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Effects of bus transit-oriented development (BTOD) on single-family property value in Seattle metropolitan area

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Abstract

Transit-Oriented Development (TOD) is considered to be a powerful model intended to achieve sustainable urban development. A well-designed TOD enhances the accessibility of different kinds of activities, reduces transportation costs and improves the comfort and safety of travel for the neighbourhood as whole, thereby increasing the willingness to pay for real estate properties located nearby. This study examines the housing price premiums of bus transit-oriented development (BTOD), a particular type of TOD that has become quite common in practice, especially in cities where public transportation is provided primarily through a bus system instead of a metro or light rail system. BTOD projects are built at major nodes of a bus network and typically include housing units and commercial services. Our research focuses on four completed BTODs in the Seattle metropolitan area, and employs data on sales prices, physical attributes, neighbourhood characteristics and location features for almost 7000 single-family homes located within a 1.5-mile radius. Using Hedonic price analysis, we find that these BTODs have generated significant positive effects on the values of adjacent homes, especially those located within 0.5 miles. Results from a more sophisticated longitudinal analysis using the data for Renton, one of the BTODs, confirm the price premiums while gaining additional insights about the temporal variations. These findings have an important policy implication, which is especially relevant for cities with an extensive bus transit system: local governments can generate additional tax revenues while advancing sustainability through bus transit-oriented developments.

Keywords

Bus Transit-Oriented Development (BTOD), planning, property value, transport

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摘要
公交导向式开发 (TOD) 被认为是旨在实现城市可持续发展的一种强大模式。精心设计的 TOD 增强了各种活动的可及性，降低了交通成本，提高了整个街区的出行舒适度和安全性，从而增加了人们对附近房地产的支付意愿。本研究考察了公共汽车导向式开发 (BTOD) 带来的住房溢价。BTOD 是特定类型的 TOD，在现实中已经变得相当普遍，特别是在主要通过公共汽车系统而不是地铁或轻轨系统提供公共交通的城市。 BTOD 项目建在公交车网络的主要节点上，通常包括住房单元和商业服务。我们的研究重点是西雅图大都会地区四个完整的 BTOD，并运用了距离 1.5 英里半径范围内的近 7,000 家单户住宅的销售价格、物理属性、街区特征和位置特征数据。我们使用特征价格分析，发现这些 BTOD 对周边房屋的价值产生了显著的积极影响，特别是位于 0.5 英里距离内的房屋。通过使用其中一个 BTOD 项目 Renton 的数据进行更精细的纵向分析，结果确认了溢价，同时获得了关于时间性变化的更多洞见。这些发现具有重要的政策意义，这对于拥有广泛的公共汽车交通系统的城市尤为重要：地方政府可以通过公共汽车导向式开发推动可持续发展，从而增加税收。

关键词
公共汽车导向式开发 (BTOD)、规划、房产价值、交通

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Introduction

A major challenge facing American cities for the last half a century has been the combination of increasing dependence on the automobile and the declining efficiency of public transportation. As an indication of the adversity experienced by public transportation, state and local expenditures on public transportation rose from US$3.2 billion in the mid-1970s to US$22.8 billion in the early-2000s, while the annual passenger volume only rose from 8.0 billion to 9.5 billion during this time period (Hanson and Giuliano, 2004). Solving the transportation problem is not simple, because it involves many issues that are most effectively addressed by taking diverse approaches (Meyer and Miller, 2001). Transit-oriented development (TOD), which is commonly characterised as a compact, mixed-use development near major transit facilities with a high-quality walking environment, is a highly promising approach that can generate many positive effects (Calthorpe, 1993; Cervero, 2004). From 2004 to 2014, the Federal Transit Administration (FTA) allocated US$18.9 billion to build new or expanded transit systems which involve an important goal of promoting TOD through the Capital Investment Grant program (Office USGA, 2014).

Promoters of TOD argue that this model of urban development can improve transportation systems, increase transit ridership, reduce emissions and provide more residents with good housing and services (Calthorpe, 1993; Cervero, 2004). The benefit of convenient access to various kinds of activities is expected to become capitalised into the market value of real estate properties. The increases in land value due to TOD-related public investment in infrastructure and changes in land use regulations can generate additional revenues that could be used to finance more TOD projects, and thus create a virtuous cycle (Suzuki et al., 2015). Moreover, increasing land value may attract more commercial and service activities in the station areas, thus further enhancing land value and economic vibrancy.

A distinctive type of TOD is based on transit service provided by regular buses, instead of rail transit or bus rapid transit (BRT). Such a TOD is typically centred on a transit centre, which is a major node in the bus network and exhibits some other common TOD features such as high-density development, mixed-use development that includes housing, retail and other services and facilities for walking and biking. We call this type of TOD 'bus transit-oriented development' (BTOD) for the convenience of description. BTOD is a significant component of transit-oriented development; Cervero (2004) noted that 7.8% of TODs in the US were bus transit-based. The presence of BTOD will undoubtedly continue to rise in the future because, for most cities, it would be inefficient to build a metro or light rail system (Small and Verhoef, 2007); instead, public transportation will be provided primarily through a bus transit system, and major nodes of bus service will be where most future opportunities for transit-oriented development are found.

