EFFECTS OF BUS RAPID TRANSIT ON HOUSING PRICE: EVIDENCE FROM SYDNEY, AUSTRALIA

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ABSTRACT

This paper examines the impact of a Bus Rapid Transit (BRT) system on residential housing prices in Sydney, Australia. A quasi experimental approach and a hedonic regression model are employed to identify the housing price uplift at three points in time: after announcement of the project, construction period, and after the opening of the BRT system. Catchment and control areas are selected from the property sales data to control for the potential external shock on housing price. The hedonic regression model takes account of the property and neighbourhood attributes which are expected to affect the property transaction price and thus identifies land value uplift from the BRT system. This research found that the commencement of operation of the BRT system has a significant contribution to uplift of house prices after the opening of the system, with a price premium of 3.6 percent identified. The research outcomes provide evidence for government sectors aiming to raise financial funding for public transport improvement through the gain of land value uplift.

Keywords: Land value uplift, Bus Rapid Transit, Analysis of Variance, Hedonic regression

INTRODUCTION

When budgets are being squeezed how does government continue to properly fund improvements to public transport? One way is to tap into rising land values and residential property prices that come from better access to transport infrastructure through value capture. Value capture is increasingly being seen as a potential funding source for public transport but information is lacking on the amount that public transport adds to land values, particularly from bus-based infrastructure. Whilst many studies have examined the land value uplift that has followed the implementation of new rail-based infrastructure, there is a lack of information on how much bus-based infrastructure can add to land values. Perhaps more importantly, a value capture policy needs to be informed by when the value uplift occurs. If land values rise before the operating phase of the new infrastructure, basing a land value capture tax on post-operational land values will miss potential uplift contributions.

This paper is motivated by a need to provide information central to the implementation of a value capture policy for bus-based infrastructure in a developing country context. Bus Rapid Transit (BRT) is an enhanced bus system, operating on bus lanes or dedicated infrastructure (called locally a 'transitway') to combine the flexibility of buses with the efficiency of rail. This paper identifies the land value uplift through a study of Sydney's Liverpool-Parramatta Transitway in Australia. Bus modes are important in the Australian lower density city environment and transitways are increasingly being considered as a way to provide cost-efficient, flexible public transport.

The paper is structured as follows. The next section identifies the theoretical underpinnings of land value uplift before reviewing studies examining land value uplift and the timing of value uplift for public transport investments generally and BRT more specifically. The following section introduces the methodology used in this paper followed by a description of the key elements of the case study in Sydney, Australia. The two sections which follow address the analysis of the two key issues of quantifying uplift and the timing of uplift for the case study area. A final section concludes the paper.

LITERATURE REVIEW

Land rent theory, developed by Alonso (1964) and Muth (1969), is the theoretical framework for the link between accessibility to goods and services and land values. These theories hold that land rent (and therefore the underlying land value) reflects accessibility gradients with higher values of rent reflecting higher accessibility.

Empirically, there is a well established literature demonstrating that transport infrastructure provides improvements in accessibility and therefore land value uplift with uplift benefits being distributed in relation to the proximity of the location to the infrastructure and to both residential and commercial properties. RICS (2002) and Smith and Gihring (2006) and Smith et al. (2009) reviewed over 100 international studies on the impact of public transport on property values, focussing mainly on the impact of rail projects (heavy rail, metro and light rail). In Australia, Chernih (2003) attempted to explain house prices in Sydney and included a variable which assesses the impact of proximity to rail stations on residential price but this study did not link changes in accessibility to specific public transport infrastructure.

The majority of the studies looking at valuing the increased accessibility brought about by enhanced or new transport infrastructure has concentrated on rail, light rail or metro investments. Rail based infrastructure is regarded as fixed once built and so any improvements in accessibility are perceived as permanent. Bus Rapid Transit (BRT) is a high capacity urban public transport system, typically with its own right of way (as for rail based modes) which is gaining in popularity because of its better cost effectiveness (vis a vis light rail), quicker implementation with capacity and passenger attractiveness comparable to rail. But compared to rail, BRT is seen as more flexible and, as Rodriguez and Targa (2004) noted 'ironically, it is BRT's flexibility that also appears to be one of its main weaknesses' p.589 with planners, funders and importantly users perceiving it as less permanent than rail systems. These perceptions could impact on BRT's ability to capitalise accessibility into land values.

The potential of BRT, as opposed to rail infrastructure, to uplift land values has been relatively neglected in the literature. Rodriguez and Targa (2004) and Munoz-Raskin (2010) studied the impact of BRT in developing countries such as Bogotá and Columbia where it has been hugely successful and evidence of land value uplift of between 6 percent to 9 percent occurred, depending the distance from the BRT station. As BRT penetration increases, more studies have become available each showing positive effects of BRT on land values (Deng and Nelson, 2010; Cervero and Kang, 2011). In developed countries, Cervero and Duncan (2002) investigated the effect of BRT in Los Angeles, but found no evidence of value uplift. Perk and Catala (2009) studied BRT in Pittsburgh where uplift values of around 16 percent were found and this is in excess of the uplift value attributed to new light rail, although they identified that other positive factors may have been responsible. Dubé et al. (2011) in Quebec, Canada, found value uplift of 3 percent to 7 percent but confined to properties located far enough away to avoid noise but close enough to use the BRT.

