides for population densities were available at the time of writing this paper, so an alternative method was applied to determine the thresholds for mapping net population density. This involved multiplying the net dwelling density thresholds by the dwelling occupancy, i.e. average number of people per dwelling. It is assumed that population and dwelling densities are related through this variable, as the sum of people living in all households in any given residential area would ideally be equivalent to the total population for that area (though this would not be exact due to census data collection methods). Thus, if each household had a dwelling occupancy of two, the population density would be roughly double that of dwelling density.

The average persons per household census statistic for Canberra in 2011 was 2.6, which is the same as the average people per household for Australia in the same year (ABS, 2015b). This figure is expected given typical household compositions in Canberra. Of all households in the ACT in 2011, the majority were family households (71.1%), whilst 23.4 per cent were single person households and the remaining 5.6 per cent were group households (ABS, 2015b). The thresholds used to map net population density in the study area are provided in Table 4.05.

Table 4.05 – Assigned net population density thresholds for mapping population density in the study area

<table>
<thead>
<tr>
<th>Net Population Density</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low density</td>
<td>&lt; 15.6 p/ha</td>
</tr>
<tr>
<td>Low density</td>
<td>15.6-31.2 p/ha</td>
</tr>
<tr>
<td>Medium density</td>
<td>31.2-44.2 p/ha</td>
</tr>
<tr>
<td>High density</td>
<td>44.2-59.8 p/ha</td>
</tr>
<tr>
<td>Very high density</td>
<td>&gt; 59.8 p/ha</td>
</tr>
</tbody>
</table>
4.3 Observations

The 2011 population for Canberra was 356,586, which was a 10.3 per cent increase from 2006 (ABS, 2015a), which equates to a growth rate of approximately 2 per cent per annum. Canberra’s population density also increased over this period of time, by 7 per cent from 1.4 p/ha to 1.5 p/ha (Table 4.06). Despite a growing population, the ACT region is considered to have very low population and dwelling densities for an Australian city, due to the distribution of residents over a large area (2360 km²) and the main type of development being single residential dwellings. This is in line with Gordon’s (2011) observations of what characterises the low average population density in Canberra.

Table 4.06 also shows that the net population and dwelling densities are twice as high as the gross densities for the 400 m light rail corridor. Similarly, the net densities are 1.4 times higher than the gross densities in the 1.5 km walkable corridor. Scale plays an important role in determining density. Gross density is generally lower than net density, as it is calculated over a greater land area that includes non-residential land uses (whereas net density is measured only for residential lands). Also the population and dwelling densities in the study area corridors are substantially higher than those for the ACT region, as the light rail corridor covers a much smaller land area than the ACT region. Hence the number of people and dwellings are more concentrated in the light rail and walkable corridors.

Table 4.06 – Gross and net population and dwelling densities (persons per hectare and dwellings per hectare) for the Canberra region and study area (1.5 km walkable corridor and 400 m light rail corridor).

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACT (gross)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>1.4 p/ha</td>
<td>1.5 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>0.6 dw/ha</td>
<td>0.6 dw/ha</td>
</tr>
<tr>
<td><strong>1.5 km walkable corridor (gross)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>9.4 p/ha</td>
<td>13.1 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>4.4 dw/ha</td>
<td>5.7 dw/ha</td>
</tr>
<tr>
<td><strong>400 m light rail corridor (gross)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>16 p/ha</td>
<td>26 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>7 dw/ha</td>
<td>11 dw/ha</td>
</tr>
<tr>
<td><strong>1.5 km walkable corridor (net)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>12.6 p/ha</td>
<td>18.4 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>6.2 dw/ha</td>
<td>8.1 dw/ha</td>
</tr>
<tr>
<td><strong>400 m light rail corridor (net)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>population density</td>
<td>34 p/ha</td>
<td>55 p/ha</td>
</tr>
<tr>
<td>dwelling density</td>
<td>15 dw/ha</td>
<td>23 dw/ha</td>
</tr>
</tbody>
</table>

*p = persons; dw = dwellings

Gross and net population and dwelling densities for the study area (1.5 km walkable corridor and 400 m light rail corridor) increased considerably between 2006 and 2011 (Table 4.06). Population density increased by 62 per cent in the 400m corridor and by 46 per cent in the 1.5 km corridor. Similarly, dwelling density experienced increases of up to 57 per cent in the 400 m corridor, and approximately 30 per cent and 1.5 km corridor over the five year period. These figures reflect the
outcomes of ACT Government’s strategic planning for urban intensification along Northbourne Avenue and Flemington Road (Figure 4.04).