While BTOD is becoming increasingly common in practice, it has not attracted sufficient attention from researchers. Therefore, the objective of this research is to fill a significant gap in the TOD literature by taking a concrete step towards understanding the economic benefits of BTOD. Focusing on its effects on residential property value, this article is expected to create new knowledge about, as well as inform the practice of, this type of transit-oriented development.

The empirical analysis is based on case examples in King County, WA, which is part of the Seattle metropolitan area. King County has completed four BTOD projects, each having a transit centre as the fundamental component, coupled with relatively high-density residential development, mixed land use including multi-family housing, retail stores and services and facilities for pedestrians and bicyclists (KCDOT, 2013b). The transit service is provided by regular buses. Examining the resulting price premiums for single-family properties, the results will indicate the potentials for residential value capitalisation created by BTOD. They can shed new light on BTOD as a possible source of property value creation and tax revenue generation, as well as an approach to sustainable urban development.

Literature review

Classical economics theory proposed that the value of urban land is a function of its location. The Von Thunen Model, developed almost 200 years ago, illustrates how transportation savings determine bid rent and explains why land prices are higher in some locations than in others (Von Thünen, 1966). The more recently developed Alonso Model (Alonso, 1964), an updated and expanded version of the classical model of land allocation, reinforces the understanding of the relationship between transportation and land value in the context of the contemporary city. Both models can be used to show that TOD enhances accessibility, reduces transportation cost and hence can increase the values and prices of properties located nearby.

Conceptually, the price effects of TOD on surrounding real estate properties consist of several parts:

First, the introduction of transit service into the neighbourhood increases travel options for residents and employees in the area and reduces travel costs for trips to the central business district (CBD) and other activity centres (Fejarang, 1993). The transportation accessibility improvement translates into land values.

Second, the mixed land use associated with TOD enhances local access to different kinds of daily activities, such as shopping, schools and parks and recreation. The increased proximity to these activities results in shorter travel distances, lower vehicle trip rates and fewer total vehicle miles (Ewing and Cervero, 2010). The mixed-use advantage is capitalised into land values.

Third, the pedestrian friendly design typically incorporated into TOD may be attractive to many home buyers. Houses located on interconnected streets and smaller blocks are more likely to command a premium than houses on cul-de-sac streets and large blocks (Bartholomew and Ewing, 2011).

Fourth, better transit service and other desirable features associated with TOD can attract more people, as well as new investments and businesses. The resulting employment growth and economic vibrancy in the local area will spur land values. However, this effect may be largely redistributive, since the relative gains in TOD areas typically come with relative losses for other areas (Cervero, 2004).

Fifth, increased accessibility and the subsequent higher land value will likely lead to higher development intensity in the form of increased floor area ratios for both residential and non-residential buildings. This effect, known as factor substitution, tends to reinforce the land value premiums.

Most published studies show that adjacency to transit, the most fundamental feature of TOD, has significant positive effects on residential property value (Cervero and Duncan, 2002; Cervero and Kang, 2011; Gibbons and Machin, 2005; Kay et al., 2014; Ma et al., 2014; McDonald and Osuji, 1995; Mathur and Ferrell, 2013; Rodriguez and Mojica, 2009; Seo et al., 2014; Wang et al., 2015). Since researchers employ different regression models, the estimates often are not easy to compare. In general, using otherwise comparable housing units located far from metro or BRT stations as the control group, these studies indicate that the premiums for properties located 1/8 to 1/2 mile from the transit range from 3.5 percent to 25 percent.

However, some studies find no significant positive relationship, or even a negative relationship, between proximity to transit and property value (Andersson et al., 2010; Bowes and Ihlanfeldt, 2001; Yan et al., 2012). A number of empirical analyses identify more complex patterns of impact created by proximity to transit in the United States, as well as in Europe, China and Latin America. A recent article based on housing transaction data in Los Angeles shows that proximity to rail transit stations generally increases multi-family property values, but the effect is the opposite for single-family properties (Zhong and Li, 2016). Similarly, complexities of impact are reported from Portugal, China and Columbia. A study conducted in the Lisbon metropolitan area found an overall premium of the metro proximity on property values, but a negative impact for proximity to some rail lines (Martínez and Viegas, 2009). In a recent study on the Beijing-Shanghai line of China's high-speed railway (HSR), Chen and Haynes (2015) found that proximity to HSR leads to an increase in the market price of real estate properties in non-provincial capital cities, but the effect is reversed in provincial capital cities. Two articles on Bogotá report that middle-income properties are valued more if located closer to the BRT system, while low-income housing bears the opposite price effect, and high-income residences show no significant price effect (Bocarejo et al., 2013; Munoz-Raskin, 2010).

While most researchers focus on how transit accessibility affects property value, some also investigate the effects of other TOD features, such as mixed land use and pedestrian-friendly design. For example, a study of TODs in Portland, Oregon finds that home buyers are willing to pay a premium for houses in neighbourhoods containing interconnected streets and smaller blocks (Song and Knaap, 2003). Results from another study, conducted by Duncan

(2011), suggest that an increase in street intersection density will augment the positive value of transit proximity. However, there are also publications reporting contrary findings. For example, a case study conducted in Taiwan shows that larger lot size is associated with higher housing price nearby (Andersson et al., 2010).