Although there has been a substantial body of literature capturing the impact of public transport investments on land value uplift, the timing of the value uplift is far from clear. For example, the land value may not only start being affected after the opening of the new public transport systems. Instead, the land value may gradually increase since the new infrastructure is announced because of the way in which the announcement is built into developers' or home buyers' expectation. In addition, construction phases create many negative externalities which may act to depress land values, not increase them. Identifying when value uplift occurs is as important as quantifying uplift as there is no guarantee that uplift occurs linearly between announcement and opening and ignoring this aspect is likely to bias the estimation of the impact of the greater accessibility brought about by public transport infrastructure on land value uplift.

RICS (2002) suggested that the association between public transport investment and land value should be analysed from the decision is made to opening and afterwards, and this investigation will require data at least three points in time. McMillen and McDonald (2004) is an early study that looked at how value uplift was related to the timing of announcement, construction and operation of a transport investment. They found positive effects following announcement in common with Mikelbank (2004). Mulley and Du (2007) investigated the impact of Metro on house price in Tyne and Wear in the UK using an Analysis of Variance (ANOVA) approach. They investigated the price impact from announcement of the project to starting of construction and the opening of Metro, but found no strong evidence suggesting this impact is significant and suggested that other factors such as the property attributes should be taken into account using more sophisticated modelling approaches.

Controlling for the other factors that influence house price can be undertaken using the hedonic modelling approach which treats the house as a bundle of attributes. This approach was taken by Rodriguez and Mojica (2009) to identify the effect of BRT on the asking prices of residential properties in Bogotá using sales data from 2001 to 2006. Whilst the hedonic model does take account of the property attributes, neighbourhood attributes, and accessibility attributes, the time-series data are used to identify the effect of BRT extension lines on land value in Bogotá during 2001 and 2006 rather than the distinction of land value uplift before and after the opening. Chatman et al. (2012), using repeat sales data and a hedonic pricing approach, found positive effects following the operation of the River Line in New Jersey (US) but these did not compensate for property depreciation that followed announcement and construction. Similarly, Concas (2013) used hedonic regression to quantify the price impact of the roadways in Florida from the pre-construction phase through to the construction phase, the opening year and post-opening years. In contrast to Chatman et al (2012), the results identified land value uplift to be significant from the construction phase of the road infrastructure onwards.

The discussion above highlights the importance of identifying the time period where the price impact of transport infrastructure occurs as well as quantifying the uplift value, particularly in relation to the contribution of BRT in capitalising increased accessibility into house prices. The next section briefly reviews the approaches suggested in the literature to capture the land value uplift and introduces the methodology used in this paper.

METHODOLOGY

The methods used to capture the effect of transport infrastructure on land value have been extensively discussed in the literature. As reviewed in Salon and Shewmake (2011), the simplest method is comparing the price change before and after the intervention of new transport infrastructure. The drawback of this approach is that the selected study areas may not be comparable over time due to external factors such as citywide housing price slump. This method can be extended by using a quasi experimental approach that compares the house price means of properties close to the transport infrastructure (the 'treatment' or 'catchment'), with house price means in 'control' areas over time. The advantage of this approach is that aggregate data, always more readily available, can be used and it is useful for exploratory analysis of the impact of new infrastructure.

However, house prices are not only affected by the intervention of transport infrastructure but also by other factors such as property attributes and neighbourhood characteristics. These factors cannot be simply captured by the before-and-after approach even when the catchment and control areas are compared. These other price determinants can be controlled by using a hedonic regression model which can be specified as in Equation (1).

$$Y_i = constant + \sum_j \beta_j X_i^j + \gamma D_i + \varepsilon_i \qquad \text{Equation (1)}$$

where Y_i is the price of property i which is predicted by a vector of observable attributes related to the property and a dummy variable D_i identifying whether this property is located in the catchment area or control area.

The focus of this analysis is not only the identification of the effect of transport intervention on property price but also understanding when this effect occurs. Thus, the full hedonic model employed in this analysis extends Equation (1) by introducing the time dummies and interaction terms of time and catchment dummy variables as specified in Equation (2).

$$\begin{aligned} Y_i = {} & constant + \sum_j \alpha_j P_{ij} + \sum_j \beta_j N_{ij} + \theta_2 \cdot Phase2 + \theta_3 \cdot Phase3 \\ & + \gamma_1 \cdot C \cdot Phase1 + \gamma_2 \cdot C \cdot Phase2 + \gamma_3 \cdot C \cdot Phase3 + \varepsilon_i \end{aligned} \qquad \text{Equation (2)}$$

where Y_i is predicted by a number of property attributes (P_{ij}) and neighbourhood attributes (N_i). $Phase$ 2 (construction) and $Phase$ 3 (opening) are the dummy variables of time which represent the time period where the property was sold and are designed to capture price changes over time using $Phase$ 1 (announcement) as a reference point. C is the dummy variable capturing the sold properties located in the catchment area, so C takes the value of zero in the control areas and a value of one if in the catchment areas. The interaction terms of C and the time dummies examine the price difference between catchment and control areas in each phase.

This analysis first employs a quasi experimental approach using ANOVA analysis to identify the average price changes in the study area since the announcement of the BRT project in Sydney and the price difference between catchment and control areas. This is followed by a more disaggregate approach using the hedonic model as introduced above to capture the accessibility impacts of BRT on housing price in three phases: after announcement, construction phase, and in the operation phase of the Liverpool-Parramatta Tway (LPT) in Sydney.

