An exploratory analysis of Bus Rapid Transit on property values: A case study of Brisbane's South East Busway

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Abstract: Drawing on the South East Busway (SEB) in Brisbane, Queensland, a full-featured bus rapid transit (BRT) network in Australia as a case study, this paper explores the impact of BRT on residential property values and how this varies spatially. Using Hedonic Price Models (HPM), we detected a negative impact of proximity to SEB stations on housing price within a 2.4-kilometre buffer of SEB corridor. On average, housing price decreases by AUD$1,133 with every 100-metre increase closer to a station. Consequently, properties located within 1200-metre radius of SEB stations could get up to AUD$30,180 lower in price compared to other properties. Furthermore, a segmented regression method was used to assess the combined effects of improved accessibility to SEB stations and proximity-related effects to the SEB corridor on property values. The model results reveal a more complex picture describing the spatial change of the impact of SEB on housing prices: a positive effect of access to SEB stations but a more substantial negative effect of immediate proximity to SEB corridor. The strong association between the distance to the SEB corridor and housing prices may suggest the proximity-related negative externalities of BRT, perceived as a main disadvantage of tyre-based transit. We argue that location characteristics of SEB as well as adjacency to a highway might have contributed to the negative proximity-effects and limit its ability to uplift property values.

Introduction

Over the past two decades, Bus Rapid Transit (BRT) has gained increasing popularity around the world due to the high quality services it provides together with the flexibility and lower cost compared to other transport modes. As such, investment on BRT has been surging world-wide: over 50 BRT systems have been constructed and in operation across both developing and developed countries since 2000 (Deng & Nelson, 2011). In Australia, BRT has also been introduced and quickly expanded in major metropolitan areas. Brisbane, the third largest city in Australia, has been developing a world class BRT network since 2000 with several expansions still under planning and construction. Three dedicated busways were constructed, and one of them, the South East Busway (SEB) has been in operation for nearly 15 years.

There has been increasing interests in evaluating BRT performance (Jordan *et al.*, 2009; Hidalgo & Carrigan, 2010; Hollenhorst, 2012; Hidalgo *et al.*, 2013). It is commonly acknowledged that BRT is a cost-effective mass transit mode to improve urban mobility and reduce road congestions and carbon emissions (Weinstock, 2011). However, the construction and operation of BRT have also resulted in mixed effects on the property values, especially for those residing along the BRT lines and catchments. On the one hand, good access to public transport is one of the key factors on people's relocation choices for both residential and commercial purposes. According to the land rent theory (Alonso, 1964; Muth,1969), all else being equal, people are willing to pay more for locations with better transit offerings. Therefore, good access to public transport is expected to exert positive effect on land value appreciation within the catchment, especially in congested and land-constrained cities where public transport plays a major role in determining accessibility change (Deng & Nelson, 2012).

On the other hand, the literature reported mixed impact of BRT on land and property values. For instance, Transmilenio, a full-featured BRT system implemented in Bogota, Colombia, in 2000 has gained the most attentions from scholars and been praised internationally for its good performance and less expenditure in operation. While there are some evidences of land value appreciation conferred by Transmilenio (RodriGuez & Targa, 2004; Munoz-Raskin, 2006; Mendieta & Perdomo 2007; Munoz-Raskin, 2010), the literature also reported negative impact in certain context. Munoz-Raskin (2006) found that high-value properties were valued higher if they were close to a feeder line, but in the case of trunk lines, the effect was the opposite. Another study shows that closer to Transmilenio yield positive effects on properties owned by middle-income households, while for low-income households, the impact was negative (Munoz-Raskin, 2010). Cervero (2002) detected mixed effect of the dedicated-lane BRT in Los Angeles on property values, where only slight negative impact on residential property values but small gains on commercial land parcels were observed. In the case of Pittsburgh, Pennsylvania, Perk (2010) found that the value of single-family properties decreases as the distance from a BRT station increases.

There are also some evidences of BRT's impact on land and property values from the densely populated cities in Asian. Cervero and Kang (2011) reported that in Seoul, Korea, BRT improvements prompted property owners to convert single-family residences to higher density apartments and condominiums; they also found that land price for residential area within 300 metre of BRT stops were higher. For retail and other non-residential land uses, such impact was constrained in a smaller catchment within 150m of the BRT stops. In Guangzhou, China, the BRT system has resulted in an increase of real estate price by 30 percent during the first two years of its operation (Suzuki *et al.,* 2013). However, no appreciable capitalization benefits were identified in Beijing's South Axis BRT system (Zhang & Wang, 2013).

In Australia, a report by Transit Cooperative Research Program show that property values near Brisbane's South East Busway grew 20% faster than that in the surrounding area due to the improved accessibility (Levinson *et al.*, 2003). However, Corinne and Chi (2013) show that property values within 100m to BRT stations in Sydney grew slower than those located between 1200m to 1600m due to increased noise and air pollution induced by the BRT, and no statistically significant evidence was identified to indicate property value uplift due to BRT implementation. Evidently it is yet to obtain comprehensive understanding of the impact of BRT on property values (Stokenberga, 2014), especially in the Australia context where commuters are less dependent on public transport.