An interesting result reported by Duncan (2011) is that more people-servicing commercial activity in TOD area is related to higher value of transit proximity. It suggests that other TOD features, including mixed land use and pedestrian-friendly design, also play a role in determining the direction and magnitude of the impact on property values.

Existing studies also find that TODs relying on different types of transit service generate different housing price premiums. Regional commuter rail has been shown to command a higher premium (US$25 per square footage) than light rail (US$4 per square footage) (Cervero and Duncan, 2002). Ma, Ye and Titheridge (2014) report a price premium of about 5 percent for properties located near rail transit stations, but detect no statistically significant price difference for properties in BRT station areas. Among the publications reviewed for this research, only one examines the effect of bus transit, finding a modest increase in land values resulting from adding an extra bus stop within walking distance (Wang et al., 2015). Research on TODs located at major nodes of a regular bus network, i.e. BTOD, is generally lacking, and hence their impact on property value is largely unknown.

Research questions and study areas

This study aims to address the following two questions:

(1) What are the effects of BTODs on the market values of single-family residential properties located nearby?

(2) How do the price premiums of BTODs change over time?

The study areas are the four completed BTODs in King County located at, respectively, Overlake Transit Centre, Renton Transit Centre, Redmond Transit Centre and Northgate Transit Centre. These BTOD projects are in quite different locations within the Seattle metropolitan area (Figure 1).

The Overlake Transit Centre BTOD was opened in 2001. Currently, there are 12 transit lines serving this station. A multi-family project, named The Village at Overlake, is located right near the station. This apartment has 308 affordable housing units, 536 park-and-ride spaces and 30 barrier-free and wheelchair-accessible housing units (KCDOT, 2013c). All housing units at this apartment are affordable for households earning up to 60 percent of the area median income (US$35,000–40,000 per year). It is a joint development project between King County, the King County Housing Authority and a private developer.

Renton Transit Centre was opened in 1996 and was marked as a pilot TOD project right afterwards. Fifteen transit lines serve this centre, linking Renton with Seattle downtown and other employment centres in the region. The BTOD took almost a decade to complete the components, including multi-family buildings, open spaces, street-level commercial space and park-and-ride spaces (KCDOT, 2010). The three mixed-use multi-family projects built by a private developer near the Renton Transit Centre have over 250 affordable units and 15,000 square feet of street-level retail space. The BTOD is a joint development project of the City of Renton, King County Metro and private companies.

The Redmond Transit Centre BTOD was opened in 2008. Currently, nine transit lines serve this station, providing connections to

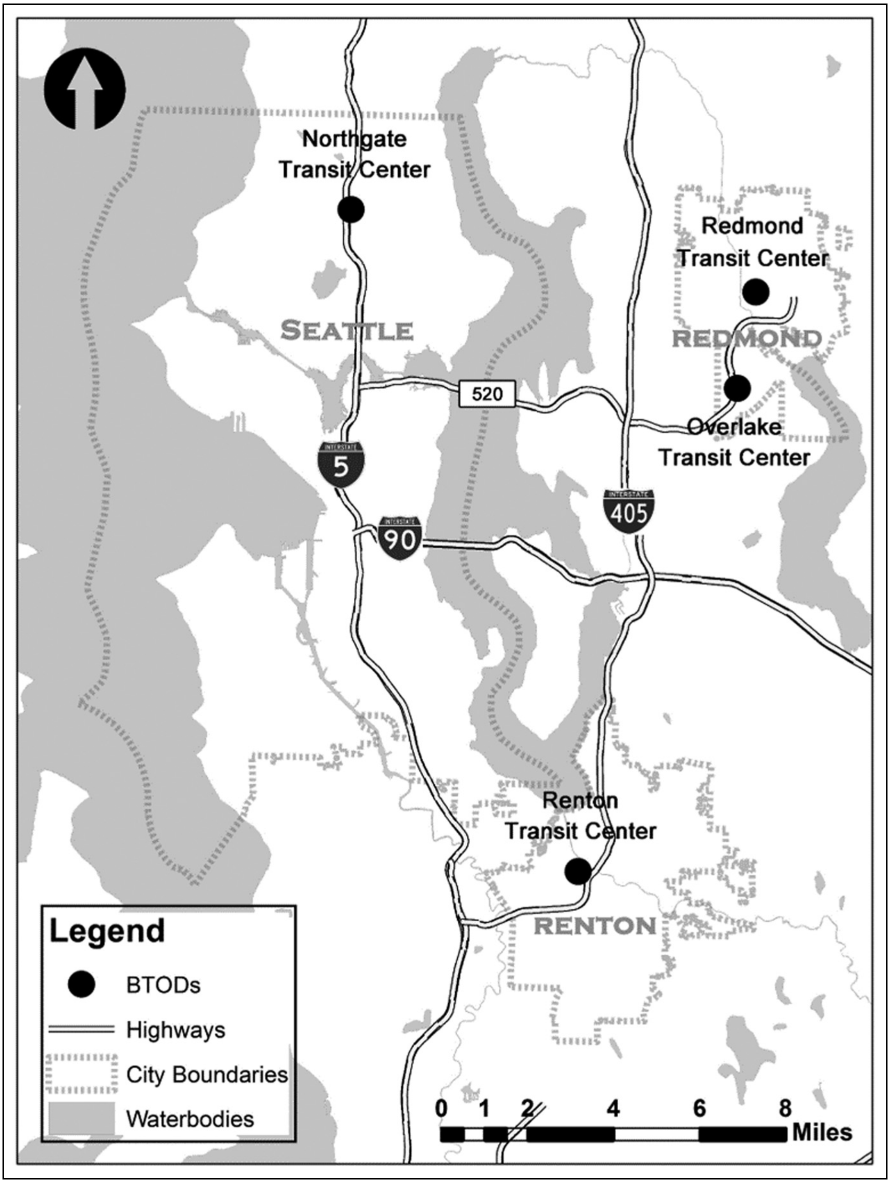

Figure 1. Bus transit-oriented development (BTODs) in King County, Seattle Metropolitan Area.

