18TH ANNUAL PACIFIC-RIM REAL ESTATE SOCIETY CONFERENCE

ADELAIDE, AUSTRALIA, 15-18 JANUARY 2012

# ASSESSING THE IMPACT OF RAIL INVESTMENT ON HOUSING PRICES IN NORTH-WEST SYDNEY

**XIN JANET GE, HEATHER MACDONALD, AND SUMITA GHOSH**

**University of Technology Sydney**

## ABSTRACT

*Rail investments alter the accessibility and amenity of residential properties, and thus affect housing prices and overall affordability. This project investigates the impact of the Epping-Chatswood rail link in North-west Sydney on home prices, testing out alternative methodologies for estimating price impacts through spatial analysis of historical property sales data obtained from the RP Data Australia. The paper focuses on one station, comparing price trends before and after the construction of the rail link was announced in 2002, and before and after the opening of the rail line in early 2009. The paper concludes with an assessment of the usefulness of alternative methodologies.*

Keywords: Hedonic analysis, housing prices, transportation investments

## INTRODUCTION

Recent debates over a new metropolitan strategy for Sydney have highlighted the importance of infrastructure investment, particularly in public transport, if the region is to manage projected growth and ensure commensurate economic growth. Transportation infrastructure investment decisions have significant impacts on the location and timing of growth, but they also have important impacts on land values, liveability, and the feasibility of particular types of new or infill development. A wide range of studies of the impacts of light and heavy rail development on property values in European, Asian, and North American contexts has provided insight into the variations found in these effects. Issues such as the urban design and other attributes of the neighbourhood, the demographic and socio economic characteristics of nearby residents, the quality and extent of the public transportation network, and the broader spatial economic structure of the city all mediate the impacts of new transport investments. However, relatively little research has focused on the impacts of infrastructure investment on home prices in Australian cities.

Recent, in-progress, and planned additions to Sydney's light and heavy rail networks offer promising cases for research into the effects these new investments have had on property values. The Epping-Chatswood rail link opened in 2009, providing the first post-Olympics addition to the CityRail network. Significantly, it is a beltline rather than radial link, contributing to long-standing plans to link up Sydney's radial train lines with routes that serve non-CBD work destinations. This analysis focuses on one of the stations on this new line, but the methods we develop here will have value for future analyses of the long-planned Northwest Rail Link supported by the current state government. While the price impacts of new transit investments are inherently interesting because of what they tell us about how residents value accessibility and alternatives to private vehicle travel, they also have potential application in future debates about alternative approaches to funding infrastructure (such as through value-capture).

In this paper, we develop a pilot study of the relationship between a new rail investment and housing prices around a single station in Sydney's northwest (the Macquarie University station on the Epping-Chatswood rail link). We use repeat sales analysis for homes located within 1.5 kilometres of the station to investigate how home prices changed over four time periods: November 2000 to October 2002 (before construction), November 2002 to October 2004 (after construction began), February 2007 to January 2009 (before the rail line opened) and February 2009 to March 2011 (after the line opened). The following section of the paper provides a brief overview of the study area and the rail line. Next, we review relevant research on the impacts of transport investments on home prices, before outlining the methodology in more detail. Section 5 presents the models we develop, followed by the discussion of our results. We conclude with an outline of a future research agenda designed around explicit tests for other groups of complicating factors.

## STUDY AREA PROFILE

The study area is located around the Macquarie Park business area and Macquarie University in the Ryde local government area. Macquarie Park has developed rapidly as a high tech business park, occupied by industries related to research and development, electronics and computer technologies, and communications media. The original idea for the business park was that it would accommodate industry spinoffs from Macquarie University, similar to Silicon Valley around Stanford University in California.

## Demographic and socio-economic profile

As a node in Sydney's Global Arc, the Ryde / Macquarie Park area contains a mix of middle income residential suburbs, with substantial commercial and institutional land uses, including a fairly large student population around the university and a shopping centre. Table 1 summarises key features of the four suburbs. Chatswood and Macquarie Park have younger populations than Epping and North Ryde, and their residents are much more mobile, with substantial shares of recent migrants moving from overseas and higher proportions of renters. Chatswood residents have higher incomes than residents of Macquarie Park, and are more likely to be employed full time. This is reflected also in their higher rates of homeownership and higher housing costs.

## Table 1: Profile of Local Area

| | Chatswood | North Ryde | Macquarie Park | Epping |
|---|---|---|---|---|
| **Population (persons)** | 20,963 | 9,266 | 6,114 | 19,369 |
| **Predominant age group** | 20-29 | 40-49 | 20-29 | 40-49 |
| **Distance to Sydney CBD (kilometres)** | 8 | 11 | 12 | 16 |
| **Individual income (average per week)** | $528 | $491 | $411 | $562 |
| **Household income (average per week)** | $1,188 | $1,238 | $989 | $1,432 |
| **Employment** | | | | |
| **Full time** | 63.80% | 62.50% | 61.30% | 61.60% |
| **Part time** | 25.30% | 28.30% | 24.90% | 28.80% |
| **Unemployment** | 5.50% | 3.50% | 8.80% | 4.30% |
| **Out of labour force (persons)** | 3,973 | 3,051 | 1,733 | 5,193 |
| **Transport to work by train** | 17.9% | | | 14.8% |
| **Migrants in past year (%)** | 20.4% | 10.3% | 24.1% | 14.1% |
| **Migrants in past year from overseas (%)** | 29% | 15% | 30% | 20.4% |
| **Migrants in past 5 years (%)** | 45% | 23.6% | 49.1% | 32.5% |
| **Migrants in past 5 years from overseas (%)** | 42.5% | 19.4% | 46.6% | 31.8% |
| **Purchasing** | 23.8% | 32.1% | 19.5% | 28.3% |
| **Renting** | 40.5% | 21.6% | 59.4% | 27.1% |
| **Household Structure** | | | | |
| **Couples with Children** | 27.8% | 37.8% | 12.5% | 39.6% |
| **Childless Couples** | 24.0% | 23.7% | 20.4% | 22.8% |
| **Single Parents** | 23.0% | 19.3% | 37.2% | 17.8% |
| **Lone Households** | 13.6% | 7.1% | 20.9% | 9.5% |

Source: Australian Bureau of Statistics 2006 Census of Population and Housing

Spatial analysis reveals some relatively sharp differences between the university area and the surrounding communities, and a distinctive demographic profile for residents of areas with easy access to rail stations. Clusters of more mobile residents (those who lived elsewhere 5 years prior to the most recently available census data) are seen along the rail lines (Figure A1), but are particularly concentrated around Macquarie University. A substantial share of those migrants has international origins (Figure A2), reflecting the cultural diversity of the area; again, international origin migrants are especially concentrated around the university, as we would expect.

The housing stock of the area is predominately composed of single family homes, with concentrations of apartments around the Macquarie University rail station (Figure A3). Apartments are also concentrated around most of the existing train stations, reflecting both intensification strategies and the land market. We would anticipate further intensification of uses around the new stations, as new development opportunities are recognised.