Figure 4.04 – Strategic locations for urban growth and future development in the ACT region.
Source: ACT Government, 2015
Figure 4.05 displays the distribution of net population density within the light rail and walkable corridors for the years 2006 and 2011. The southern extent of the study area contains mostly low population density (15.6-31.2 p/ha), whilst the majority of the northern area has very low population density (less than 15.6 p/ha). There are pockets of higher population density in the areas surrounding the city centres of Civic and Gungahlin at each end of the light rail line, and immediately adjacent to Northbourne Avenue in Turner/Braddon. These areas also experienced an increase in population density over the five years. Population density in parts of Civic rose substantially from very low (< 15.6 p/ha) in 2006 to very high (> 59.8 p/ha) in 2011. In Turner and Braddon, population density rose from medium-high (between 31.2 and 59.8 p/ha) to very high (greater than 59.8 p/ha). Gungahlin had increases in population density from low-medium to medium-high. These increases can be attributed to the increased development of multi-unit dwellings in the city centres and along the Northbourne corridor.

The high density patch in Watson can be attributed to a large development of resort-style apartments in a leisure/accommodation zone. There are also patches in the suburb of Harrison where population density increases from very low in 2006 to low and medium in 2011. These areas are zoned urban residential, which is based on compact residential design, such as terraces and attached dwellings. The lowest population densities are recorded in the rural areas surrounding Harrison that are as yet undeveloped. A large proportion of the northern part of the study area is non-urban (designated as hills, buffers and ridges in the Territory Plan) and urban, which is mostly the industrial suburb of Mitchell. In general, population density has increased in the study area, particularly in the northern and southern extents of the corridors, over the five year study period.

Figure 4.06 shows the distribution of net dwelling density within the light rail and walkable corridors for 2006 and 2011. As with population density, dwelling density has increased overall within the study area between 2006 and 2011, particularly in the northern and southern areas of the corridors. Low (6-12 dw/ha) and very low (less than 6 dw/ha) dwelling densities are dominant in the southern and northern extents of the study area respectively. Some areas in Harrison increased from very low to low dwelling (and associated population) densities over the five year period. These areas were previously rural and are now zoned for residential development, some of which has occurred in the last few years, particularly along Flemington Avenue.

The highest dwelling densities are visible around the city centres of Gungahlin and Civic, as well as along the Northbourne corridor, all of which have also experienced increases in density over the five years to medium (12-17 dw/ha), high (17-23 dw/ha) and very high (greater than 23 dw/ha). Additionally, there is very high dwelling density in the New Acton precinct where high rise apartments have recently been developed. These patterns reflect the development of multi-unit blocks (including mixed-use developments) in strategic urban growth areas and highlight the urban intensification that was planned for the Northbourne corridor, shown above in Figure 4.04. It is also evident that dwelling density is closely correlated with population density within the light rail and walkable corridors, and the maps clearly demonstrate this relationship.

It is evident that population and dwelling densities in some suburbs adjacent to the transit corridor of Northbourne Avenue—particularly Braddon (39 p/ha) and Turner (25 p/ha)—are already higher than in most of the other urban and residential areas of the city. Noting that the other case study cities of comparable size that have installed light rail systems have seen an increase in density along
their respective corridors, it accordingly seems likely that this will also occur in Canberra. It can be inferred, therefore, that it is highly likely the introduction of light rail will result in further increases in population and dwelling densities in these and other residential areas along the full corridor, particularly in areas where there is already an urban centre, such as Dickson/Lyneham (approximately half-way) and at light rail stops.