major job locations in the metropolitan region. This BTOD project has a 332-unit multi-family mixed-use building located near the transit centre. It also has street level retail and two levels of parking. Several other affordable apartments surround the transit centre. Other TOD elements include streetscape design, pedestrian-friendly design and park-and-ride lots (KCDOT, 2013a). This project was jointly developed by the King County Department of Transportation, the City of Redmond and Sound Transit.

The Northgate Transit Centre was opened in 1992, and a year later a Comprehensive Plan was adopted to guide a TOD project.[1] The transit centre currently has 14 transit lines and about 300 parking spaces. A mixed-used multi-family building, which was completed in 2009, has 338 apartment units (including both low-income and market-rate apartments). The BTOD also provides 30,000 square feet of pedestrian-oriented retail space, a 14-screen cinema, a 20,000 square foot neighbourhood clinic, a 2.9 acre senior housing development and 925 underground parking stalls shared by residents and the cinema, retail and park-and-ride customers.

Methodology and data

The Hedonic price model, initially proposed by Rosen (1974), is the most commonly used method to analyse the effect of a relevant attribute on housing price. In this study, a linear function is specified for the regression model, and the estimated coefficients measure the amount of change in the dependent variable associated with a one-unit change in each of the independent variables. To answer the two research questions stated in the previous section, a cross-sectional analysis with pooled data for all four BTODs and a longitudinal analysis with data for a selected BTOD are performed.

The spatial dependence diagnostics were conducted to check whether spatial autocorrelation exists. This test is important because the presence of spatial autocorrelation is likely to bias the model results. Lagrange Multiplier (LM) and Robust LM diagnostics were used to provide guidance on model selection (Anselin and Rey, 1991). For the cross-sectional pooled analysis and longitudinal study, both LM-LAG and LM-ERROR statistics are significant at the 1% significant level, indicating the presence of spatial dependence. We thus estimated and compared spatial lag models and spatial error models, and found that the spatial lag models show better goodness-of-fit, with higher log likelihood and lower Akaike info criterion (AIC). Thus, the spatial lag model was finally chosen for this analysis.

Cross-sectional pooled analysis

In order to answer the first research question, a cross-sectional pooled analysis of the four completed BTOD projects is performed by estimating the following spatial lagged Hedonic regression model:

$$P = \rho w_P + c_0 + \sum \alpha_i A_i + \sum \beta_j B_j + \sum \mu_k U_k + \sum v_l V_l + \varepsilon \qquad (1)$$

Where: P is the inflated sales price for single family property located within 1.5 miles of a transit centre;[2] A_i are the physical characteristics of the property; B_j are the measures of TOD characteristics, including distance to the corresponding transit centre and measures of land use mixture and walkability; U_k are the other locational variables; V_l are the neighbourhood socio-economic characteristics that may generate neighbourhood effects on property value; ρ is the spatial autoregressive coefficient; w_P is the vector of spatial lags for the dependent variable P; ε is the error term; and c_0 is a constant. Only transactions after the year in which the corresponding transit centre opened are included in this Hedonic model, to capture the actual effects of BTOD on surrounding residential property values.

The dependent variable, the inflated sales price, is measured based on the recorded transaction price obtained from the King County Assessor's office. Transaction prices are inflated to dollar values in 2015 using the annual S&P/Case-Shiller Seattle Home Price Index.

The physical characteristics variables included in the model are lot size, total finished area above ground, total basement area, number of bedrooms, number of bathrooms, number of fireplaces, age of the house and building condition that measures the condition of the home with a 1–5 score (from lowest to highest). These data items are included in the residential building records maintained by the King County Assessor's office.

The TOD characteristics variables include proximity to the transit centre of the BTOD, land use mixture and pedestrian-oriented design. Proximity to the transit centre is measured in two alternative ways: first, as a continuous variable of distance to the transit centre, assuming the effect of the BTOD on housing price is a linear function of the distance (Model 1); and second, as a series of dummy variables of threshold distances to the transit centre, assuming the effect does not follow a linear function of the distance (Model 2). We apply both measures in our study by estimating two regression models, each with one of these two alternative measures of proximity to BTOD. For the regression with dummy distance variables, we adopt commonly used threshold distances to divide all observations into three groups: located within 0.5 mile from transit station (*Dummy_distance1*), located 0.5–1 mile from transit station (*Dummy_distance2*) and located 1–1.5 mile from transit station (reference group, with little accessibility benefit from BTOD).