Households in the surrounding northern suburbs are on average above the median size for Sydney, but rates of crowding are minimal. Figures A4 and A5 show the distinctive patterns around well-established train stations, with smaller households but more people per room in the census collection districts with high rates of accessibility, in contrast to the surrounding relatively traditional suburbs. We could see these patterns as a foreshadowing of the land use and demographic changes that might occur around the new stations on the Epping-Chatswood line, as new development opportunities are recognised (with the exception of the Macquarie University node, which already looked more similar to the areas around existing stations).

## The Epping-Chatswood Rail Link

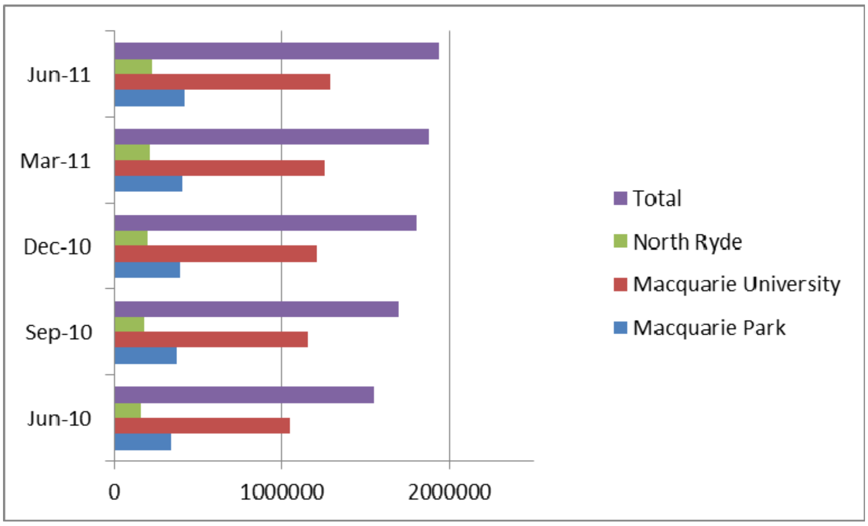
Construction began on the Epping and Chatswood rail line in November 2002; it was completed in December 2008 and opened in February 2009 (CityRail NSW, 2011). It is a 24 kilometre underground link connecting the North Shore line with the Northern line. The line serves residential areas with a population of about 50,000 residents, living in a mix of single and multifamily housing. The Macquarie shopping centre, Macquarie University, Macquarie Business Park, and Macquarie hospital are key commercial and institutional destinations for rail users (Figure 1).

## Figure 1: The Epping-Chatswood Rail Link


Source: CityRail

The line provides an average of four trains per hour from 5am to 11:30pm. Figure 2 shows the average commuters exiting at each of the stations on the new line for the period of June 2010 to June 2011. More than a million commuters exited at the Macquarie University station each quarter (Cityrail NSW, 2011); this implies that the rail investment effectively accommodates the need of commuters who work or study in the areas. However, the data shows commuters entered the stations were not able to obtain. The new link opens up the northwest corridor and improves accessibility to the CBD by train, providing commuters with an alternative to the heavily trafficked highway network that also serves the area (the M2 toll road and MetroRoad 3).

## Figure 2: Commuter Use of the Epping-Chatswood Rail Link, June 2010 – June 2011




Source: Bureau of Transportation Statistics

The rail link we investigate is relatively recent, and early ridership counts need to be set in the context of the pre-existing spatial configuration of the area: it was developed around highway rather than transit access, and reflects the typical big blocks of car-dependent office park / shopping centre development, surrounded by relatively low density traditional suburban neighbourhoods. Figure 3 shows the morphology of the area: in its current form, it lacks the residential (and commercial) density and pedestrian accessibility that distinguishes locations that have developed around a pre-existing station. Thus, the case study we investigate represents an opportunity to understand how retrofitting existing suburban locations with rail service may affect property values. This also highlights the limitations of analyses over a relatively short time period: the impacts of rail investment on home prices (and property values more generally) may evolve considerably over time, as the new levels of accessibility enable or attract new development patterns.

## Figure 3: Aerial View of Study Area


Source: SKM Imagery

## REVIEW OF RECENT RESEARCH

Public policy choices are based in part on assumptions of residents' preferences for alternative public investments or interventions. Opinion polls and surveys offer some (imperfect) ways to gauge these, but more rigorous investigations of how people express their preferences through purchasing decisions may offer a better basis for decision making. Revealed preference studies have been used to test the impacts on home prices (and less commonly rents) of everything ranging from bicycle paths and parks, to landfills and power stations. Examining the impact of a particular land use on home prices offers a way to estimate the positive or negative value of that land use, as expressed by home buyers.

There are two major ways to understand impacts: based on space (proximity / exposure to the land use), or based on time (before and after studies). Hedonic models based on space typically compare sales prices or trends for homes located close to the land use, with those located further away. Spatial effects can be quite complex. In some cases (such as landfills) impacts are almost exclusively negative, and there may be a linear relationship between proximity to the unwanted land use and price discounts. In most cases however impacts are mixed, and may vary in a non-linear fashion. Thus, homes close to a rail line may suffer the disamenity of noise, which will be outweighed for homes close to stations by the amenity of accessibility (Chen, et al., 1998; Debrezion, et al., 2007). Geographic analysis can be a powerful tool in sorting out the multi-faceted impacts of a particular land use.

Quasi-experimental models based on time focus on price changes before and after a particular event / decision. Typically, effects are found at two time periods – when a decision is made and publicised, and once the investment has been completed. A difficulty with this method is that it may take some time for the impacts of a new investment (a park, or a rail line) to be capitalised into housing prices (for instance, because the location becomes attractive for a particular sort of redevelopment that will attract the particular sort of buyer who values a bike trail or a light rail station). It may also be unclear at what point a decision has been made; governments have been known to back off projects even after some investment has been made. Thus, as with spatial models, time effects can also be non-linear; it may require a long time frame to fully model the land value impacts of some sorts of investments. Yiu and Wong (2005) examine the effects of changing price expectations (resulting from transportation improvements in progress) over time.

The relationship between accessibility and land value lies at the heart of urban economic theory (Alonso 1964; Muth 1969). The bid-rent model is a powerful theoretical concept, but it is complicated by contextual variations among specific places. The relationship between transit investments and housing prices has been studied extensively in many national settings, but theoretical expectations that the accessibility effects of train stations will outweigh the disamenities of noise and traffic, are complicated by the particular local and regional context of these cases. Thus, reviews of studies reveal a wide range of price effects, even when studies have similar methodologies and data (Wardrip 2011; Bartholomew and Ewing 2011; Debrezion, Pels, and Rietveld 2007).