DESCRIPTION OF THE CASE STUDY

Study area

The Liverpool-Parramatta transitway (LPT) is the first bus rapid transit (BRT) system which connects the major centres of Liverpool and Parramatta in the South-West of Sydney, Australia. The termini are in Liverpool Local Government Area (LGA) and Parramatta LGA respectively. The transitway route traverses the two further LGAs of Fairfield and Holyroyd. The intention of the infrastructure was to provide North-South public transport services connecting Liverpool in the south, Parramatta in the north and suburbs along the route to major employment, education and recreation centres (NSW Audit Office2005). The 31 km route with 33 stations includes 20 km of new dedicated bus-only infrastructure and 10 km of on-road bus priority. Transitway stops were designed to emulate rail-based public transport rather than simple bus stops. Figure 1 shows the route of the LPT.

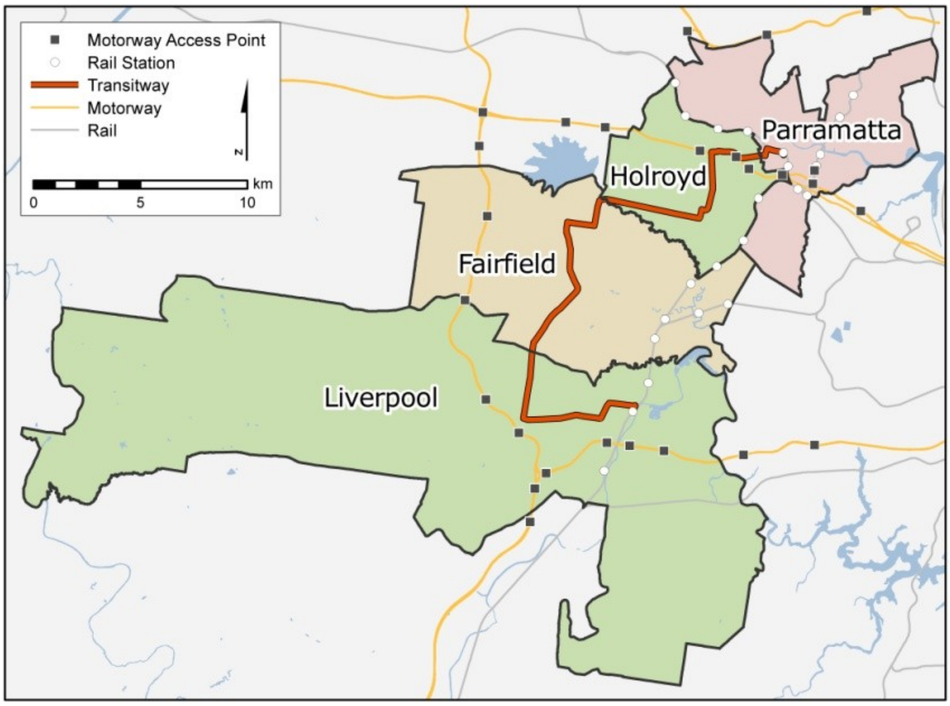

Figure 1. The Liverpool-Parramatta transitway Source: GIS layers

The building of the LPT was announced in mid 1998, constructed from February 2002, and opened in February 2003 at a final cost of over $350 million. The aim of the LPT was to markedly change accessibility in south west Sydney in providing a new north-south public transport link where existing local bus services provided local east-west links, and by using dedicated infrastructure to provide a high quality public transport experience with faster, more reliable services. In the first year of operation, the actual patronage was just under 1 million passengers per annum and this rose to nearly 2 million in 2006. Patronage on the transitway continues to grow with the most recent figures for 20011/2012 showing patronage at 2.7 million (STA2012).

The LGAs through which the LPT operates are quite diverse. Fairfield is recognised as one of the most diverse LGAs in Australia, attracts new migrants which are reflected by over half of its population being born overseas. The Australian Bureau of Statistics' SEIFA (Socio-Economic Indexes for Areas), using 2006 census data, covers all areas in Australia and is designed to have an average of 1000. In all the LGAs of the study area, these are identified as relatively disadvantaged with Liverpool at 966, Fairfield at 876, Holroyd at 972 and Parramatta at 987.

The LPT offers the opportunity to examine land value uplift consequent on bus infrastructure investment in a relatively self-contained spatial area. The aim of the transitway was to improve accessibility in the SW of Sydney and to provide links along a trunk route within an integrated network rather than increase capacity. In this way, the LPT was not designed to provide the flexibility and spatial coverage more usually associated with bus routes. In common with other BRT systems, the LPT has significant dedicated infrastructure and a service pattern similar to a rail link. As a case study, these features are important as it limits the opportunity for other factors to provide confounding changes which could interfere with identifying both the timing and quantity of value uplift.

Catchment and control areas

This analysis first defines the catchment and control areas for the residential property sales data as shown in Figure 2. Property sales data from 2000 to 2006 were sourced from RP data[1] who collate information from a number of different sources, including the Valuer General and Land Title offices. Residential sales properties located within 400 meters of a LPT stop are grouped into the same catchment area.

The control area corresponding to each of the catchment area is identified by several criteria. The first criterion is the composition of property types in terms of the percentages of houses and units in each catchment area. The second criteria relates to land use mix in the catchment areas (e.g., green space, commercial areas, schools and warehouses) and its socio-demographics (income and occupation types), identified using arterial imagery from Google Earth and Australian Census data respectively. Control areas are then selected by matching property type mix, land use mix and socio-demographics from the nearby neighbourhoods of similar size located outside of walking distance to the LPT stops. The pairing results are summarised in Table 1.