This is consistent with the ACT Government’s planning strategy, which outlines an approach to creating a more compact and sustainable city by concentrating new development along transport corridors and which aims to encourage and facilitate greater urban density along the Capital Metro light rail corridor.
Figure 4.05 – Net population densities for residential land uses within the study area in 2006 and 2011. Source: ABS
Figure 4.06 – Net dwelling densities for residential land uses within the study area in 2006 and 2011. Source: ABS
5.0  A methodology for a longitudinal study

The introduction of the light rail in Canberra will potentially have a significant impact on the growth and development of Canberra. The first stage from Civic to Gungahlin (and possibly Russell) will run through the spine of the inner north to a major town centre and suburbs with an expected population of 80,000 by 2050. The proposed future next stages will possibly spread through Canberra linking town centres and possibly Queanbeyan with implications for the future planning and design of Canberra. The overall objective is to transform Canberra from a car-based city to a sustainable city based on transit oriented development.

As construction begins on light rail, it will be very important to track the changes occurring (activated and induced) in the adjacent areas in terms of economic, social and environmental factors. Increasing density will have significant implications for a range of planning considerations including appropriate provision of smart infrastructure and services, impacts on ecosystem services (including biodiversity, the water cycle and carbon storage). It would also be desirable to provide a clear understanding based on key planning assumptions of what the future might hold for longer term planning.

A proposed methodology for a longitudinal study of the light rail corridor(s) is outlined below as the basis for further refinement and discussion with Capital Metro and the ACT Government.

CURF, in partnership with collaborating research platforms at the University of Canberra, brings together a unique set of skills in planning, environment and micro economic analysis—i.e., the triple bottom line often referred to. Bringing these skills together we can develop a study that tracks changes and explores future scenarios of land use and density, demographic change, economic activity and environmental change such as carbon storage, water, biodiversity and other ecosystems. This would initially be over the next 10 years—i.e., ‘transforming the national capital with light rail’.

The following steps are suggested for further discussion at a roundtable of relevant stakeholders.

5.1  Methodology

Transforming the national capital with light rail
A longitudinal study of social, economic and environmental change

1. Extend the work of the CURF density paper and set a baseline on a number of agreed parameters including development density, environmental parameters, economic activity and service provision (in agreement with Capital Metro and the ACT government).

2. Develop a set of agreed assumptions on current and future land use zonings, density provisions, demographic change, environmental and climate change measures.

3. Apply the well-established NATSEM micro-simulation model to track the development of new economic activity stimulated during the period of the light rail development; apply and extend
the methodology being developed by CURF on greenhouse gas emission reductions to a broader study of the carbon cycle in the light rail corridor aimed at a policy objective of positive net carbon storage in the corridor post light rail (in discussion with the ACT Climate Change Council).

4. Develop an approach for scenario planning (with CURF partners in the Crawford School ANU) to provide a deeper understanding of the planning implications of land use and planning zonings for the future built form and lifestyle options in the corridors.

5. The digital mapping of change over time and use of scenarios for strategic planning using the new Canberra hub for Australian Urban Research Infrastructure Network (AURIN), run by NATSEM with CURF.

6. Host a series of roundtables at CURF with key experts and Capital Metro; initially on the details of the methodology to ensure it meets the needs of end users (particularly Capital Metro and the Environment & Planning Directorate).

7. Establish a process of review and evaluation over the study period with an appropriate advisory committee. The advisory committee could include, along with Government stakeholders, representatives of the community and business sectors.

The above methodology recognises the importance of strategic and on the ground planning in managing change in urban environments. Scenario planning is increasingly used for strategic planning to better ascertain possible outcomes when planning for risk and uncertainty.

5.2 Strategic versus on-the-ground

Scenario planning using case studies to inform future scenarios:

- base case (population projections and known planned development projects/areas)
- scenarios based on type of development, e.g. ribbon along corridor or nodal around stops/urban centres
- scenarios incorporating various rates/amounts of population growth and residential development.