We can identify three sets of contextual factors that help to account for variations among findings:

1. Local value of accessibility: both push and pull elements mediate the attractiveness of transit. The frequency, reliability, and coverage of the transit system, compared to the intensity of traffic congestion, result in different values being placed on accessibility in different locations (Giuliano and Agarwal 2010; Cervero et al 2004; Hess and Almedia 2007). Where transit systems serve most employment areas, and provide rapid and predictable alternatives in comparison to the time spent in private vehicle travel (and the unpredictability of traffic jams), transit accessibility is more likely to be valued. Gatzlaff and Smith (1993), for instance, found few price effects from the Miami Metrorail, because the system covered a very limited area. Bus routes show much more limited or no effects, although there is some evidence that Bus Rapid Transit (BRT) systems have positive effects on home values (Perk and Catala 2009).

2. Travel characteristics of area residents: transit accessibility is not equally valuable to all residents. For instance, smaller households with relatively simple travel needs (such as working couples with no children and two full time jobs) are likely to be better served by transit than families with children, who are more likely to have complex daily travel patterns to a wider variety of locations (Duncan 2008). Thus, residents of denser housing types (such as townhouses and apartments) may be more likely to value accessibility than residents of lower density single detached homes (Cervero et al 2004). There are divergent findings about the value of transit accessibility to lower- versus higher-income suburbs: some studies find that transit is more valuable to those in higher paid occupations concentrated in the CBD locations likely to be best served by high volume transit (Bowes and Ihlandfeldt 2001; Bartholomew and Ewing 2010), but others find that effects are more marked in lower income neighbourhoods where transit opens up a much wider range of employment opportunities (Immergluck 2009; Kahn 2007; Weissbourd, Bodini and He 2009). Some of these differences may be attributable to local employment structure and thus journey-to-work patterns.

3. Design characteristics of the station area: rail stations are more likely to have positive impacts on neighbouring properties if they are themselves easily accessible. In other words, the design of the surrounding area, including pedestrian walkability and safety, the mix of uses clustered around the train station, and the contrast between walk-and-ride and park-and-ride stations all affect whether accessibility benefits outweigh disamenities (Bartholomew and Ewing

2011). For instance, Bowes and Ihlandfeldt (2001) find price discounts for homes close to park-and-ride reliant stations (where walkability is compromised and large parking lots have negative externalities), but positive effects for homes further away (from 1 to 3 miles from the station), where residents capture the benefits of easy parking at the train station. Duncan (2010) finds that accessibility to light rail stations has more positive impacts on home prices (especially for higher density homes), in neighbourhoods with more street intersections per hectare. Another example of the importance of local urban structure is shown by Goetz et al's findings of sharply differing price effects on the east and west sides of a rail line in Minneapolis. Properties on the eastern side were cut off from station access by a freeway and industrial area alongside the line, while those on the western side had easy walking access to the stations (Goetz, Ko, Hagar, Ton and Matson 2010). Prices showed larger increases for homes on the west side of the track.

Bartholomew and Ewing (2011) conclude their survey of literature by arguing that "…*because much of [the studies on transit and home value] ignore the role that urban form and development design play in real estate value (and transit ridership), its explanatory power is extremely limited*" (Bartholomew and Ewing 2011, 30). Wardrip (2011) suggests that the regional economy, and in particular the strength of the local housing market, is a key element mediating whether transit investments have positive impacts on prices. He argues that additional incentives are needed to attract growth, but that parallel strategies are also needed to protect housing affordability when new transit investments redistribute growth and housing demand to some locations.

Our investigation of the impacts of new rail access on homes around the Macquarie University station offers an opportunity to explore how the particular contextual factors of the area might mediate the impacts of that increased access. New rail investments are unlikely to happen in Greenfield locations, where they can shape the pattern of land uses and development from the start; almost all current and immediate future investments in Australia are likely to occur retroactively, after suburbs have developed, and thus usually in suburbs that evolved around the needs of the car rather than transit. Thus, rather than being an anomaly, our case offers a useful model of the short term effects that rail investment is likely to have on property values, in a typical suburban employment / commercial centre with associated suburban housing. We emphasise, however, that it is a short term analysis: the study will also serve as a benchmark for future investigations of how the impacts of rail investment evolve over time, as once-suburban landscapes adapt to the new opportunities offered by rail.

## METHODOLOGY

Despite some limitations, such as collinearity and heteroscedasticity, hedonic regression models offer a powerful way to investigate impacts, since hedonic methods isolate the factors that might affect dwelling values and enable us to estimate the influence a variable of interest (in this case, proximity to railway stations) may have on dwelling value (Bajic, 1983; Rosen, 1974; Can, 1990; Feng, et al., 1991; Gatzlaff and Smith, 1993; Hess and Almeida, 2007).

Our methodological choices were driven by the data constraints we encountered. Unlike analysts in the USA and Canada, very little detailed information is publically available on the precise characteristics of dwellings, given that local rates are based on land rather than improved value (consequently, there is no pressing reason to collect the detailed data relied on in most of the hedonic analyses described above). To address this gap, we decided to adopt a repeat-sales analysis, which does not require an equivalent level of detail about each home because it assumes that characteristics remain relatively constant over time. Clapp and Giacotto (1992) compared the results of both Assessed Value and Repeat Sales methods; they found that the results obtained by each method were comparable, but that if one had access to the data needed for the Assessed Value method, that would be preferable because it allows for a much larger sample of cases and thus a more efficient model. The main weakness of Repeat Sales is the smaller number of cases. However, in the absence of adequate data for an assessed value model, we believe the choice of a repeat sales model is defensible.

The factors that impact on dwelling prices can be divided into five categories:

- Physical features of dwellings (structure type, land size, number of bedrooms, bathrooms, and car spaces, age of the building, and position) (Kain and Quigley, 1970; Follain and Jimenez, 1985). Newer and larger homes usually have higher prices, all else being equal.
- Neighbourhood characteristics such as median income, population growth, and household composition (Brigham, 1965; Cervero, et al., 2002; Landis, et al., 1995; Quigley, 1985).
- Railway station proximity, measured by the straight-line distance to the nearest railway station. We assume that prices would increase as distance to the rail station decreases, if accessibility is valued (Kiel and Zabel, 2008).
- Accessibility, as measured by the quality of the railway network. The number of destinations, frequency and reliability of train services can all be hypothesized to affect prices (Debrezion, et al., 2011).

- The timing of the announcement of the project, the commencement and completion of construction, and the opening of the rail system can all influence dwelling values (Lin and Hwang, 2004; Agostini and Palmucci, 2008).

Accordingly, the conceptual hedonic regression model is

$$P = f(H, N, \mathrm{Pr}, A, T) \qquad (1)$$

Where the dependent variable *P* denotes the dwelling price sold in dollars, which is a function of five categories of independent variables. The five integrated categories are:

*H* is a vector of variables that describe dwelling characteristics, such as number of bedrooms, bathrooms and car park spaces;

*N* is a vector of variables that explain the neighbourhood characteristics (Hess and Almeide, 2007);

*Pr* is a vector of variables that measure the distance to railway stations;

*A* is a vector of variables that represent the level of quality and accessibility of the rail link; and

*T* is a vector of dummy variables indicating before and after rail construction and opening, when *1* represents after rail construction or opening and *0* otherwise.