Drawing on the South East Busway in Queensland as a case study, this paper aims to draw empirical evidence on the impact of BRT on property values, focusing on the following two research questions: 1) how does the improved accessibility by SEB impact on residential property values? and 2) how does the impact by SEB on property values vary spatially within its catchment?

Two hypothesizes were formulated: 1) the improved accessibility due to SEB results in higher property values within the SEB catchment; and 2) the impact of SEB on property values is constrained within a certain distance from the SEB line, which diminishes eventually away from the BRT line.

The next section presents the study area and data used in this research. This is followed by three models we developed to test our hypotheses. The results are then provided followed by a discussion of key findings as well as possible extensions for future research. This paper is ended with a brief conclusion, identifying limitations and significance of this study.

Study area and data

The study area

Brisbane is the capital city of Queensland and the third largest city in Australia with 2.3 million inhabitants in 2012 (Australian Bureau of Statistics, 2013). It is one of the major business hubs and fastest growing regions in Australia, averaging at 4.7 per cent economic growth between 2001 and 2012 (Queensland Treasury and Trade, 2012). To meet the rapid urban development, Brisbane developed an extensive transportation network within the city, which incorporates rail, bus and ferry.

A BRT system in Brisbane was first put on the transport policy agenda in 1994 (Tanko & Burke, 2013). Within 6 years of design and development, the first BRT line – South East Busway – started operating and has been expanding to around 30km busway network. It radiates from the CBD and comprises the SEB, Northern Busway and Eastern Busway, with several extensions still under planning or constructing (Figure 1).

The SEB is a 16.5km dedicated bus corridor serving the central CBD from south-eastern low-density communities since 2000, with a part of the route running in parallel to a Motorway (M3, see Figure 1). A journey from Eight Miles Plains to the CBD takes about 18 minutes, while it can take up to 60 minutes to drive on the non-BRT road (Deutscher & Pasieczny, 2003).

We define a 2.4km buffer within the south section of the SEB from Greenslopes to Eight Mile Plains as the case study area (Figure 1). This is based on our assumption that beyond this catchment buffer, the impact of SEB on property values is limited which is out of the scope of this exploratory study. The north section from the CBD to Greenslopes was excluded due to the complex effect of the CBD and the Brisbane River on the property market. Part of the sample data in the north section of the SEB was also excluded to reduce the potential compounding effect of the Eastern Busway and its bus stations (Figure 1). Figure 1 displays the residential property sales data we used as sample data, which are discussed in the next section.