Some catchment areas (Catchments 11, 12, 13, 14, 15, 17, 18) which do not have sufficient property sales during 2000 and 2006 are not used as there is insufficient data to identify an appropriate control area. Catchment 1 (Parramatta Station) is also removed from the dataset although there are sufficient observations because it is not possible to identify a suitable control matching the 97 percent of units in the catchment. A further control area, control 3 is not shown on the map as its original pair was merged with an adjacent stop. The final dataset

[1] RP Data is a business that provides property information in Australia and New Zealand. http://www.rpdata.com/

consists of 5,315 properties in the catchment areas consisting of 56 percent of houses and 46 percent of units, and 5,835 properties in the control areas consisting of 57 percent of houses and 43 percent of units.

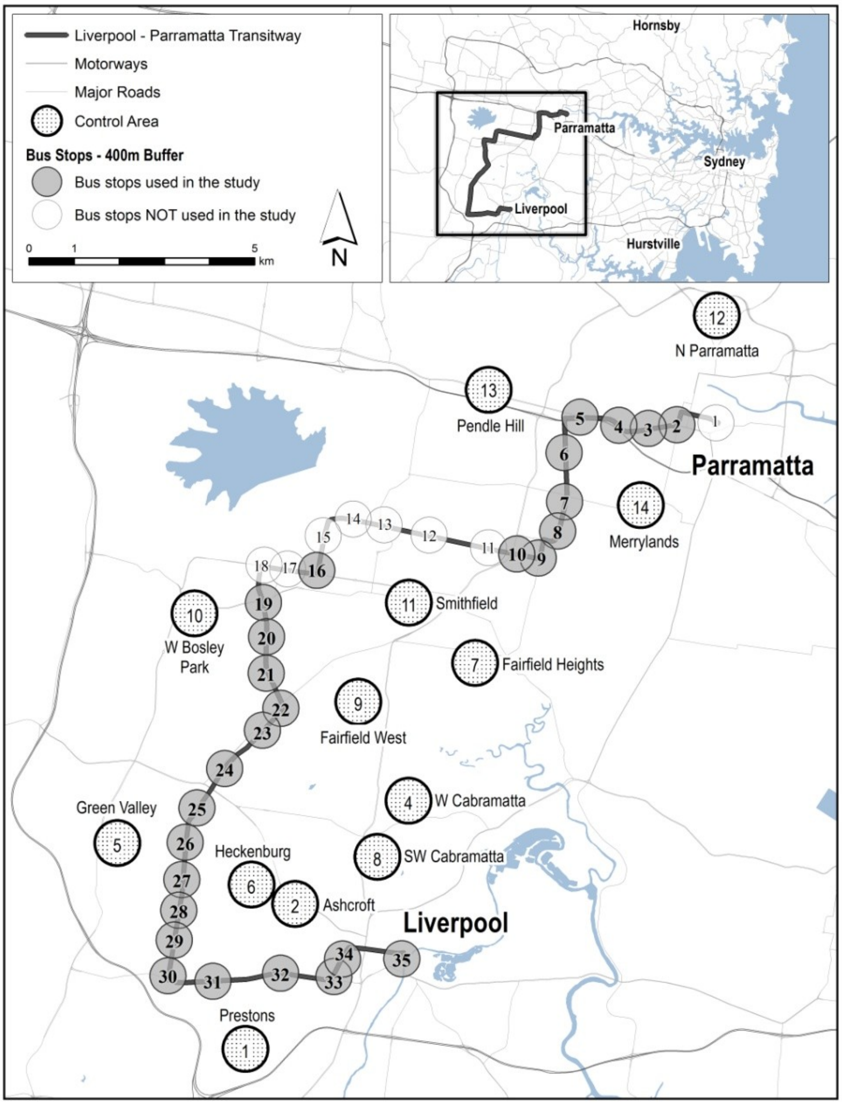

Figure 2. Cathcment and Control Areas Source: GIS layers

Table 1. A Comparison Table of Catchment and Control Areas

Catchment	Control	Catchment	Control
2	14	24	7
3,4,5,6	13	25,26	5
7,8	12	27,28,29	6
9,10	11	30,31	1
16,19	10	32,33	2
20	8	34,35	4
21,22,23	9		

ANALYSIS OF VARIANCE

Hypotheses

Using the sales data acquired, this section first investigates the transaction price of the sales properties in the catchment and control areas over three phases of time period. The first phase is defined as the time period after the LPT project was announced (2000 to 2001) and before the construction started. The second phase is the construction year (2002). The third phase starts from the opening year of 2003 to 2006 when the latest sales data and Census data are available for this study. The sales prices are adjusted to real values in 2000 based on Australian Consumer Price Index (CPI). The mean sales prices of the catchment and control areas over the three time periods are shown in Figure 3.