Equation (1) can be expanded to

$$P_{it} = g(H_{it}) + h(N_{it}) + k(\mathrm{Pr}_{it}) + l(A_{it}) + m(T_{it}) \qquad (2)$$

Where $P_{it}$, is the price for each of the dwellings *i* at time *t*. Table 2 lists the dependent and the independent variables in the five categories, along with the definition, unit of measurement and data source for each of the variables.

Changes in the quantities of housing services can lead to relative housing price changes (Abelson, 1997). To assess the impacts of the new rail investment on property prices, we investigate whether the price changes observed were related to the rail line. Because we have limited information for a hedonic model, we use a repeat sales approach, comparing results at each of two pairs of time periods: before and after construction commencement, and before and after service commencement (Dewees, 1976; Bajic, 1983; Lin and Hwang, 2004). We estimate separate models for each of these time periods. Finally, we test changes in sales prices over both time periods to determine the relative effects of each.

Data was obtained from RPData and GIS analyses of distance to station. Sales data was tested before building the models. Hedonic regression models were built through stepwise selection in SPSS. The derived models were evaluated against the mean squared error, adjusted R-square and *p*-value. The variance inflation factor (VIF), which detects multicollinearity in regression models, is also reported for each model. We do not include an explicit test for spatial autocorrelation, because we assume that housing prices are correlated with location. We include location measures (distance to the station) in our model to reflect the influence of location.

## Data Sources

Since a single station is used in this pilot study, accessibility and neighbourhood variables are omitted as we assume the variables are similar within the single station area. Very few homes in the area around the station are single family detached dwellings, and thus very few transactions were observed for these housing types (shown in Figure 8). Consequently, we focus this analysis on strata titled units. This provides a sample of 520 residential units within 1.5 kilometre of the station, accounting for a total of 811 repeated sales, from January 2000 to March 2011. Sales data were collected from RPData Australia, which included dwelling address, sales prices and sale dates for each instance. We supplemented the dwelling characteristic data with data drawn from individual strata plans, obtained from NSW Land and Property Management Authority. Based on this, we calculated the repeated sale prices (HP_H), standardising prices using the Sydney established housing price index (HPI) from the Australian Bureau of Statistics. The HPI covers transactions in detached residential dwellings and relates to changes in the total price of dwelling and land (ABS, 2011).

The original housing price index was based on 89-90=100 and changed to 03-04=100 since June 2005. To make it consistent we converted both indices to December 2010 = 100.

## Table 2: Definition of variables

| Vector | Variable | Definition | Measurement | Source |
|---|---|---|---|---|
| Dwelling Prices (*P*) | HP_H | Sale price | Dollar (00') | Rpdata |
| | CHP_H | Change in sale price | Dollar (00') | derived from Rpdata |
| Property characteristics (*H*) | BEDS | Number of bedrooms | Number | strata plan |
| | BATHS | Number of bathrooms | Number | strata plan |
| | CARS | Number of car parking spaces | Number | strata plan |
| | VIEWS | Dummy variable for views | 1=with, 0=otherwise | strata plan |
| | ENSUIT | Dummy variable for ensuite | 1=with, 0=otherwise | strata plan |
| | LIVING | Number of living rooms | Number | strata plan |
| | Year_C | Unit holding period | number of year | count |
| Railway station proximity (Pr) | DIST | Straight-line distance to the rail station | Kilometres | GIS |
| Accessibility variables (*A*) | PDST | Dummy for proximity to station | 1=less than 1km, 0=otherwise | |
| | MROAD | Dummy for location on the main road | 1=mainroad, 0=otherwise | |
| | DCBD | Straight-line distance to Sydney CBD | Kilometres | GIS |
| | MIS | Dummy for main interchange station (i.e., Chatswood or Epping) | 1=interchange, 0=otherwise | |
| | FRET | Frequency of rail service | Number services per day | Sydney Train |
| | TIME | Time to access bus service | Minutes | GIS |
| | UNI | Distance to University | Kilometres | GIS |
| | SHOP | Distance to shopping centre | Kilometres | GIS |
| | BPARK | Distance to business park | Kilometres | GIS |
| | HOSP | Distance to hospital | Kilometres | GIS |
| Neighbourhood characteristics (*N*) | INCOME | Median income for the area | Dollar | ABS |
| | POP | Population growth rate, | Percentage | ABS |
| | VACANT | Change in residential vacancy rate, 2001-2006 | Percentage | ABS |
| Before and after events (*T*) | CONS | Dummy for start of construction | 0=before, 1=after | |
| | OPEN | Dummy for commencement of rail service | 0=before, 1=after | |

Source: indicated in table

Basic features of dwelling units such as number of bedrooms, bathrooms, living rooms, and parking spaces were obtained from the strata plan of each individual building from the local council. The distance from each dwelling to the railway station was measured by calculating X and Y coordinates for each address, using the Proximity tool in ARCGIS. The construction of the Epping to Chatswood rail link began in November 2002 (CityRail NSW, 2011) and this is used as the basis for a dummy variable to categorise sales before and after commencement of construction. The rail link opened on 23 February 2009 (Bibby, 2009); again, this is the basis for a dummy variable distinguishing sales in each time period.

Table 3 summarises descriptive statistics. The Spearman's correlation coefficients between the dependent variable, unit prices (HPRICE), and the independent variables, are listed in the last column of the table. The results suggest that distance to rail station (DIST), the dummy for Construction (CONS), and some dwelling features (BEDS, BATHS and CARS) are positively correlated to the unit prices (HPRICE) at the 0.01 level.

## Table 3: Descriptive statistics for models 1 through 5

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation | Correlations |
|---|---|---|---|---|---|---|
| HPRICE | 811 | 1302 | 8488 | 4718.1 | 1028.7 | 1 |
| DIST | 811 | .13 | 1.56 | .8177 | .48544 | .589** |
| CONS | 811 | .00 | 1.00 | .7226 | .44801 | -.206** |
| OPEN | 811 | .00 | 1.00 | .1887 | .39148 | .018 |
| BEDS | 811 | 1.00 | 3.00 | 2.0222 | .46295 | .618** |
| VIEWS | 811 | .00 | 1.00 | .0506 | .21922 | .022 |
| BATHS | 811 | 1.00 | 2.00 | 1.2115 | .40747 | .517** |
| CARS | 811 | .00 | 2.00 | 1.1652 | .46595 | .419** |
| ENSUIT | 811 | .00 | 1.00 | .0999 | .30002 | .319** |
| LIVING | 811 | .00 | 2.00 | 1.1430 | .35383 | .361** |
| Valid N (listwise) | 811 | | | | | |

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). Source: Authors' calculations

Four sets of repeat sales data were used to test the association between sales trends before and after the construction and the opening of the rail link. The four periods were from November 2000 to October 2002 (before construction), November 2002 to October 2004 (after construction); February 2007 to January 2009 (before opening) and February 2009 to March 2011 (after opening). Four hedonic price regressions were then separately estimated, i.e., before and after the construction commenced (two samples with 159 and 148 cases respectively) and before and after opening (two samples with 156 and 153 cases respectively).