Land use mixture is measured using the entropy index equation, expressed as follows:

$$Land\,use\,mixture = \frac{-\Sigma\left(L_{ij}\ln L_{ij}\right)}{\ln N_j} \qquad (2)$$

Where L_{ij} is the percent of area j allocated to land use type i, and N_j is the number of land use types in area j. In this study, j is the area within a 0.25 mile radius of each property, and N_j includes six land use types: single-family, multi-family, commercial, office, institutional and parks and recreation.[3] Entropy scores calculated using equation (2) vary from 0 (when land use is maximally homogeneous) to 1 (when land use is maximally mixed) (Frank et al., 2004, 2006). In addition to land use mixture, distance to the nearest commercial land is included in the models to assess whether proximity to commercial service creates housing price premiums.

Pedestrian-oriented design is measured by length of walkable roads within a range to each observation in this study, and walk score from WALKSCORE.COM. For length of walkable roads, we define the range as a 0.25-mile radius of each property. The walkable roads are included in the County's Transportation Network data file except for highways, expressways, freeways, ramps and other non-walkable roads. The length of walkable roads within a quarter mile radius in which a house is located is a key determinant of its walkability. The Walk Score measures the walkability of all the observed properties based on the walking route distance to amenities in various categories (such as groceries, restaurants, coffee shops, banks and schools) using a decay function. It also measures intersection density, block density and population density with a total score of 100 showing the highest walk score (Walk Score, 2017).

The third group of independent variables measures other location characteristics of each sampled property. These variables include distance to CBD (downtown Seattle), distance to highway, distance to nearest lake, distance to nearest river, distance to nearest park, number of bus stops (except the BTODs) within a quarter mile radius of each observation, a dummy variable indicating whether or not the property has a view of a lake, river, mountain or city skyline and a dummy variable capturing whether or not the property has detected major traffic noise. The distances are quantified in ArcGIS using Geospatial data from the King County GIS Centre. The number of bus stops is calculated in ArcGIS using Geospatial data from the King County Metro and Sound Transit. View and Traffic noise data are obtained from the King County Assessor's office; the dummy variables are assigned '1' if a view and major traffic noise are present for a sampled property.

The neighbourhood socio-economic characteristics constitute the last group of independent variables. This study uses the percentage of white residents at block level and median household income at block group level as proxies of factors that may generate neighbourhood effects on property value. Both variables are based on the latest Census. An additional important neighbourhood variable is school quality, using data obtained from GREATSCHOOL.org which rates K-12 public schools based on student achievement, student growth and test scores on a 1–10 scale (from lowest to highest); the variable was calculated by a weighted sum model as follows:

$$School\,Quality = \sum_{i=1}^{n} R_i d_i \qquad (3)$$

Where n is the number of schools located within a 1.5 mile distance to each property and R_i is the GreatSchool rate for ith school. d_i is a distance score for ith school calculated by a linear distance decay function with 10 to 1 (10 is those located within 0.2 mile of observations, and 1 is those located within 1.5 mile of observations).

Longitudinal case study

In order to answer the second question, a longitudinal case study of the Renton BTOD was conducted. Renton is a city in King County, with a population in 2010 of 90,927. It is located 11 miles southeast of downtown Seattle, at the southeast shore of Lake Washington and the mouth of the Cedar River. It is home to many large manufacturing companies, including Boeing, which has been the most important employer in Renton since the Second World War. A timeline for the Renton bus transit-oriented development is as follows (KCDOT, 2010):

1995: Renton's first Comprehensive Plan adopted, which zoned the area of the Renton Transit Centre into mixed-use designation.
1996: Renton Transit Centre opened. Private companies recruited to support mixed-use development around station area.
1997: Renton Transit Centre marked as a location for a pilot BTOD project.
1999: Renaissance Place, the first 110-unit multifamily complex completed. King County and Dally Homes reached an agreement of joint development of the BTOD project.
2000: Renton Piazza, a plaza adjacent to the transit centre, completed. Renton Pavilion Centre, another commercial service project near transit centre, completed.
2001: Renton Transit Centre expanded and renovated to include additional transportation facilities as joint-development projects of King County Metro Transit and City of Renton. The second multifamily project, a 55-unit apartment complex, built near the transit centre. Meanwhile, a private developer decided to develop Metropolitan Place, a project with 90 apartments above a two-story garage containing 240 parking stalls, which are partly for park-and-ride users. King County Metro Transit and the developer also agreed on goals of park-and-ride capacity and mixed-use affordable housing.
2002: The newly expanded transit centre opened, and the 90 apartments of Metropolitan Place opened shortly after. In the same year, 4000 square feet of street-level retail space built into the northwest corner of Metropolitan Place.

2004: A freestanding city parking garage with 250 park-and-ride spaces built next to the transit centre.

In sum, the bus transit-oriented development in the Renton Transit Centre has an explicit timeline, and therefore can be used for a longitudinal analysis. The years before 1996 are defined as before-BTOD, the years from 1996 to 2005 as during-BTOD construction, and the years after 2005 as post-BTOD. The temporal dimension is incorporated into our Hedonic analysis in two ways. In the first set of longitudinal models (Models 3 and 4), temporal dummy variables are created to represent the years of transaction, and thus capture sales price variations among different years. To have enough observations for each time period, every dummy variable is for two consecutive years. The temporal distribution of the sampled transactions for Renton is shown in Table 1. The period of 2004 and 2005 has the largest sample size, and is treated as the reference group for the regression analysis.