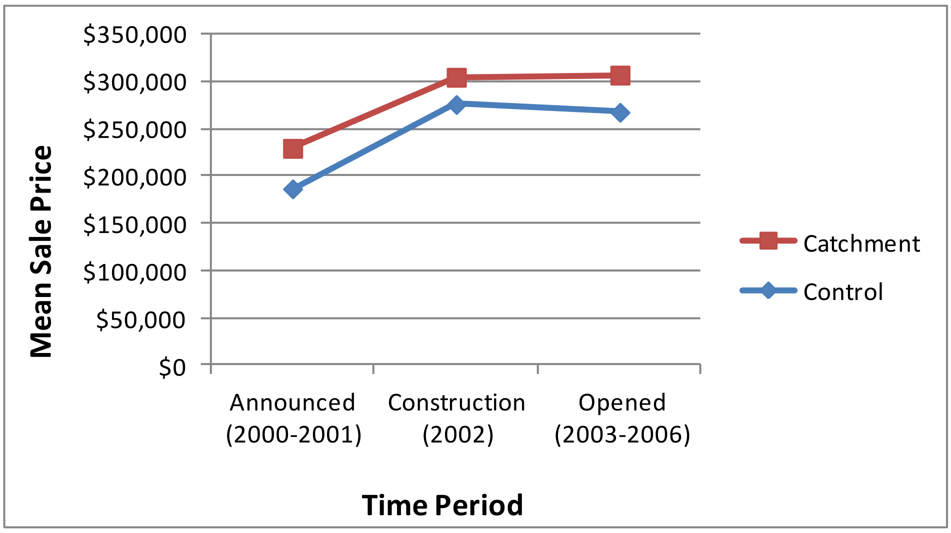

Figure 3. Mean Sale prices of Catchment and Control Areas

Figure 2 shows that the average sales price of properties in the catchment areas has been higher than the control areas on average since the LPT project was announced, and both prices markedly increased from the first phase to the second phase, and then the prices remained at the same level from the second phase to the third phase. The similar patterns of price changes in the catchment areas and control areas suggest that there was no noticeable external shock on the property prices which happened in only one of the areas, confirming the selection of control areas is appropriate in terms of the historical trend of price changes.

However, this evidence does not identify whether the average price in the catchment areas is statistically significant higher than the control areas over time or whether this price increase comes from the increased accessibility provided by the LPT. One-way ANOVA is used to test the significance of price differences in this section. The one-way ANOVA is conducted with the following two hypotheses:

Hypothesis 1:
Null Hypothesis (H_0): There is no significant difference in property prices in the control and catchment areas at a point in time.
Hypothesis 2:

Null Hypothesis (H_0): There is no significant change in property prices in one area over time.

In general, the price difference of the sales properties is analysed in two dimensions. The first hypothesis tests the cross-sectional price difference between catchment and control areas at a point in time during the three phases of the LPT projects, so the null hypothesis is tested in Phase 1, Phase 2 and Phase 3 separately. The second hypothesis investigates the price changes over time for both the catchment and control areas. Thus, the average price changes between Phase 1 and Phase 2, Phase 2 and Phase 3, as well as Phase 1 and Phase 3 are analysed for the catchment and control areas separately.

Results of ANOVA

The results of the one-way ANOVA are summarised in Table 2. The "contrast" refers to the pair used to compare the means between two samples. Some of contrasts do not show the same normality of variance after the test of homogeneity using the Levene's test and thus the non-parametic statistical analysis using Mann–Whitney test [2] is employed to test for significance for these contrasts as noted in Table 2. Other parametric pairs are analysed using a standard one-way ANOVA.

Table 2. Results of the Analysis of Variance

Hypothesis 1			**Note**
Contrast	**p-value**	**Reject H_0**	
CatchmentPhase1-ControlPhase1	0	Yes	Parametric
CatchmentPhase2-ControlPhase2	0.063	No	Parametric
CatchmentPhase3-ControlPhase3	0	Yes	non-parametric
Hypothesis 2			**Note**
Contrast	**p-value**	**Reject H_0**	
CatchmentPhase1-CatchmentPhase2	0	Yes	non-parametric
ControlPhase1-ControlPhase2	0	Yes	Parametric
CatchmentPhase2-CatchmentPhase3	0	Yes	non-parametric
ControlPhase2-ControlPhase3	0.433	No	Parametric
CatchmentPhase1-CatchmentPhase3	0	Yes	Parametric
ControlPhase1-ControlPhase3	0	Yes	non-parametric

For Hypothesis 1, the price difference between catchment and control areas is significant in Phase 1 and Phase 3. This price difference is statistically insignificant in Phase 2 although Figure 2 shows the average price in the catchment areas as higher than the control areas. For

[2] The Mann-Whitney test compares the medians and the distributions of two samples. The null hypothesis is that one sample tends to have a higher value than the other sample (Mann and Whitney, 1947).

Hypothesis 2, all but one of the contrasts show a significant price difference between two points in time, suggesting that the prices of properties in catchment and control areas significantly increased over the three time periods, except for the average price of control areas between Phase 2 and Phase 3 which fails to reject the null hypothesis.

The exploratory analysis presented above has tested the significance of the price difference between catchment and control areas over the three time phases. However, although in general the catchment areas show a significant higher price than the control areas, it is unclear whether house prices have appreciated from the commencement of the LPT project. For example, it is possible that the higher price in the catchment areas is because the neighbourhood attributes or property attributes are generally better than the control areas, or the price increase over time is simply a result of the overall increasing housing price in this region. These factors cannot be captured by the one-way ANOVA or the non-parametric analysis since they simply compare the means of the two samples without controlling for the other determinates of housing price. Therefore, the next section presents a hedonic modelling approach to take these factors into account and to quantify the contribution of the LPT on housing prices.

HEDONIC REGRESSION

Data description

Dependent Variable
As discussed above, the property price as the dependent variable in the model is the transaction price of the sales data, adjusted by Australian Consumer Price Index. The transaction price as a market clearing price is expected to better represent the real market value of the property as compared to the asking price which may be over-estimated by the property owners. The transaction price in the hedonic model is transformed to the natural logarithms. The transformed log variable has the advantage of mitigating heteroscedasticity as a result of the reduced scale of the values (Rodriguez and Mojica, 2009). It also enables the identification of the accessibility benefits of the LPT on property price in percentages as derived from coefficients $\gamma_1, \gamma_2, \gamma_3$.