## Table 4: Descriptive statistics for model 6

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation | Correlations |
|---|---|---|---|---|---|---|
| CHPRICE | 627 | -4502 | 3737 | -284.687 | 821.377 | 1 |
| YRSOWN | 627 | .00 | 14.00 | 5.5167 | 2.88673 | -.283** |
| DIST | 627 | .13 | 1.56 | .8444 | .49420 | -.229** |
| CONS | 627 | .00 | 1.00 | .8086 | .39371 | -.147** |
| OPEN | 627 | .00 | 1.00 | .2424 | .42889 | .209** |
| BEDS | 627 | 1.00 | 3.00 | 2.0367 | .45246 | -.147** |
| VIEWS | 627 | .00 | 1.00 | .0478 | .21361 | .013 |
| BATHS | 627 | 1.00 | 2.00 | 1.2400 | .42604 | -.301** |
| CARS | 627 | .00 | 2.00 | 1.1946 | .47335 | -.097* |
| ENSUIT | 627 | .00 | 1.00 | .1053 | .30714 | -.077 |
| LIVING | 627 | .00 | 2.00 | 1.1451 | .35702 | -.050 |
| Valid N (listwise) | 627 | | | | | |

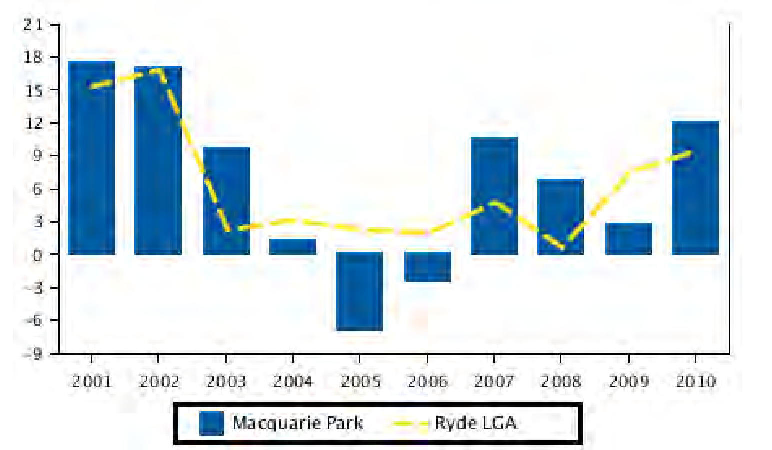
**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). Source: Authors' calculations

Finally, we used change of the repeat sales price (CHPRICE) as the dependent variable. All remaining independent variables were held constant to test the effects of the two events on price changes. For example, a unit was sold in Nov. 1998 for $200,000 and in November 2003 for $300,000 (in constant terms), so the change in the sale price is $100,000 over a 5-year period. There were total of 520 cases used in the models. In addition to the variables used previously, a variable for number of years (YRSOWN) between sales was added to the model. The change in dwelling prices is affected by the number of years between sales. The longer the time between resale, the higher the change in dwelling prices we would expect to observe. Table 4 shows the descriptive statistics and correlations among the variables in the model. The change in sales price (CHPRICE) was significantly correlated to the number of years a property was held for (YRSOWN), distance to the rail station (DIST), and for both the construction (CONS) and opening (OPEN) dummy variables (at the 0.01 level and 0.05 level respectively).

## Results

Figure 4 shows a substantial unit price increase in Macquarie Park in the two years (2001 and 2002) before commencement of the construction of the link. Sydney experienced similar trends but at a reduced level (6.8% and 8.6% respectively), as shown in Figure 5. In 2003, once construction had commenced, unit prices continued to increase but at a slower rate (9.8% in Macquarie Park and 1.1% in Sydney). While the link was under construction unit prices continued to post positive gains in Sydney, but grew more slowly (or declined) in Macquarie Park.

### Figure 4: Capital Growth in Median Prices in Macquarie Park (Unit)




| | Macquarie Park | Ryde LGA |
|---|---|---|
| Period | % Change | % Change |
| 2001 | 17.6% | 15.4% |
| 2002 | 17.1% | 16.8% |
| 2003 | 9.8% | 2.3% |
| 2004 | 1.4% | 3.2% |
| 2005 | -7.1% | 2.2% |
| 2006 | -2.7% | 1.9% |
| 2007 | 10.6% | 4.7% |
| 2008 | 6.8% | 0.6% |
| 2009 | 2.9% | 7.6% |
| 2010 | 12.1% | 9.4% |

Source: RPdata, 1st December 2011

Source: RPData

Prices in Macquarie Park increased again as the construction neared completion in December 2008, compared to lower or negative rates of growth in the rest of Sydney. Macquarie Park posted higher gains in 2009 and 2010 (2.9% and 12.1% respectively) once service on the rail line commenced than was the case in Sydney (4.8% and 11%). Macquarie Park out-performed the Ryde local government area in every year except 2009. Property price trends in Macquarie Park appear to be more volatile than in Sydney, which suggests external factors may have had a large impact.

### Figure 5: Capital Growth in Median Prices in Sydney (Unit)


| Period | Sydney % Change | City of Sydney % Change |
|---|---|---|
| 2001 | 6.8% | 7% |
| 2002 | 8.6% | 9.3% |
| 2003 | 1.1% | 5.3% |
| 2004 | 5.7% | 0% |
| 2005 | -0.4% | 1.2% |
| 2006 | 2.5% | 3.3% |
| 2007 | 7.1% | 4.3% |
| 2008 | -2.9% | 2.6% |
| 2009 | 4.8% | 2.1% |
| 2010 | 11% | 14.6% |

Source: RPdata, 1st December 2011

Source: RPData

### Effects of constructing and opening of the rail link

Model 1 (shown in Table 5) tests the effects of the commencement of construction, and the completion and opening, of the Epping-Chatswood rail link (at the end of 2002 and 2008 respectively). All 811 observations were included in the model, representing all repeat sales for units within 1.5 km of Macquarie Park station from January 2000 to March 2011. The model provides a reasonable explanatory fit, with an adjusted $R^2$ of 65.3%. The variance inflation factor (VIF) is a measure of multi-collinearity. All VIFs are below 10, indicating that no significant collinearity exists among the independent variables in the model. The dummy variables for location on a main road, views, ensuite, and number of living rooms were omitted. The variables for distance from dwellings to rail station (DIST), number of bedrooms (BEDS), number of bathrooms (BATHS), and number of parking spaces (CARS) were the attributes selected by SPSS stepwise procedures. All selected variables showed the expected sign except for the distance variable (DIST) which showed a positive relationship between proximity to rail station and dwelling prices (in other words, prices increase for units further from the station).