In the second set of longitudinal models (Models 5, 6 and 7), Hedonic price analysis is performed for each of the three time periods separately, and results compared. The underlying assumption of this before-during-after analysis is that the housing price effects of the TOD characteristics have been changing over time. Conceptually, the effects did not exist before the BTOD was initiated in 1996. These models may provide more statistical evidence of causality that cannot be obtained by cross-sectional study.

Table 2 displays the descriptive statistics of the variables used in the models. Means and standard deviations are provided for interval and ratio variables; proportions of cases that are equal to '1' are presented for dummy variables. The sample for the cross-sectional pooled analysis of all four BTODs consists of 6877 records of valid transactions after the corresponding BTOD started.[4] The sample for the longitudinal analysis of the Renton BTOD contains 1238 valid records of transactions, all within the time span from 1990 to 2015 for which the S&P/Case-Shiller Seattle Home Price Index is available. For physical characteristics and TOD characteristics, the basic statistics of the pooled data are mostly similar to those of the Renton case. However, they are quite different in sales price, other location characteristics and neighbourhood socio-economic characteristics. Sampled single-family homes in Renton on average have much lower sales prices, are located closer to highways and parks but farther from rivers and lakes, and are located in neighbourhoods with relatively higher racial diversity, lower median household income and lower school quality. Also noted is that CBD distance is not included in the longitudinal models, because the sampled properties in Renton have very similar distances to CBD and these small variations are not meaningful.

The Pearson correlation matrix revealed that most coefficients between the independent variables are below 0.3. Only one correlation coefficient is above 0.7 in absolute value, which is between distance to CBD and walk score. This high correlation probably reflects the fact that Walk Score is higher for locations with good sidewalks, denser streets and shorter distances to shops, restaurants, banks and recreational activities, and that such locations tend to be close to the CBD. Walk score is also quite highly correlated with distance to commercial land, with a coefficient of −0.63. In general, multicollinearity does not present a serious problem in our data.

Results

Results of the cross-sectional pooled analysis

The results of two cross-sectional pool models are presented in Table 3. The adjusted R-squares show that both Model 1 and Model 2 explain over 65% of variation in

Table 1. Temporal distribution of sampled transactions for Renton.

Year	Before-TOD	Year	During-TOD	Year	After-TOD
	Sample size		Sample size		Sample size
1990–1991	36	1996–1997	75	2006–2007	116
1992–1993	77	1998–1999	113	2008–2009	66
1994–1995	83	2000–2001	98	2010–2011	68
		2002–2003	148	2012–2013	86
		2004–2005	**226**	2014–2015	46

Table 2. Descriptive statistics of variables.

	Cross-Sectional Pooled Analysis		Longitudinal Case Study	
	Mean or Proportion	Std. Deviation	Mean or Proportion	Std. Deviation
Dependent Variable				
Inflated Sales Price	458,997.18	195,289.92	339,751.47	128,397.84
Physical Characteristics				
Lot Size (Sqft)	7559.77	6002.73	7570.08	4806.73
Total Finished Area (Sqft)	1546.91	648.53	1665.20	705.12
Total Basement Area (Sqft)	598.77	530.89	464.89	554.81
Number of Bedrooms	3.27	0.93	3.34	0.87
Number of Bathrooms	1.86	0.72	1.93	0.74
Number of Fireplaces	1.15	0.67	0.98	0.71
Age (Year)	59.07	28.07	47.30	31.73
Condition	3.49	0.67	3.32	0.56
TOD Characteristics				
Transit Centre Distance (Feet)	5657.71	1624.20	5570.01	1823.57
Dummy_Distance1 (<0.5 Mile)	0.05		0.10	
Dummy_Distance2 (0.5–1.0 Mile)	0.32		0.28	
Land Use Mixture	0.43	0.20	0.51	0.23
Commercial Land Distance (Feet)	1132.12	891.14	1256.94	740.41
Number of Bus Stops	6.00	3.92	4.00	3.31
Length of Walkable Roads (Feet)	26,182.33	7817.96	22,526.34	6613.98
Walk Score	55.82	23.66	42.13	21.33
Other Location Characteristics				
CBD Distance (Feet)	40,149.53	11,868.44		
Highway Distance (Feet)	5563.25	4954.25	3656.95	2348.00
River Distance (Feet)	2625.38	2089.65	3350.77	1951.52
Park Distance (Feet)	1291.93	737.09	1143.92	750.33
Lake Distance (Feet)	5473.41	3257.04	8006.58	3613.16
View	0.02		0.09	
Traffic Noise	0.20		0.12	
Neighbourhood Socio-Economic Characteristics				
Percent White Residents	73%	17%	48%	21%
Median Household Income (US$)	81,472.26	25,772.04	63,999.67	19,041.38
School Quality	6.15	3.61	3.05	2.12
Valid Cases	**6877**		**1238**	

Table 3. Outcomes of regression Models 1 and 2.