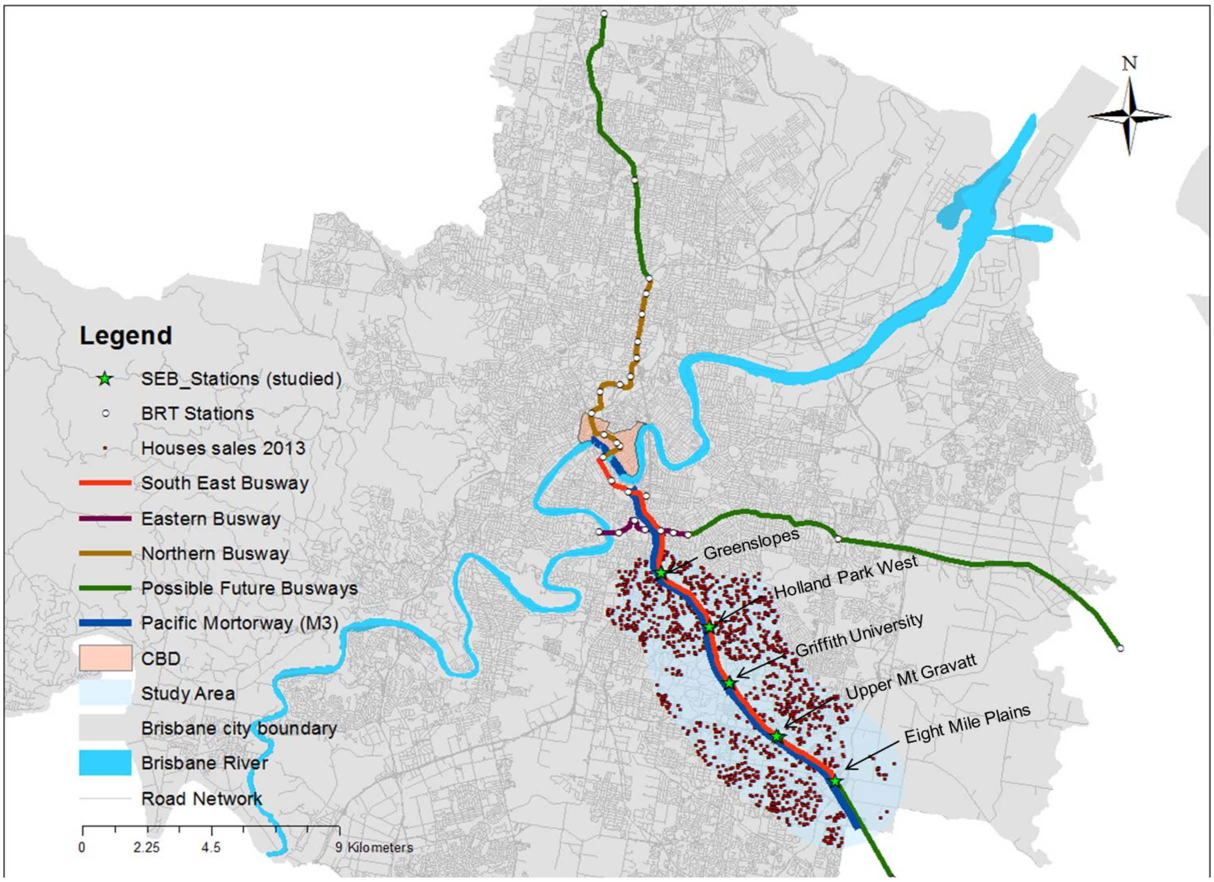

Figure1. The BRT, bus stations and residential property sales data within the study area

Data

Residential property sales data within the study area in 2013 was used in this study, which was extracted from the Australian Urban Research Infrastructure Network (AURIN) database (AURIN 2015). This accounts for 1,313 property sales and include attributes such as the sale price, date, address, property type (house or townhouse), area size, number of bedrooms, bathrooms, parking spaces and so on. The data were geocoded by matching the address attributes with the Geocoded National Address File (G-NAF, 2014), an authoritative address index for Australia, containing the geographic coordinates and address information (state, suburb, street and number in Australia). Other spatial data, including the location of Brisbane CBD and Brisbane River, local schools, and the local transportation network were also processed and mapped (Figure 1).

Access to BRT services was defined as the network distance to the nearest SEB station. It was calculated in ArcGIS using the network analysis tool. Other locational characteristics of the properties, such as the distance from the property to SEB corridor (Euclidian distance from point to line), distance to the CBD (Euclidian distance from point to polygon) and network distance to the nearest school were also computed in GIS.

To control for neighbourhood characteristic of the properties, we used the 2011 Index of Relative Socio-economic Advantage and Disadvantage at suburb level, a type of the Socio-Economic Indexes for Areas (SEIFA). SEIFA is a summary index calculated and released by Australian Bureau of Statistics (ABS), which measures the relative social and economic conditions, such as income, educational attainment, the unemployment and so on of cities, towns and suburbs across Australia (SEIFA, 2011).

Table 1 describes each of the variables used in the three models (termed as HPM1, HPM2 and SRM) we developed in this study which are described in the next section.

Table 1: A descriptive of variables used in this study and their summary statistics (N=1313)

Variable	Description	Mean	Std. Deviation
Dependent variable			
PRICE	House sales prices	600682.899	282295.296
Independent variables used in all three models			
Month	The month of sale (2013)	6.748	3.309
prtype	Property type, which 1=house; 0=townhouse	0.924	0.265
Area_Size	Area in the property in sq. metres	672.277	876.465
N_Bedroom	Number of bedroom	3.51	0.978
N_Bathroom	Number of bathrooms	1.77	0.85
N_Parking	Number of parking spaces	1.85	0.974
So_Eco_Status	2011 SEIFA Index of Relative Socio-economic Advantage and Disadvantage at suburb level	1048.743	24.847
Dis_CBD	Straight-line distance to CBD district	8447.478	3193.521
Dis_School	Network distance to nearest school	716.34	361.407
Independent variable used in the first HPM			
Dis_Station	Network distance to the nearest SEB station	2058.978	824.654
Independent variable used in the second HPM			
Access_1200m	A categorical variable which equals to 1 if Dis_Station <= 1200m, otherwise it is 0	0.167	0.0103
Independent variables used in the third model			
Dis_Busway (DB)	Straight distance to the SEB line	1268.285	675.987
DUM1	A categorical variable which equals to 1 if DB >= 600, otherwise it is 0	0.79	0.409
DUM2	A categorical variable which equals to 1 if DB >= 1600, otherwise it is 0	0.35	0.476
Dis_ Busway _600m	= DUM1*(DB- 600)	726.17	596.233
Dis_ Busway _1600m	= DUM1*(DB - 1600)	148.737	244.379
Access_1400m	A categorical variable which equals to 1 if Dis_Station <= 1400, otherwise it is 0	0.25	0.431

Methodology

Hedonic price model (HPM) is a commonly used methodology in real estate appraisal, in which the value of a property is determined by the characteristics of the house itself, the locational characteristics, as well as the characteristics of the surrounding neighbourhood (Rosen, 1974). Through regression modelling, the hedonic pricing model can be used to estimate the extent to which each of the factors affects the property values.