### Table 5: Regression Results of Model 1

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | | 95.0% Confidence Interval for B | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. | Lower Bound | Upper Bound | Tolerance | VIF |
| 1 | (Constant) | 1768.095 | 107.350 | | 16.470 | .000 | 1557.376 | 1978.814 | | |
| | DIST | 695.065 | 53.628 | .328 | 12.961 | .000 | 589.797 | 800.333 | .668 | 1.497 |
| | CONS | -629.605 | 50.125 | -.274 | -12.561 | .000 | -727.995 | -531.214 | .898 | 1.114 |
| | OPEN | 338.031 | 57.046 | .129 | 5.926 | .000 | 226.054 | 450.007 | .908 | 1.101 |
| | BEDS | 986.734 | 50.818 | .444 | 19.417 | .000 | 886.983 | 1086.485 | .818 | 1.222 |
| | BATHS | 437.254 | 62.267 | .173 | 7.022 | .000 | 315.028 | 559.479 | .703 | 1.422 |
| | CARS | 212.589 | 52.501 | .096 | 4.049 | .000 | 109.534 | 315.643 | .757 | 1.322 |
| | Sample | 811 | | | | | | | | |
| | $R^2$ | .656 | | | | | | | | |
| | *Adj*_$R^2$ | .653 | | | | | | | | |
| | *Sig.* | .000 | | | | | | | | |

a. Dependent Variable: HP_P

Source: Authors' calculations

The finding contrasts with others in the literature; for instance, Debrezion, et al. (2011) found a negative relationship, with a 1% price decline with increases in distance from a station. However, others have found that dwellings located very close to a rail station decrease in relative value as a result of congestion effects, while those within walking distance, but not immediately adjacent, increase in value (Gatzlaff and Smith 1993; Chen, Rufolo and Duecker 1998). Traffic congestion could be a factor affecting the value of the dwellings around the area given the urban structure of the immediate location (shown in Figure 3).

The estimation and interpretation of the coefficients for the commencement of construction (CONS) and opening of rail service (OPEN) variables are of primary interest. The negative coefficient for CONS suggests that prices for homes close to the station could have declined by $62,960 after construction began (holding other factors constant). The positive coefficient for OPEN suggests that unit prices in Macquarie Park could have increased by $33,803 after the link was completed (all else being equal).

### Comparison of periods before and after construction and opening

Model 1 considered the entire period, 2000 to 2011. Our next step is to test the effects of construction on unit prices during shorter timeframes, before and after the construction of the rail link (November 2000 to October 2002, compared to November 2002 to October 2004), and before and after commencement of service (February 2007 to January 2009, and February 2009 to March 2011). Using an approach developed by Bajic (1983), the changes in demand between those pairs of time periods is compared in models 2, 3, 4, and 5. We test for the equality between the parameters of the two regressions estimated for each period. If the implicit prices of attributes other than distance and proximity variables do not change between the before and after models, we could conclude that the rail system is responsible for the price changes we observe. Table 6 shows the results of this regression included coefficients, *t*-tests and VIF results. The models are significant at the 95 per cent confidence level.

Models 2 and 3 explained 58.5% and 53.3% of variation respectively. The variables for distance to rail station (DIST), number of bedrooms (BEDS), and number of bathrooms (BATHS) were positive and statistically significant. Distance has a slightly more positive effect for model 2 (808.33), compared to model 3 (645.23). In other words, homes within one kilometre of the station were priced $80,833 higher than those further away during the period before construction commenced, but this differential dropped to $64,523 over the period after commencement of construction.

## Table 6: Regression results of Models 2, 3, 4, and 5

| | Model_2 | Model_3 | Model_4 | Model_5 |
|---|---|---|---|---|
| **Variables** | **Before Construction** *(Nov 00 – Oct 02)* | **After Construction** *(Nov 02 – Oct 04)* | **Before Opening** *(Feb 07 – Jan 09)* | **After Opening** *(Feb 09 – Mar 11)* |
| Constant | 1570.3 (5.295[a]) | 1365.87 (4.193[a]) | 1178.56 (5.623[a]) | 1825.3 (11.088[a]) |
| DIST | 808.33 (6.159[a]/1.466[b]) | 645.23 (4.655[a]/1.482[b]) | 560.54 (4.55[a]/1.608[b]) | 665.77 (7.938[a]/1.255[b]) |
| BEDS | 1087.67 (7.178[a]/1.135[b]) | 883.556 (5.96[a]/1.204[b]) | 957.09 (10.059[a]/1.22[b]) | 1036.2 (12.89[a]/1.199[b]) |
| BATHS | 575.45 (3.704[a]/1.464[b]) | 431.822 (2.623[a]/1.691[b]) | 415.89 (2.969[a]/1.253[b]) | 283.7 (2.539[a]/1.316[b]) |
| CARS | | | 402.65 (3.484[a]/1.518[b]) | |
| ENSUIT | | 741.129 (3.694[a]/1.160[b]) | | |
| **Sample size** | **159** | **148** | **156** | **153** |
| **$R^2$** | **0.593** | **0.546** | **0.688** | **0.737** |
| **Adjusted $R^2$** | **0.585** | **0.533** | **0.679** | **0.731** |
| ***Sig.*** | **.000** | **.000** | **.000** | **.000** |

[a] *t*-statistics and [b] *VIF* in parentheses and significant at the 0.01 level    Source: Authors' calculations

Models 4 and 5 have higher adjusted R squared scores, and variable signs and significance are consistent with those in models 2 and 3. There is a significant and positive association between unit price and distance to rail station (DIST), number of bedrooms (BEDS), and number of bathrooms. Being within one kilometre of the station had somewhat more positive effects on price after the opening of rail service (model 5) than it did in the period immediately prior to the opening (model 4), but the difference is quite small ($10,523).

### Effects of the Link Opening on Dwelling Prices

The final model (model 6) converted the repeat sales price for each case into a change in value between sales, using this as the dependent variable to investigate the price impacts of each of the events studied. Table 7 presents the results of this model. This model explains a smaller share of the changes in price over the period, with an adjusted R squared value of 26.2%. We included a new variable to reflect the holding period (the time between each sale). The coefficient for the commencement of service (OPEN) is positive, suggesting there was an average $58,460 increase in unit prices after the opening of the rail link. However, the coefficient for the commencement of construction is negative, suggesting a decline of $21,098 in unit prices after construction commenced. This suggests that demand for dwellings appreciated more in the periods before the commencement of construction and after the opening of service. It is possible this reflects the expectation of price appreciation that pushed prices up before the construction of the link. The positive effect of the completion of the link suggests that increased accessibility was capitalised into prices at that time. The amenity effects of the new rail link were capitalised into homes early, prior to the development and after the completion of the rail link, rather than during the period of constructing the link.