Property Attributes
Each house price is associated with property including the contract date of the sale, property type (house, or unit), area size, the number of bedrooms, bathrooms, number of parking spaces and the latitude and longitude for properties sold during 2000 and 2006 in the LGAs of Liverpool, Holroyd, Fairfield and Parramatta. The literature has identified the size of the property, as measured by its square area, as an important determinant of house price. In the Australian case, the area recorded by the Valuer General and Land Title office when a property is sold is the area of the plot. This has the unfortunate consequence of associating the area of the plot (the external area of the site) of a unit (apartment or flat) with the transaction price of that unit and distorts a comparison of size between houses and units. For this reason, this study uses the number of bedrooms, bathrooms, and parking spaces were used to control for the size of the property. The property type is controlled by a dummy

variable (Type=0 if house; Type=1 if unit) and the way in which the control areas are selected by matching the percentage of houses and units with their contrast catchment areas (as discussed in the previous section). Unfortunately, some property data do not contain all the property attributes (bedrooms, bathrooms, and parking spaces) which reduces the sample size to 1,167 properties as only properties with at least one bedroom and one bathroom are used in this hedonic regression. The reduction in observations was undertaken as the property attributes are considered important to ensure that any uplift in land value is not confounded.

Neighbourhood Attributes
Neighbourhood attributes are used to explain the external characteristics influencing property prices. The purpose of controlling for these external effects is to allow the accessibility impact of LPT on property price to be observed. The neighbourhood attributes selected for this analysis include the level of English-speaking background, unemployment and income. These variables are derived from the Australian Bureau of Statistics 2006 census data at the Collection District (McMillen and McDonald) spatial level. Due to the lack of continuously historical data, these variables are assumed to be unchanged between 2000 and 2006.

The level of English-speaking background is used to characterise the neighbourhood's ethnicity since the LGAs of Liverpool and Fairfield in particular attract those newly migrated to Australia and which may have a moderating effect on the local housing market. The level of unemployment and individual income is used to capture the socio-demographics of the neighbourhoods. A higher level of English-speaking background, a lower level of unemployment and higher income is hypothesised to have a positive impact on the property price.

The hedonic model also includes a dummy variable capturing properties located within 50 metres of a LPT station. These properties, although having very good accessibility to the LPT stations, may suffer from the negative environmental impact from the BRT system such as noise and air pollution. This follows the finding by Cervero and Kang (2011) that a BRT system had a negative impact on residential properties located within 100 meters of a BRT station in Seoul, Korea.

Time and Catchment Dummies
The time dummies are included in the model to capture overall price change over time from when the LPT was announced, through the construction phase and then the after-opening phase. The interaction terms of catchment dummies and time dummies are used to measure the average price difference between properties in the catchment areas and control areas by phase. A summary of all the variables in the hedonic model is presented in Table 3.

The descriptive statistics of property and neighbourhood variables are summarised in Table 4, as well as being segmented into catchment and control areas to illustrate the similarity of the property and neighbourhood attributes in both areas. This shows how the property attributes and neighbourhood attributes in the control areas are close to those of the catchment areas with only the average transaction price being slightly higher in the catchment areas as shown in Figure 1. This is further evidence that the selection of control areas is appropriate and confirms that, despite the lower sample size due to missing data, the data appear representative of the catchment and control areas.

Table 3. A Summary of the Variables in the Hedonic Model

Variable	Description	Source
Dependent Variable		
lnPrice	Transaction price of property in natural logarithms (Australian Dollars)	RP data
Property Attributes		
bed	Number of bedrooms	RP data
bath	Number of bathrooms	RP data
parking	Number of parking spaces	RP data
type	Type=0 if house; Type=1 if unit	RP data
Neighbourhood Attributes		
english	The precent of individuals where English is the primary language spoken at home	Census
unemployment	The percent of unemployed persons looking for work	Census
income	The percent of individuals with gross income of more than 1,600$ per week	Census
buffer50m	=1 if within 50m of a BRT stop	GIS
Time Dummies		
phase1	After announcement; before construction (2000-2001)	RP data
phase2	After construction; before opening (2002)	RP data
phase3	After opening (2003-2006)	RP data
Catchment Dummies		
c*phase1	Interaction term of catchment and phase1 (c=1 if in catchment area; c=0 if in control area)	RP data GIS
c*phase2	Interaction term of catchment and phase2 (c=1 if in catchment area; c=0 if in control area)	RP data GIS
c*phase3	Interaction term of catchment and phase3 (c=1 if in catchment area; c=0 if in control area)	RP data GIS

Table 4. Descriptive Statistics of the Variables

Area	Variable	Obs	Mean	Std. Dev.	Min	Max
All Properties	Price (AU$)	1167	277139.60	96040.20	85123.97	863636.40
	bed	1167	2.87	0.92	1.00	7.00
	bath	1167	1.35	0.59	1.00	4.00
	parking	1167	0.90	0.83	0.00	5.00
	Type (dummy)	1167	0.37	0.48	0.00	1.00
	english (%)	1167	0.36	0.15	0.03	0.78
	Unemployment (%)	1167	0.04	0.01	0.01	0.09
	Income (%)	1167	0.02	0.01	0.00	0.07
	buffer50m (dummy)	1167	0.01	0.11	0.00	1.00
Control Areas	Price (AU$)	559	266836.50	101576.60	85123.97	863636.40
	bed	559	2.81	0.94	1.00	7.00
	bath	559	1.35	0.61	1.00	4.00
	parking	559	0.87	0.86	0.00	5.00
	Type (dummy)	559	0.42	0.49	0.00	1.00
	english (%)	559	0.36	0.16	0.03	0.78
	Unemployment (%)	559	0.04	0.01	0.01	0.08
	Income (%)	559	0.02	0.01	0.00	0.05
	buffer50m (dummy)	559	0.00	0.00	0.00	0.00
Catchment Areas	Price (AU$)	608	286629.30	89684.01	99173.55	657894.80
	bed	608	2.91	0.91	1.00	7.00
	bath	608	1.34	0.56	1.00	4.00
	parking	608	0.93	0.81	0.00	4.00
	Type (dummy)	608	0.33	0.47	0.00	1.00
	english (%)	608	0.37	0.14	0.12	0.65
	Unemployment (%)	608	0.04	0.01	0.02	0.09
	Income (%)	608	0.02	0.01	0.00	0.07
	buffer50m (dummy)	608	0.02	0.16	0.00	1.00