We developed two hedonic price models (termed as HPM1 and HPM2 respectively) to test the first hypothesis on whether the improved accessibility due to SEB has resulted in higher property values within the SEB catchment. Then a segmented regression model (SRM) was constructed to test the second hypothesis on the spatial diversity of the mixed effects of SEB on property values due to both accessibility and environmental affluence. All models were estimated by means of ordinary least squares (OLS) regression.

Hedonic price models (HPM)

Two hedonic price models were developed to evaluate the value of accessibility to the SEB station using property sales data as dependent variable and factors that may affect housing price, including property characteristics (area size, property type, number of bedrooms, number of bathrooms and number of parking spaces), neighbourhood socio-economic status, locational amenities and time of sale as the independent variables. The difference between the two models sits on the accessibility measure used in each model, with HPM1 using the network distance from each property to the nearest SEB stations measured in GIS as a continuous variable, while HPM2 using a categorical variable to quantify the accessibility from a property to the BRT stations, with 1 representing a property within 1200-metre service area from the SEB stations, and 0 otherwise. The estimated coefficient of the categorical variable shows the average premium or discount in values of properties within SEB service area compared to the properties beyond it, ceteris paribus.

All the independent variables were introduced in regression models using their raw data unit. Thus, it can be directly interpreted as the premium or discount of affording a house that is marginally improvement in terms of the accessibility. The two HPMs are estimated in linear form as:

$$P_i = c+\beta_{1ij}*S_{ij}+ \beta_{2ij}*L_{ij}+ \beta_{3ij}*N_{ij}+ \beta_{4i}*M_i+ \xi_i \quad (1)$$

where
P_i = the sale price of property i
c = intercept constant term
β= the estimated implicit empirical marginal price for the corresponding property attribute
S_{ij} = the j^{th} attribute of the structure characteristics of the i^{th} property, including number of bedroom, number of bathroom, number of parking, and the property area size
L_{ij} = the j^{th} attribute of the locational characteristics of the i^{th} property, including distance to CBD, distance to school and accessibility to the nearest BRT station (either as a continuous variable as in HPM1, or as a categorical variable as in HPM2)
N_{ij} = the j^{th} attribute of neighbourhood characteristics of the i^{th} property, represented by the SEIFA Index of Relative Socio-economic Advantage and Disadvantage.
M_i = a numeric variable which controls the time of sale for the i^{th} property (Month of the year 2013)
ξ_i = a random error for the i^{th} property

All the regression coefficients of the independent variables are of interest which indicates the extent of impact of each factor to the property value. In particular, the coefficient of the accessibility to the nearest BRT station measures the attribution of BRT offers to the whole house sale value.

Segmented regression model (SRM)

While the HPMs can be used to evaluate the impact of improved accessibility on property values, these models were limited to take into account other factors, such as the impact of increased noise level and pollution on the value of properties in its nearby precinct. In order to test the second hypothesis, a SRM was developed to evaluate the spatial variation of the BRT's impact on the property values. Two breakpoints were set to divide the distance from a property to the BRT corridor into three segments after a number of trial-and-error:

- Within 600 metres from the SEB corridor
- Between 600 and 1600 metres from the SEB corridor
- Beyond 1600 metres from the SEB corridor

As such, the segmented regression model was constructed to examine whether there are differences on the impact of BRT to house prices over varying ranges of distance to the BRT corridor. It is shown as:

$$P_i=c+\beta_{1ij}*S_{ij}+ \beta_{2ij}*L_{ij}+ \beta_{3ij}*N_{ij}+ \beta_{4i}*M_i+ \beta_{5i}*DB_i+ \beta_{6i}*(DB_i- 600)*Dum_1+ \beta_{7i}*(DB_i- 1600)*Dum_2+\beta_{8i}\ Access\_1400m_i+\xi_i \quad (2)$$

where

DB_i= the distance from the i^{th} property to the BRT corridor

Dum_1=1 if DB_i>= 600; 0 otherwise

Dum_2=1 if DB_i>= 1600; 0 otherwise

$Access\_1400m_i$=1 if the distance from the i^{th} property to the nearest BRT station is less than 1400-metre; 0 otherwise.

L_{ij} = the j^{th} attribute of other characteristics of location for i^{th} property, including distance to school and distance to CBD.

P_i, C, S_{ij}, N_{ij}, M_i and ε_i perform as the same function as in equation (1).

Once Dum_1 and Dum_2 are defined by the value range of DB_i, then Equation (2) can be rewritten in its segmented form as:

$$P_i = \begin{cases} P_i = c+\beta_{1ij}*S_{ij}+\beta_{2ij}*L_{ij}+\beta_{3ij}*N_{ij}+\beta_{4i}*M_i+\beta_{5i}*DB_i + \beta_{8i}\, Access\_1400m_i+\varepsilon_i & DB_i<=600 \\ P_i = c+\beta_{1ij}*S_{ij}+\beta_{2ij}*L_{ij}+\beta_{3ij}*N_{ij}+\beta_{4i}*M_i+\beta_{5i}*DB_i + \beta_{6i}*(DB_i-600)^* + \beta_{8i}\, Access\_1400m_i+\varepsilon_i & 600<DB_i<=1600 \\ P_i = c+\beta_{1ij}*S_{ij}+\beta_{2ij}*L_{ij}+\beta_{3ij}*N_{ij}+\beta_{4i}*M_i+\beta_{5i}*DB_i + \beta_{6i}*(DB_i-600)^* + \beta_{7i}*(DB_i-1600)^* + \beta_{8i}\, Access\_1400m_i+\varepsilon_i & DB_i>1600 \end{cases} \quad (3)$$