The model also estimates a negative effect for the distance to the rail station, suggesting smaller price changes for homes further away from the rail station (i.e., the rate of change is $17,556 lower for every kilometre away from the station). Not all the signs of the coefficients in the model were as expected. Interestingly, the coefficient for the number of years owned (YRSOWN) is -95.43, implying a $9,543 lower increase for each additional year between sales, all else being equal. This may be explained by the overall price trends, with declines during the middle years (shown in Figure 4). The coefficient for numbers of bathrooms is also lower in this model, suggesting that homes with more bathrooms appreciated by lower rates. This could reflect a premium for smaller homes closer to the rail station, which may be consistent with findings elsewhere in the literature, that only some sorts of households are likely to benefit from the increased accessibility (Wardrip 2011). Variables in previous models (numbers of bedrooms and car spaces) are omitted from this model. The adjusted $R^2$ for this model is low with only 26.2% of variation explained by the independent variables, implying that the rail system is only one of many factors influencing changes in dwelling values.

## Table 7: Regression results of Model 6

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | | 95.0% Confidence Interval for B | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. | Lower Bound | Upper Bound | Tolerance | VIF |
| 1 | (Constant) | 977.279 | 113.173 | | 8.635 | .000 | 755.032 | 1199.527 | | |
| | YRSOWN | -95.436 | 11.384 | -.335 | -8.383 | .000 | -117.792 | -73.081 | .737 | 1.357 |
| | DIST | -175.565 | 68.175 | -.106 | -2.575 | .010 | -309.446 | -41.684 | .701 | 1.427 |
| | CONS | -210.985 | 83.214 | -.101 | -2.535 | .011 | -374.399 | -47.571 | .741 | 1.349 |
| | OPEN | 584.600 | 69.896 | .305 | 8.364 | .000 | 447.340 | 721.861 | .885 | 1.130 |
| | BATHS | -450.258 | 79.512 | -.234 | -5.663 | .000 | -606.403 | -294.113 | .693 | 1.442 |
| | Sample | 627 | | | | | | | | |
| | $R^2$ | .268 | | | | | | | | |
| | *Adj*-$R^2$ | .262 | | | | | | | | |
| | *Sig.* | .000 | | | | | | | | |

a. Dependent Variable: CHP_P

## SUMMARY

The analysis presented in this paper supports the argument that rail access plays an important role in determining dwelling values. The models presented in Table 5 to 7 suggest that the commencement of construction had negative impacts, and the opening of the rail line had positive impacts on dwelling price appreciation (after controlling for other attributes of dwellings), which fits with other studies reviewed above (Hess and Almeida 2007, Agostini, et al., 2008, Duncan, 2008, Lin and Hwang, 2004). However, those effects were stronger in the periods before construction began and after the rail link opened than they were in the periods following construction commencement and before opening. This contrasts with some findings in the literature (Yiu and Wong 2005).

We also found some indication that dwelling prices increased more substantially for homes closer to the station, suggesting that better accessibility to new transit services had more positive effects on home value appreciation. Price changes were reduced the further away from the rail station a home was. This fits with most of the literature reviewed above (Debrezion et al 2007; Bowes and Ihlanfeldt 2001; Chen, Rufulo and Dueker 1998).

## CONCLUSIONS

This paper analyses the effects of the new rail link on dwelling prices by combining spatial and statistical analysis. GIS allowed us to measure distances between properties and Macquarie University rail station; the statistical analysis estimated the impact of the variables in our models. This methodological approach demonstrates the usefulness of GIS tools for property market analyses.

The study adds to the growing literature on the relationship between new rail lines and dwelling prices. Our findings show that dwelling prices appreciated more before the commencement of construction and after the opening of rail service than they did after starting the construction and before the opening. The findings raise interesting questions about why the effects of new rail investments appear to be capitalised into existing housing prices earlier in Sydney compared to other locations. Why did housing prices in this case respond to new rail investment so rapidly, with the most marked increases occurring prior the commencement of the rail construction and after the link opening, but decreasing during the construction period? There are two likely explanations for this:

Access to a train station may be valued more highly in Sydney compared to the other (primarily US-based) cases examined in the literature. Given the relatively higher price of petrol in Australia compared to the US, and the high costs of parking in the Sydney CBD, this is a plausible explanation. Perceptions of traffic congestion may add to the premium that prospective buyers place on a home convenient to rail service. Thus, the effects of expectations for improved accessibility might have been capitalised into housing prices sooner in Sydney compared to US cities. However, it is possible that this pushed prices to unaffordable levels, which then slowed the demand, and this was reflected in a slower rate of increase (Yates, 2007).

It is also possible that improved access may be less significant as a source of amenity for prospective buyers, and more important as an indicator of the redevelopment potential of land parcels adjacent to the new stations. Land adjacent to the new station may have appreciated in value because of the perceived potential for higher intensity uses (both residential and commercial), and the expectation that land close to a train station would be rezoned to reflect its improved accessibility. Given the long time frames of land speculators, the ten year gap between the announcement of the project and opening of the stations might be quite acceptable. These expectations appear to have been met with the increase in value now that the rail service is operating.

This study investigated only one of the new stations, on one rail line. Local economic conditions, the mix of land uses, and the relative value of accessibility given the resident profile, urban morphology, and physical characteristics of the location, will differ among stations. Future studies will explore whether the price impacts suggested by the models developed in this paper are reflected in other locations. Unfortunately, the potential for historical research is limited by data availability and also by the fact that rail lines developed several decades ago are likely to have had qualitatively different impacts on local housing and land markets. However, new rail investments planned for Sydney and other Australian cities offer interesting applications and refinements of the methodological approach we develop here.