Estimation results

The hedonic model (Equation (2)) was first estimated using the Ordinary Least Squares (OLS) estimator and the result identified significant heteroscedasticity through the Breusch-Pagan test. The presence of heteroscedasticity does not affect the values of coefficients but causes inefficiency that affects the standard errors of parameters. Hence, the OLS estimator with robust standard errors is used to estimate the hedonic model, with results presented in Table 5.

Table 5. Estimation Results of the Hedonic Model

Variable	Coef.	Robust Std. Err.	t	p-value	[95% C.I.]	
bed	0.123	0.011	10.84	0.000	0.101	0.145
bath	0.125	0.012	10.35	0.000	0.101	0.149
parking	-0.006	0.007	-0.79	0.431	-0.020	0.009
type	-0.236	0.020	-11.69	0.000	-0.275	-0.196
english	-0.037	0.057	-0.65	0.515	-0.148	0.074
unemployment	-2.913	0.634	-4.60	0.000	-4.156	-1.669
income	6.672	0.544	12.26	0.000	5.604	7.739
buffer50m	-0.130	0.048	-2.73	0.006	-0.224	-0.037
phase2	0.232	0.077	3.03	0.002	0.082	0.382
phase3	0.228	0.047	4.90	0.000	0.137	0.320
c*phase1	-0.065	0.068	-0.96	0.337	-0.198	0.068
c*phase2	0.032	0.092	0.35	0.726	-0.148	0.212
c*phase3	0.036	0.013	2.86	0.004	0.011	0.060
_cons	11.810	0.067	175.78	0.000	11.678	11.942
Observations	1167					
F(13, 1153)	185.07					
Prob. > F	0.00					
R-squared	0.67					
Root MSE	0.20					

In general, the hedonic model shows reasonable model fit as well as the explanatory power. The R-squared value of 0.67 suggests 67 percent of the variation in the dependent variable ($lnPrice$) can be explained by the independent variables. Most property and neighbourhood attributes are significant at the 95 percent level of statistical confidence except for parking spaces and the level of English-speaking background.

For the property attributes, the numbers of bedrooms and bathrooms have a positive impact on the property price as expected, but the number of parking spaces does not have a significant influence on the price. The parameter of property type is negatively significant suggesting the average price of units are lower than average house prices as expected as units are normally valued lower than houses within the same housing market in most Australian cities.

In terms of the neighbourhood attributes, the unemployment and income variables are both significant with the expected signs. Higher income and a lower unemployment rate are expected to increase the property price. The level of English-speaking background is not significant suggesting that ethnicity does not significantly influence the property price. The dummy variable of the 50-meter buffer around the LPT stations is significant with a negative sign, suggesting that properties located close enough to the LPT stations to experience noise and other negative externalities have lower price than properties outside of the buffer.

The time dummy variables ($Phase$ 2, $Phase$ 3) are significant which confirms the average price of sales properties increased over the three time periods as compared to the first phase. A further analysis using $Phase$ 2 as the reference was also examined and the result suggests that price in Phase 1 is significantly lower than $Phase$ 2 but the price difference between Phase 2 and Phase 3 is not significant. This confirms that overall housing market in the study area grew from Phase 1 to Phase 2 and then remained stable afterwards, so this cannot be interpreted as the contribution of the LPT.

The variables of most interest are the interaction terms of time dummies and catchment dummies as they measure the premium of property price contributed from the LPT from the announcement through the construction phase and then the opening phase. The results show that the average price in the catchment areas is only significantly higher than the control areas in $Phase$ 3, with the price difference not being significant in the first two phases before the opening. As the dependent variable of price is in natural logarithms, the coefficient of $c * phase3$ can be interpreted as the percentage of the price uplift due to LPT in the third phase. That is, the opening of the LPT led to a 3.6 percent price uplift in the catchment areas, relative to the control areas, after controlling for property and neighbourhood attributes.

The price premium for residential properties benefiting from a BRT intervention in previous studies generally range between 3 percent and 16 percent, varying with the locations and methodology in use (Cervero and Duncan, 2002; Rodriguez and Targa, 2004; Perk and Catala, 2009; Munoz-Raskin, 2010; Cervero and Kang, 2011; Dube, et al., 2011). The 3.6 percent price premium identified from the LPT in Sydney appears to be relatively lower than other cities, and it is only significant after the opening of the BRT system. This is possibly because the LPT is the first BRT project in Sydney and it is implemented in an area having poor accessibility to public transport. Thus, the expectation of the potential benefit brought about by a new BRT system in this area may be lower than cities where BRT has been well-developed such as Bogotá and some Asian cities. As a result, the full benefits of the BRT system in Sydney may not be realised until a few years after the opening when the improved accessibility becomes more attractive to local residents or investors. This can be seen from the passenger volume of the LPT which rapidly grew from under 1 million in the first year of operation (2003) to around 2 million in 2006 (STA, 2012).