The coefficients of DB_i indicate the various impact of proximity to BRT corridor for three cases above. Therefore, variation between the impacts can be examined by comparing these coefficients if they are significant at a high significance level. As such, this model is effective to test statistically if the distance to BRT corridor shows different relationships with house prices between three properties groups with different range of distance to BRT corridor. The coefficient of $Access\_1400m_i$ (β_{8i}) tests if there is a difference between properties within the BRT station 1400-metre service catchment and those outside, that is, the impact of accessibility to BRT system holding all else constant. Figure 2 shows the spatial partitioning of study area and corresponding value of variables DB and Access_1400m for a property sales sample in study area.

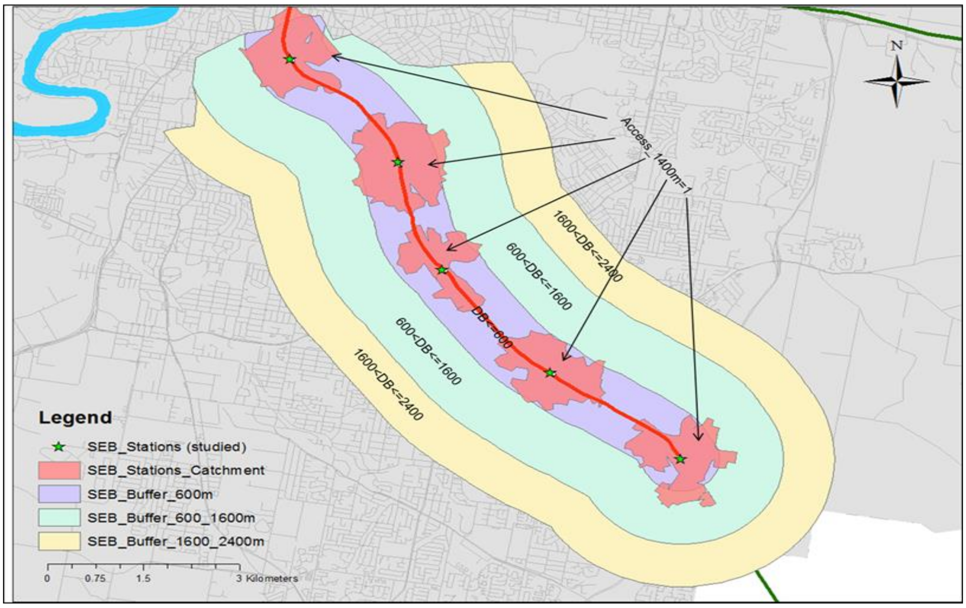

Figure 2: Spatial partitioning of the study area

Results

Results of Hedonic price models

Estimation results from HPM and MRM are presented in table 2.

Table 2: Estimation results of Hedonic Price Models (HPM1 and HPM2)

	HPM1 (*dependent variable:* PRICE)				*HPM2* (*dependent variable:* PRICE)			
	Coefficients	*SE*	*t Statistic*	*VIF*	*Coefficients*	*SE*	*t Statistic*	*VIF*
Intercept	-437621.829	208014.641	-2.104**		-382041.071	196807.150	-1.941*	
Month	5980.690	1339.508	4.465***	1.006	6001.480	1338.439	4.484***	1.007
So_Eco_Status	472.441	194.853	2.425**	1.200	449.990	188.340	2.389**	1.123
Dis_School	-51.768	12.968	-3.992***	1.125	-54.329	13.023	-4.172***	1.136
N_Bedroom	31968.222	6410.603	4.987***	2.012	32427.440	6409.740	5.059***	2.015
N_Bathroom	120865.981	7425.902	16.276***	2.039	120775.428	7419.451	16.278***	2.039
N_Parking	27627.062	4978.793	5.549***	1.206	27764.590	4972.326	5.584***	1.204
Area_Size	194.746	5.113	38.090***	1.028	194.582	5.109	38.085***	1.029
prtype	126250.614	17635.873	7.159***	1.122	121282.683	17683.800	6.858***	1.130
Dis_CBD	-12.880	1.635	-7.879***	1.396	-12.759	1.604	-7.954***	1.346
Dis_Station	11.334	6.024	1.881*	1.264	-	-	-	-
Access_1200m	-	-	-		-30179.523	12580.201	-2.399**	1.129
Adj. R- Square			0.6785				0.6791	
Prob.>F-statistics			0.000				0.000	
Observations			1313				1313	

***p-value<0.01, **p-value<0.05,*p-value<0.10. - Not applicable.

Most of the independent variables in HPM1 and HPM2 are significant at the 5% level with a few significant at the 10% level. Besides, all the variance inflation factors (VIF) are less than 5, showing no strong multicollinearity exists in these two linear regressions. The adjusted R-squared measure indicates that 67.85% of the variation in property sales prices is explained by the independent variables in HPM and 67.91% for HPM2. This is acceptable since it was not possible to take all factors affecting home values into the models. However, the statistically significant variables can still be used to identify their influence on houses prices.