Mapping changes over space and time at a number of scales (site, local, landscape, regional), using data obtained from various sources:

- population and dwelling densities from census data (five yearly basis)
- land use changes and zoning, development approvals/plans etc that generate them
- other information from census data that can highlight longer term implications of light rail and demographic changes, e.g. car ownership, distribution of age groups, etc.
Predicted versus actual changes to the urban form and types and locations of development, e.g. urban regeneration or infill close to light rail and estates in outer areas of corridor (high versus low density development) will be informed by planners and modelled using NATSEM’s microsimulation models.

Digital mapping of the above to examine city change will be an integral part of the study. NATSEM with CURF is now the Canberra hub for AURIN, the network that is developing data hubs across the country. In this respect we will be best placed to undertake this kind of research in the future.

The shared production of this longitudinal study will be leading edge in terms of being triple bottom line in approach and generated in partnership between government and the Canberra universities facilitated by CURF. This approach is being recommended globally as the way to tackle urban futures in an environment of continuous change.
6.0 Conclusion

This paper has addressed the relationship of the level or intensity of urban density with the provision and operation of adjacent light rail infrastructure. The relationship is symbiotic—contemporary sustainable urban planning must be aligned with sustainable transport planning to achieve good urban outcomes. But for Canberra, the question that has long been posed: how can transit operate successfully, and provide the associated financial, social and environmental advantages without being supported by a sufficient level of density, i.e. for communities in need of transit that do not necessarily have the density to make light rail feasible?

‘Transport planning decisions affect land use development and land use impacts transport activity’ (Bardhan, 2013). The clustered development associated with transit stops along a light rail line advocated by Chatman and Noland (2014) is a concept that would align with the ACT Government’s strategic planning objectives to intensify development along Northbourne Avenue and Flemington Road, particularly around, not only the end-points of Gungahlin Town Centre and Civic, but also the intermediate core centres, including Braddon, Lyneham and Dickson.

Gordon considers the opportunities and challenges surrounding light rail transit in Canberra, being a city with low to medium population density importantly noting that, whilst the major population centres of north Canberra are conveniently located along the Flemington Road and Northbourne Avenue corridor from Gungahlin to Civic, population density is not equivalent to ridership density (Gordon, 2011). Other factors, such as a system that is well-planned and well-designed, network extent, accessibility and reliability, and demographic characteristics, are also important in determining the success of a light rail system (Gordon, 2011).

Newman et al. (2009) stated:

*Transit needs densities over thirty-five people and jobs per hectare (fourteen per acre) of urban land and for walking and cycling to be dominant requires densities over one hundred people and jobs per hectare (forty per acre). Most new suburbs are rarely more than six or seven people and jobs per acre. Densities in urban areas need to increase to support transit and allow more people to live and work where they can find alternative transportation options. Of course it is a chicken and egg situation as often the transit system is needed to get the land-use processes to densify and focus development around stations.* (Newman et al., 2009, pp95-96, and Newman and Kenworthy, 2006)

...and further that:

*In city after city, new rail transit lines have brought higher property values, more customers for local businesses and new development.* (Newman et al., p 126)

The gross and net population densities in the study area (13 and 18 p/ha in the 1.5 km walkable corridor; 26 and 55 p/ha in the 400 m light rail corridor) are greater than the 12 p/ha and 22 p/ha densities cited by Cervero and Guerra (2011) and Gordon (2011) respectively, that are required to ensure a light rail system is cost-effective and viable. However the other variables noted should be taken into consideration when determining the viability and impacts of light rail on Canberra’s population and dwelling density.
The activated and induced impacts of light rail transport on adjacent land use have been discussed and it has been noted that these in turn affect ease of accessibility and long-term economic, social and environmental benefits (Flannery et al, 2014; Bardhan, 2013). Further, land use planning in relation to light rail, as noted by Newman (2009), is both ‘chicken and egg’. Canberra has been planned such that the locations of population centres, including Gungahlin, Dickson, Lyneham and Braddon, will support the light rail corridor; in turn the corridor will generate land use changes and support effective place-making and subsequent urban densification in these centres (Gordon, 2011).