Variables	Model 1 – Transit Centre Distance		Model 2 – Dummy Distances	
	Coefficients	z-value	Coefficients	z-value
Physical Characteristics				
Lot Size	4.604***	16.733	4.583***	16.661
Total Finished Area	139.179***	39.198	139.030***	39.158
Total Basement Area	48.502***	14.825	48.260***	14.747
Number of Bedrooms	−4157.81**	−2.167	−4113.241**	−2.144
Number of Bathrooms	20,437.64***	6.347	20,380.26***	6.331
Number of Fireplaces	5314.799**	2.190	5395.937**	2.222
Age	−947.814***	−11.316	−954.768***	−11.392
Condition	10,304.75***	4.528	10,291.46***	4.524
TOD Characteristics				
Transit Centre Distance	−2.215**	−2.363	–	–
Dummy_Distance1	–	–	22,044.72***	2.892
Dummy_Distance2	–	–	5588.2*	1.797
Land Use Mixture	10,533.58	1.382	7667.199	0.988
Commercial Land Distance	5.641**	2.404	5.368**	2.285
Length of Walkable Roads	1.137***	5.226	1.106***	5.072
Walk Score	253.520**	2.346	217.294**	1.976
Other Location Characteristics				
CBD Distance	−2.901***	−10.747	−2.989***	−10.921
Number of Bus Stops	1539.967***	3.317	1538.92***	3.313
Highway Distance	2.883***	5.558	3.001***	5.758
River Distance	3.322***	3.677	3.629***	3.969
Park Distance	−8.683***	−4.249	−9.387***	−4.509
Lake Distance	−0.080	−0.137	−0.022	−0.038
View	40,370.97***	4.095	39,657.38***	4.020
Traffic Noise	−18,814.74***	−5.286	−18,785.05***	−5.279
Neighbourhood Socio-Economic Characteristics				
Percent White Residents	64,654.61***	5.982	65,064.34***	6.024
Median Household Income	0.459***	6.593	0.468***	6.718
School Quality	1111.351**	2.203	938.394*	1.842
W-Inflated Sales Price	0.341 ***	27.326		
(Constant)	−23,855.09	−1.099	−30,666.67	−1.437
R^2		0.66		0.66
Lag coeff. (Rho)		0.342		0.341
N		6877		6877

Estimates are marked with level of significance (* < 0.1, ** < 0.05, *** < 0.01).

the dependent variable. The coefficients for most physical characteristics variables have the expected signs and are highly significant at the 0.01 level. From Model 1, the willingness to pay is about US$4.6 for an additional square foot in lot size, US$139 for an extra square foot of finished area and US$49 for one square foot increase in basement area. Controlling for the total finished area, adding an extra bedroom, which essentially makes each bedroom smaller, is associated with a US$4158 decrease in sales price. On the other hand, adding a bathroom, which is typically amenity-intensive, corresponds to a US$20,438 increase in market value. Adding a fireplace adds US$5315 to the housing price. A house that is one year older is worth US$948 less, all else being equal. A one-level elevation in the assessed condition translates into, on average, a US$10,305 increase in housing price.

Most of the locational factors show significant relationships with housing price, and most of the estimated coefficients have the expected signs. Adding an additional bus stop within a quarter mile radius increases the housing price by US$1540. Each unit of distance away from the CBD or a park is associated with a measurable drop in sales price, whereas each unit of distance away from a highway or a river (which is often associated with flood hazards and undesirable land uses) is related to a price increase. Distance to park appears to have the largest marginal effect on housing price; for every 1000 feet increase in the distance to the nearest park, the market value of residential property decreases by US$8683, all else being equal. A good view commands a sizeable price premium, as indicated by the estimated value of US$40,371. Traffic noise, on the other hand, lowers housing price, as showed by the coefficient of −US$18,815.

Neighbourhood socio-economic characteristics appear to affect housing sales prices in the expected way. All else being equal, a 1-percentage point increase in Percent White Residents in the census block is associated with an increase of US$647 in the average home sales price. A US$1000 increase in Median Household Income in the census blockgroup is associated with an additional US$459 in the average price of single-family homes. A one-score elevation in the school quality increases housing price by US$1111.

Having controlled for the effects of all other factors, we can now examine the housing price effects of the TOD variables. The Transit Centre Distance variable is significant at the 0.05 level. The negative coefficient indicates that home sales price is expected to reduce by US$2215 if the distance to the corresponding transit centre increases by 1000 feet. In other words, the BTODs create sizeable price premiums on the single-family properties located nearby. Land use mixture also shows a positive coefficient at US$10,534, but is not statistically significant. Controlled for land use mix, however, each unit distance away from commercial land is associated with around US$6 less in housing price, perhaps capturing some negative effects, such as noise and traffic, that are associated with commercial activities. As we expected, walkability is positively correlated with housing price. Increasing 100 feet in the length of walkable roads within a quarter mile radius elevates the property value by US$114, and a one-point increase in Walk Score raises the housing price by US$254.

Results for Model 2 are highly consistent with those for Model 1. One important difference is that two dummy distance variables replace the continuous variable of distance to transit centre. Again, the estimated coefficients show that the BTODs create significant price premiums on the houses located nearby. Controlling for the effects of other variables, residential properties located within 0.5 mile of the corresponding transit centre on average are sold for US$22,045 more than otherwise identical properties located 1.0–1.5 miles from the transit centre. Residential properties located 0.5–1.0 mile from the transit centre command, on average, a more modest price premium of US$5588.

Histograms and p-p plots of the residuals suggest that the errors are distributed normally.[5]

Results of the longitudinal case study

Temporal dummy variables models. Regression outcomes of the first set of longitudinal models are displayed in Table 4. The adjusted R-squares of Models 3 and 4 are 0.55, indicating that about 55% of the variation in sales prices among sampled single-

Table 4. Outcomes of regression Models 3 and 4.