The estimation results of controlling variables (Table1) in HRM1 and HPM2 present minor variation in both coefficients and significant level. Thus, only the results of these variables in HPM2 were used to conduct analysis and interpretation given the better fitting model. Two location-specific characteristics of property, distance to the CBD and distance to the nearest school present positive effects, placing value premiums of AU$ 1,276 and AU$ 5,433 for every 100-metre closer to the house, respectively. The variable Month measuring the house price changes per month show a reasonable upward trend, an approximately growth of AU$ 6,001 per month over the year 2013. Properties value more if located in higher SEIFA scored suburb, for example, an increase of 1 point in SEIFA score results in an increase of property value of AU$ 450. However, the variation of premium value might be minor because suburbs surrounding SEB show limited variation in socio-economic status (Mean of SEIFA score for these suburbs is 1049 while the standard deviation is 25 only). The property structural attribution plays an important role on the house price. Houses are much more expensive than townhouses, showing a premium value of AU$ 121,283, ceteris paribus. For every square metre of area, house prices increase by AU$ 195 on average. It was found that the value of an additional bathroom (AU$ 120,775) is over three times a bedroom (AU$ 32,427) and four times a parking space (AU$ 27,765). This is mainly due to the fact that the number of bathrooms dictates the number of people that can occupy the property comfortably. House-owners benefit more if their property is available to provide more offers for accommodation.

The estimation and interpretation of the coefficients for BRT accessibility is of key interest in this study because they measure the attribution of improved accessibility to the whole house sale value. In HPM1, the coefficient of continuous variable Dis_Station showed that the relationship between the distance to the nearest BRT station and houses sales price is positive and growing as distance from a station increases. On average, every 100-metre closer to a station decreases house prices by AU$ 1,133. While this is not a big discount and is relatively weak (significant level 94%), it can be concluded that our first hypothesis is rejected. The improved accessibility due to SEB did not result in higher property values. Evidence from HPM2 reconfirms our conclusion, the coefficient of dummy variable Access_1200 is significant at a 95% significant level with a negative sign, demonstrating that houses within 1,200-metre catchment of SEB stations, on average, show value discounts of about AU$ 30,180 compared to those beyond.

Results of segmented regression model

Table 3 shows the estimation results of the SRM, which was used to further explore the mixed effects of SEB on property values. In this study, the straight-line distance from property to SEB right-of-way was used as an indicator of the magnitude of potential negative impact on housing price and within 1,400-metre network distance to a SEB station was defined as a controlling variable of immediate proximity.

Table 3 Estimation results of segmented regression model (SRM) (dependent variable: PRICE)

	Coefficients	*SE*	*t Statistic*
Intercept	-413824.197	206629.556	-2.003**
Month	6239.812	1336.415	4.669***
So_Eco_Status	379.115	195.294	1.941*
Dis_School	-37.452	13.400	-2.795***
N_Bedroom	32053.617	6382.637	5.022***
N_Bathroom	120205.975	7395.239	16.255***
N_Parking	27963.786	4962.092	5.635***
Area_Size	194.977	5.092	38.295***
prtype	114218.496	17749.170	6.435***
Dis_CBD	-12.792	1.651	-7.749***
Dis_Busway	144.374	45.321	3.186***
Dis_Busway _600m	-115.018	56.133	-2.049**
Dis_Busway _1600m	-69.326	39.940	-1.736*
Access_1400m	26746.923	15665.614	1.707*
Adj. R- Square			0.6847
Prob.>F-statistics			0.000
Observations			1313

***p-value<0.01, **p-value<0.05,*p-value<0.10.

The adjusted R Square statistic is improved to 68.47, indicating a better goodness-of-fit than HPMs. Since estimation of other controlling variables in segmented regression model shows few variations with HPMs, no more interpretation was conduct in this regard. According to function (3), the coefficients of variable DB were calculated for each sub-equation, they are: 144.374, when DB<=600; 29.356(144.374-115.018), when 600<DB<=1600; -39.970 (144.374-115.018-69.326), when DB<=1600. All of them are significant at a high significance level with only the last one has a relatively lower significance level (92%). As such, our second hypothesis is accepted since SRM suggested that impacts of SEB on house price shows uneven results spatially. Figure 3 graphs the property sales price from the estimates. The values represent a residential property with all other controlling variables set to its median values, while changing the distance to the SEB corridor (DB) and the accessibility to SEB stations (Access_1400m).