CONCLUSION

This paper uses ANOVA and the hedonic regression model to identify the accessibility impact of the LPT on residential housing prices in Sydney. The ANOVA is used as an exploratory analysis to investigate the overall price changes from the announcement to the opening of the LPT and the price difference between the catchment and control areas. The hedonic model controls for the property and neighbourhood attributes to measure the price effect from the LPT and to identify when this effect occurred.

The results of the ANOVA suggest that the housing price of the catchment areas is significantly higher than the control areas in the phase of announcement (Phase 1) and after opening (Phase 3), but insignificant during construction phase (Phase 2). Both catchment and control areas show significant increase in the property price over the three time periods examined, except that the increase in prices for the control areas between Phase 2 and Phase 3 is insignificant.

The hedonic regression results however show that the price difference between catchment and control area is only significant in Phase 3, with a 3.6 percent price premium ocurring after the commencement of the LPT. The different findings from the two methods demonstrate the importance of controlling for the determinants of housing price other than the impact of the transport intervention. The result of the before-and-after analysis using ANOVA is unable to capture these other factors because it only compares the difference in means even when the catchment and control areas are being compared and thus confounds the results.

The price premium confirms the positive contribution of the LPT in Sydney. The presence of uplift in residential house price would support value capture as a potential funding scheme for future improvement to public transport. Thus, the findings of this research provide important evidence for potential transport policy formulation.

Although the 3.6 percent price premium identified for the LPT appears to be lower than worldwide experience, it is reasonable that the benefits of the LPT, as the first BRT system in Sydney, might be under-estimated before its opening because of uncertainty. Future research needs to continue to track the price changes over time since the LPT's opening or be extended to the other BRT systems in Sydney now in operation to investigate whether the expectations as to the potential land value uplift from BRT systems is higher than the LPT.

REFERENCES

Alonso, W. (1964). Location and Land Use. Harvard University Press, Cambridge, the United Kingdom.

Cervero, R. and M. Duncan (2002). Land Value Impacts of Rail Transit Services in Los Angeles County. National Association of Realtors, Urban Land Institute.

Cervero, R. and C.D. Kang (2011). Bus rapid transit impacts on land uses and land values in Seoul, Korea. Transport Policy, 18, 102-116.

Chatman, D.G., N.K. Tulach and K. Kim (2012). Evaluating the economic impacts of light rail by measuring home appreciation: a first look at New Jersey's River Line. Urban Studies, 49, 467-487.

Chernih, A. (2003). Impact of Proximate Public Assets and Infrastructure on Private Real Property Values. BCom Honours Thesis, School of Actuarial Studies, The University of New South Wales Sydney, Australia.

Concas, S. (2013). Accessibility and housing price resilience: evidence from limited-access roadways in Florida. Proceedings of the 92nd Annual Meeting of Transportation Research Board. Washington DC, the United States.

Deng, T. and J.D. Nelson (2010). The impact of bus rapid transit on land development: a case study of Beijing, China. World Academy of Science, Engineering and Technology, 42, 1182-1192.

Du, H. and C. Mulley (2007). The short-term land value impacts of urban rail transit: Quantitative evidence from Sunderland, UK. Land Use Policy, 24, 223-233.

Dube, J., F.D. Rosiers, M. Theriault and P. Dib (2011). Economic impact of a supply change in mass transit in urban areas: a Canadian example. Transportation Research Part A, 45, 46-62.

McMillen, D.P. and J. McDonald (2004). Reaction of house prices to a new rapid transit line: Chicago's Midway Line, 1983–1999. Real Estate Economics, 30, 463-486.

Mikelbank, B.A. (2004). Spatial analysis of the relationship between housing values and investments in transportation infrastructure. The Annals of Regional Science, 38, 705-726.

Munoz-Raskin, R. (2010). Walking accessibility to bus rapid transit: Does it affect property values? The case of Bogotá, Colombia. Transport Policy, 17, 72-84.

Muth, R.F. (1969). Cities and Housing. University of Chicago Press, Chicago, the United States.

Perk, V.A. and M. Catala, (2009). Land Use Impacts of Bus Rapid Transit: Effect of BRT Station Proximity On Property Values Along the Pittsburgh Martin Luther King, Jr. East busway. National Bus Rapid Transit Institute, University of South Florida, the United States.

Royal Institute of Chartered Surveyors (2002): Land Value and Public Transport: Stage one—summary of findings. http:/*/www.rics.org/*

Rodriguez, D.A. and C.H. Mojica (2009). Capitalization of BRT network expansions effects into prices of non-expansion areas. Transportation Research Part A, 43, 560-571.

Rodriguez, D.A. and F. Targa (2004). Value of accessibility to Bogotá's bus rapid transit system. Transport Reviews, 24, 587-610.

Salon, D. and S. Shewmake (2011). Opportunities for Value Capture to Fund Public Transport: A Comprehensive Review of The Literature with a Focus on East Asia. Working Paper in Institute for Transportation and Development Policy.

Smith, J. and T. Gihring (2006): Financing transit systems through value capture: an annotated bibliography. American Journal of Economics and Sociology, 65, 751-786. Available at: http://ssrn.com/abstract=1753302

Smith, J., T. Gihring and T. Litman (2009). Financing Transit Systems through Value Capture: An Annotated Bibliography. Victoria Transport Policy Institute, Canada.

State Transit Authority (2012). Annual Report 2011/2012. Sydney, Australia.

The Audit Office of New South Wales (2005). Auditor-General's Report- Performance Audit: Liverpool to Parramatta Bus Transitway. New South Wales, Australia.