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## APPENDIX

### Figure A1: Percent Recent Migrants

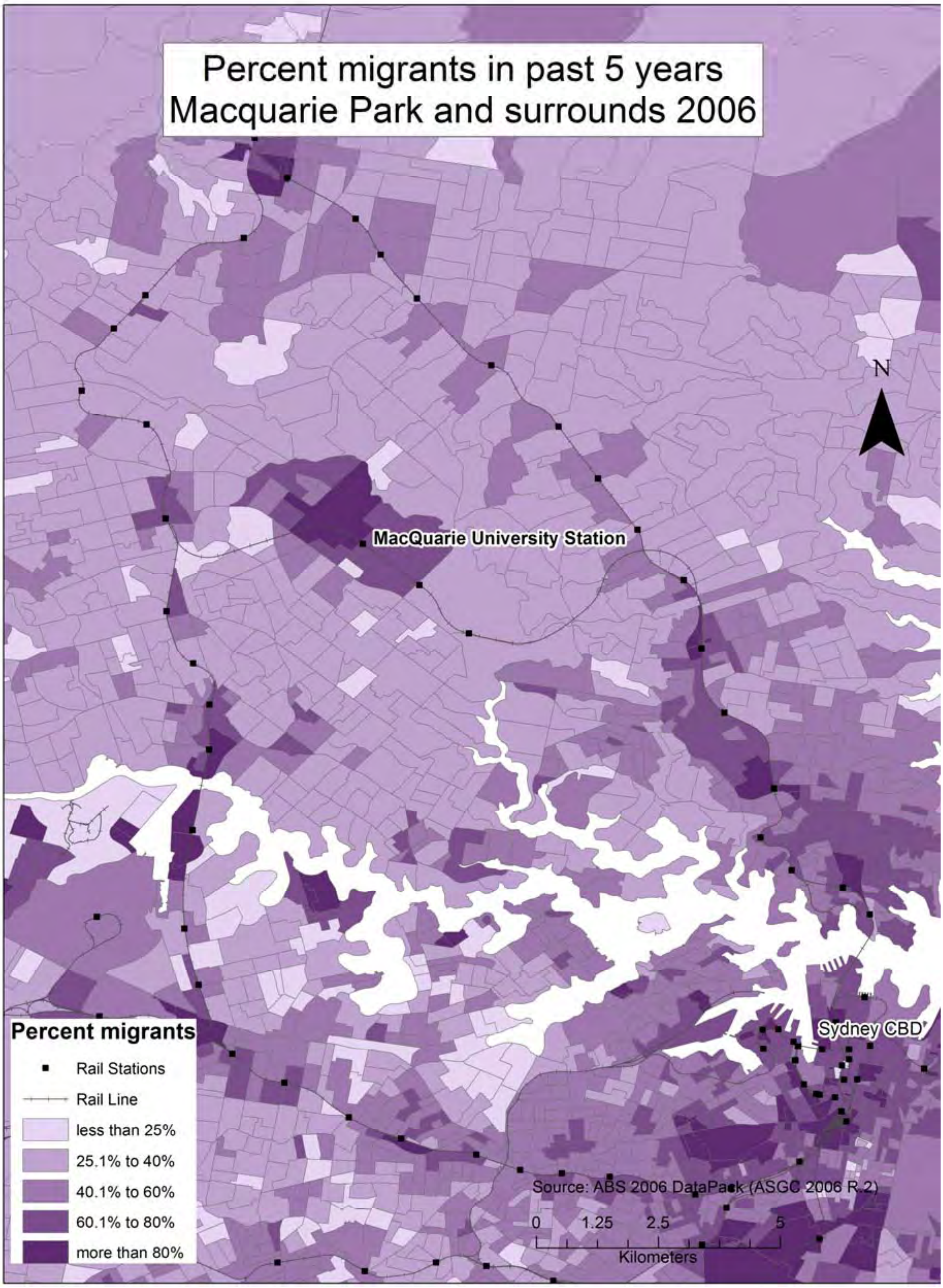

**Figure A2: Percent Recent Migrants From Overseas**

**Figure A3: Housing Stock Configuration**

**Figure A4: Mean Household Size**

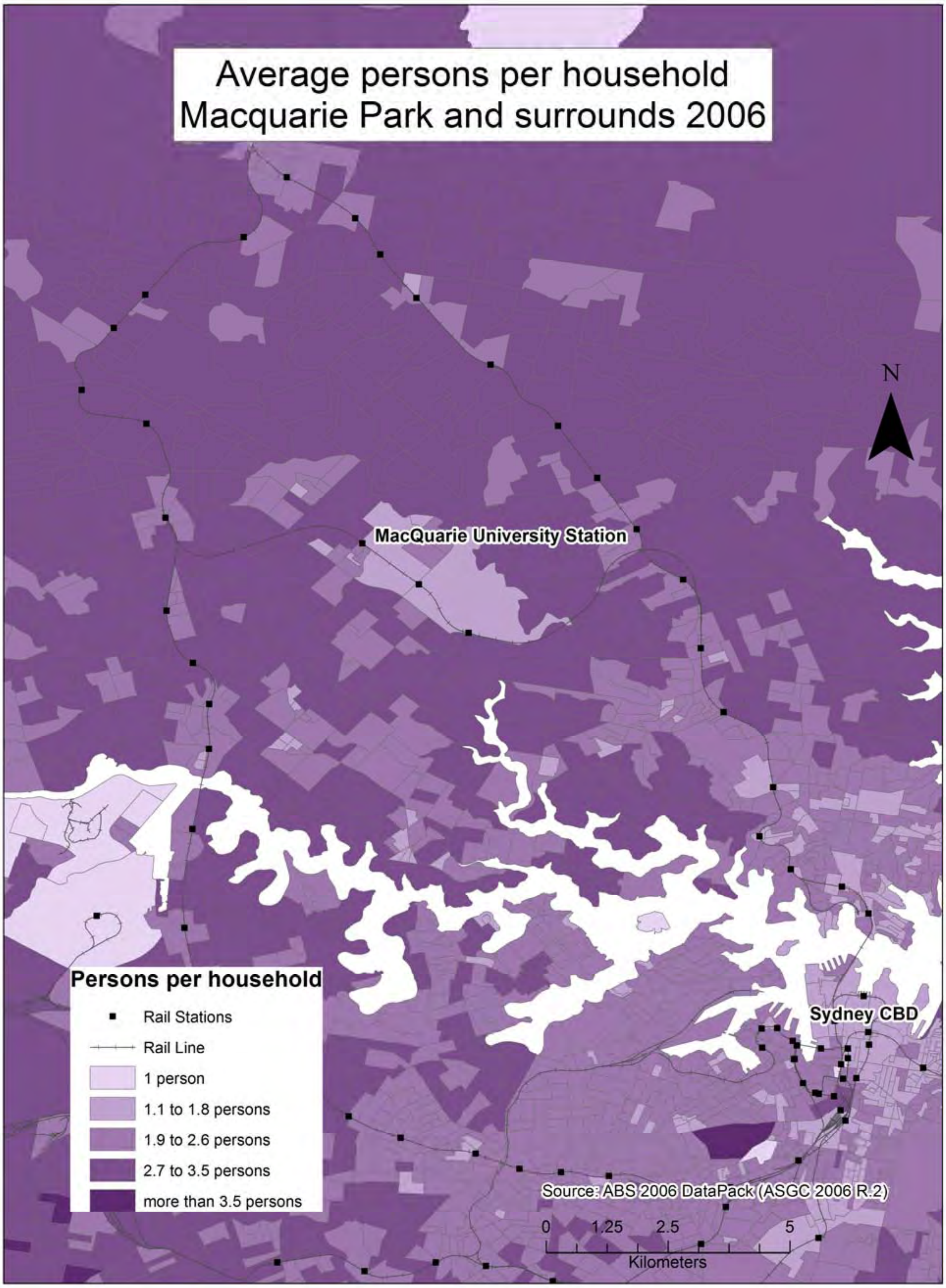

**Figure A5: Persons Per Room**