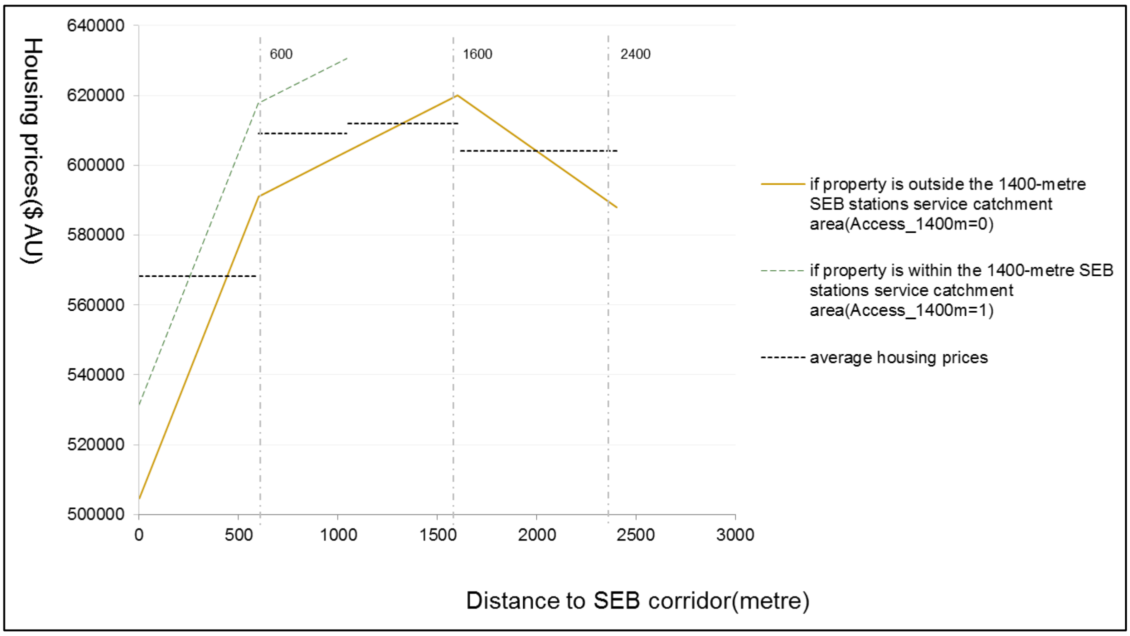

Figure 3: Network effects: estimated the relationship between the distance to SEB corridor (DB) and housing prices

The variable controlling for the benefits of immediately access to SEB stations (Access_1400m) is significant at 90% significance level in this model. It reveals, holding all else being equal, including the distance to SEB corridor, immediate proximity to SEB stations service places a premium of AU$ 26,747 on property value (shown by the green dashed line). Average housing price was calculated and plotted by black dashed line.

The yellow solid line in Figure 3 provides a good indicator of the relationship between distance to SEB corridor and housing prices (set value of variable Access_1400m as 0). Holding all else being equal, proximity to SEB results in a strong discount on property value within a 600-metre buffer of the SEB corridor. For example, every metre moving towards the SEB decreases the house price by AU$ 144. This discount is mainly associated with the negative effect of disamenities such as noise, pollution and vibrating. When distance to SEB ranges from 600-metre to 1,600-metre, the magnitude of negative effect falls sharply. The discount of house price is only AU$ 29 for one metre closer. When the distance from property to SEB is beyond 1,600-metre but less than 2,400-metre, as distance to SEB corridor increases, the housing prices decrease by AU$ 40. This result is diametrically opposed to the two cases above. Rather, it appears that properties do not suffer from the negative environmental pollution. As a result, moving away from SEB right-of-way will lead to significant drop in accessibility which decreases the property values. Hence, it was clear that value of residential property reaches the peak when the distance to SEB corridor is around 1,600 metres, whereas beyond this point, housing prices appear to fall due to decrease in accessibility, *ceteris paribus*.

Discussion

Using this method, the BRT's "capitalization benefits", which has been suggested by the literature, was not detected in the case of SEB. This suggests that people are not paying more for houses that are immediately proximate to SEB stations. Conversely, residential properties are valued less if close to SEB stations. However, this is not the only evidence that reveals that BRT has a negative impact on surrounding residential housing prices. Our findings concur with Cervero and Duncan (2002) who also found that residential properties near BRT stops generally sold for less in the case of Los Angeles County. The authors found that many transit stops in the County were located within redevelopment districts. However, this is not the case in Brisbane. A number of factors could be attributed to the findings in Brisbane. Firstly, unlike other cities in the developing countries, the overall share of bus mode in Australia's major cities is low and only equates to about five per cent of all trips while the mode share of the private car is around 86% (Cosgrove, 2011). Thus, proximity to public transport may not act as an important factor influencing people's property-purchasing behaviour and therefore, housing price in Brisbane. Second, tyre-based transit service is usually associated with undesirable perception of noise and pollution (Hecker, 2003). The situation tends to be worse because SEB was constructed adjacent to a Motorway (M3). This may further reduce the desirability to reside adjacent to it since the freeway corridor considerably reduced the walking catchment and acts to dilute the quality of the environments around the bus stations (Currie, 2006). Furthermore, the effects of SEB on property values can be beneficial due to close proximity and increased accessibility to SEB, but it can also result in a higher level of noise and other environmental pollutions. Thus, a better living environment can be preferable than the improvement in accessibility to SEB.