A density analysis has highlighted that population and dwelling densities are correlated and already increasing along the Flemington–Northbourne corridor, particularly in already established population centres, as part of the ACT Government’s urban intensification planning strategy. Case studies on similarly sized cities—Adelaide, Freiburg, Bergen and Edmonton—have highlighted the potential impacts on urban density from light rail systems.

**Insights for Canberra**

- The review of the case study cities has highlighted that there must be to an integrated approach to land use planning and light rail implementation as part of a holistic urban planning and urban transformation process. This is critical, as relying on the private sector to rezone and redevelop without a precinct strategy to reinforce these outcomes makes it less likely for the best urban outcomes to occur. International experience has shown that the lack of an integrated planning framework is one of the key inhibitors to land use and transport integration.

- The international and interstate case studies include a range of populations demonstrating light rail can be beneficial for small–medium sized cities. The study found some evidence (Ginn, 1998) to support a quantifiable minimum population threshold of 200,000 for sustaining an urban light rail system which might facilitate urban renewal or patronage targets. Two of the case study cities and other international cities have both successful light rail systems and populations significantly less than that of Canberra.

- The case studies highlight evidence of change in land use activity over time including more intensive (more dense) residential developments and the development of mixed use. Activated density – density driven by strong, planned and deliberate land-use policy implementation - has been shown to be more highly effective in achieving better urban outcomes than a reliance solely on induced density –a density achieved ad hoc through a build-the-rail-and-density-will-come approach.

- Adopting explicit Transit Oriented Development (TOD) guidelines, as is the case with Edmonton, appears to be an important factor in density increases along with a wider city plan. Such guidelines are critical for the activation of the urban regeneration along the corridor.

- Community attitudes to the urban challenge of car-dependence have changed as exhibited clearly in the cases of Freiburg and Bergen. In Freiburg a shared understanding of city building and future-proofing the city against planning challenges was cultivated in all levels of government and with key stakeholders and professional groups. Community confidence increased as new stages of light rail were planned and delivered. In Bergen the funding mechanism of implementing a toll on an existing ring road gained popular acceptance. The present and future challenges of traffic congestion and peak car use in Australia, however,
although they have been frequently and regularly identified by governments (BTRE, 2007; Infrastructure Australia, 2014) are less widely understood.

- The new light rail services examined showed that easy transfer between multi-modal systems needed to be provided. This included the integration of network design, timetables, ticketing and fare structures in most examples.
- A broader cost-benefit analysis undertaken as a potential future study would highlight the community (active travel and healthy cities) and environmental (climate change mitigation and biodiversity) benefits. The study team notes that transport economics cannot currently quantify these benefits, but if the implementation of light rail is integrated with land-use planning then at least some of the urban intensification benefits can be captured.
- The international case studies show that commercial and residential property values can be higher when the properties are constructed close to a light rail station, in part stimulated by a willingness of purchasers to pay for access to transit (McIntosh et al, 2014). Developers were aware of the investment opportunities associated with light rail to leverage the economic and also the social benefits.
- Public transportation patronage increases as light rail transit systems become operational.
- Although LRT systems can bring considerable financial, social and environmental benefits to a host city, research demonstrates that local conditions must be receptive if these systems are to have a measurable impact on urban transformation and land use change. Light rail transit cannot be a driver of new growth and land use change on its own, but as a component part (albeit a foundational part) in a long-term strategic urban planning effort to shape growth and revitalisation in the city (Higgins, 2014).

A longitudinal study to identify changes to population and dwelling density as a result of the light rail and assess the indirect effects associated with land use changes would assist future planning and management around the light rail corridor in Canberra. The impact of rezoning and precinct planning is a critical aspect of this analysis.
7.0 References


City of Edmonton City Policy (8 February 2012). *Transit Oriented Development*, Policy Number C565, approved 15 February 2012.


City of Edmonton, Sustainable Development and Transportation Services Department *Transit Oriented Development Guidelines*, 15 February 2012.