The SRM highlighted the spatial changes in the impact of SEB on housing prices: a positive effect of access to SEB stations but a more substantial negative effect of immediate proximity to SEB corridor. The value of residential property reaches the peak when the distance to SEB corridor is around 1,600-metre, whereas beyond this point, housing prices appear to fall due to decreases in accessibility, *ceteris paribus*. This means that, to some extent, the SEB pubic transport service is attractive for residents within 1,600-metre buffer of the SEB corridor and this transport advantage has been capitalised into property values. The capitalisation benefits are more significant for properties with better access to SEB station but insulated from the potential pollution generated by SEB operation. This was evidenced in the SRM where properties are most valuable in local real estate market when the distance to SEB corridor is from 600 to 1,600 metres and within 1,400- metre network distance to a SEB station. Such results concur with the findings of another Brisbane-based study that examines the changes of travel patterns (Tao et al., 2013). They detected bus shares increases at the 1,600-metre and the 3,000-metre catchment areas of Brisbane's BRT stations over the decade of operation (note that in this study, for all samples within 1600-metre buffer of SEB, the farthest distance to the a SEB station is within 3,000-metre). The Park-and-Ride services available in some of the SEB stations and the convenient feed-line services might contribute to a widen catchment area of the SEB, which determines the size of the SEB accessibility benefits that are delivered to the property market catchments.

The strong association between the distance to the SEB corridor and housing prices suggests the existence of the negative externalities of BRT, perceived as a main disadvantage by some decision-makers and transit officials (Hecker, 2003). However, when understanding SEB's proximity-related negative externalities, attentions should be paid to its locational characteristics, adjacency to a highway, which was considered as an obstacle for transit oriented development as well as a catalyst for worse quality of its surrounding environment (Currie, 2006). Nonetheless, it is important to design the BRT station in consideration of its adjacent urban development (Currie, 2006). A good example is BRT development in Guangzhou, China, where the well-designed combination of high-quality BRT services and pedestrian connections to stations has attracted high-rise commercial development towards the BRT corridor, which significantly contributed to the land value uplift of 30 percent during the first two years of BRT operations (Suzuki et al., 2013).

A number of factors may have affected the results in this study, suggesting possible extensions for future research. First, accessibility on the two sides of the SEB and M3 varies. SEB was constructed along the M3 on the eastern side. Thus, properties located on the east of SEB can access more easily to SEB stations, while for properties on the west the presence of M3 becomes a barrier to enter the SEB. Besides, properties on the eastern side of the SEB suffer less from the transportation pollution given that the SEB has partly reduced the negative environmental impacts by the M3. Therefore, it is necessary to explore further the variation of land values on the two sides of the SEB. Second, the typological features of stations may lead to variation in accessibility, implying different ability of the stations to uplift property values in the surrounding area. For example, sole-function stations are accessible by bus services only, while multi-function stations are able to be accessed by all type of transportation. In addition, Park-and-Ride service is available in some stations but not all. Third, properties proximate to the SEB feeder line stations might also have significant accessibility advantages over others, which was not considered in this study. Future research is called for to further analyse the spatial variations of SEB's impact on property values and the value of accessibility to its feeder line stations.

Conclusion

This paper presents some preliminary analysis of the impact of the SEB on residential property values in Brisbane, Australia. Classic Hedonic Price models used in this study indicate a negative impact of SEB on housing prices if close to SEB stations. A segmented regression model was constructed to evaluate the spatial change of the impact of the SEB on housing prices, and the results reveal a positive effect of access to SEB stations but a more substantial negative effect of immediate proximity to SEB corridor. In this case, the strong association between the distance to the SEB corridor and housing prices seems to suggest the proximity-related negative externalities of BRT, perceived as a main disadvantage of tyre-based transit. However, it was worth noting that the locational characteristics of SEB and its adjacency to a highway might have significantly strengthened the strong negative proximity-effect and limited its ability to uplift land values.

Several limitations need to be noted in this study such as data limitations and the inherent weakness of the research methods. One data limitation lies in the omitted factors such as school districts, flood risk and so on that may impact on the housing prices. Another is the limitation of residential property observations since existing literatures has shown a potential association between the property type and the appreciation effect of improved accessibility to public transport (Debrezion *et al.*, 2007).With regard to the methodology, the ignorance of spatial autocorrelation may introduce potential bias in this result and as is an inherent weakness in other cross-sectional studies, the snap nature of residential houses sale data used in this study does not provide a good basis for establishing causality.

While the results presented in this paper are valid only for the SEB, they are still of significance to develop a better understanding of the overall effects of BRT on property values. As further expansions of BRT networks are planned in Brisbane and across Australia, the findings of this study have the potential to be used by other Australian cities and help urban planner better plan for BRT development.

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