Variables	Model 3 – Transit Centre Distance		Model 4 – Dummy Distances	
	Coefficients	z-value	Coefficients	z-value
Physical Characteristics				
Lot Size	0.771	1.232	0.967	1.549
Total Finished Area	66.126***	10.625	65.484***	10.474
Total Basement Area	31.756***	5.418	32.723***	5.607
Number of Bedrooms	2946.844	0.787	2668.595	0.713
Number of Bathrooms	5021.13	0.777	5983.984	0.923
Number of Fireplaces	16,650.46***	3.933	16,315.57***	3.846
Age	−507.044***	−3.359	−482.353***	−3.184
Condition	10,777.9**	2.118	8460.843*	1.672
TOD Characteristics				
Transit Centre Distance	−12.390***	−3.874	-	-
Dummy_Distance1	-	-	35,758.96**	2.146
Dummy_Distance2	-	-	30,489.43***	3.700
Land Use Mixture	10802.97	0.689	6387.053	0.402
Commercial Land Distance	10.847*	1.890	10.897*	1.893
Length of Walkable Road	−0.252	−0.299	−0.001	−0.001
Walk Score	−438.2403	−1.406	−85.323	−0.298
Temporal Dummy Variables				
1990_1991	6553.82	0.412	9687.605	0.608
1992_1993	−21,751.39*	−1.842	−22,146.22*	−1.862
1994_1995	−22,144.16*	−1.929	−21,972.5*	−1.909
1996_1997	−35,361.46***	−2.972	−34,844.81***	−2.928
1998_1999	−3002.295	−0.292	−317.635	−0.031
2000_2001	−16,412.24	−1.547	−16818.54	−1.581
2002_2003	9179.77	0.983	12,345.86	1.319
2006_2007	−11,825.16	−1.179	−10,940.64	−1.091
2008_2009	−16,790.51	−1.377	−15,885.47	−1.301
2010_2011	−27,981.1**	−2.302	−28,818.17**	−2.361
2012_2013	−45,119.11***	−4.054	−44,789.92***	−4.013
2014_2015	−54,614.21***	−3.848	−54,602.58***	−3.827
Other Location Characteristics				
Number of Bus Stops	−802.776	−0.758	−1126.256	−1.066
Highway Distance	−1.634	−0.828	−1.119	−0.564
River Distance	0.252	0.112	−1.033	−0.446
Park Distance	−5.240	−1.243	−6.944	−1.635
Lake Distance	−2.242*	−1.780	−1.330	−1.011
View	5971.925	0.615	6516.056	0.667
Traffic Noise	−10,264.36	−1.251	−9224.71	−1.121
Neighbourhood Socio-Economic Characteristics				
Percent White Residents	−2154.189	−0.136	−6340.224	−0.400
Median Household Income	0.335**	2.475	0.357***	2.629
School Quality	3669.764*	1.685	2463.873	1.167
W-Inflated Sales Price	0.300***	8.654	0.300***	8.650
(Constant)	148,935.8***	3.245	56,424.83	1.483
R^2		0.55		0.55
Lag coeff. (Rho)		0.301		0.300
N		1238		1238

Estimates are marked with level of significance (* < 0.1, ** < 0.05, *** < 0.01).

family homes located within 1.5 miles from the Renton Transit Centre is explained by these models. Most physical characteristics variables significant in the first two models are still significant in Models 3 and 4, and the coefficients have the expected signs. However, lot size, number of bedrooms and number of bathrooms are no longer significant. In general, the estimated coefficients are smaller in absolute value than those in the first two models, reflecting the fact that the average sales prices of single-family homes are much lower for Renton than for the other cases.

Among the location characteristics, distance to lake is significant in Model 3 and the estimated coefficient has the expected sign but is not significant in Model 4. Distance to park has the expected negative sign, view has a positive coefficient and traffic noise has the negative sign, but they are not significant in the estimated models. Of the neighbourhood socio-economic variables, median household income remains significant and is positively related to housing value, but percent of white residents is no longer significant. School quality shows a positive effect in Model 3, although the statistical significance is quite marginal.

Half of the temporal dummy variables are consistently significant in both models. Most of these coefficients have the negative sign, reflecting the fact that the reference years, 2004 and 2005, were when housing price reached a peak in the Seattle metropolitan area.

Both models show that the Renton BTOD creates considerable housing price premiums. Model 3 suggests that every 1000-foot distance from the transit centre is associated with a US$12,390 decrease in single-family property values. This estimate is much higher than the estimated US$2215 in Model 1, suggesting that the magnitude of the housing price premium created by the Renton BTOD is greater than the average for all four BTODs. Model 4 indicates that single-family houses located within 0.5 mile or between 0.5 and 1.0 mile from the transit centre command a large premium. The estimated US$35,759 for properties in the first distance category is quite consistent with the results of Model 2, but the estimated US$30,489 for properties in the second distance category is unreasonably high and requires a closer examination in future research.

Land use mixture is not significant in either Model 3 or Model 4. However, distance to nearest commercial land use is marginally significantly positive in both models, which is broadly consistent with the first two models. This indicates that single-family houses located farther away from commercial activities are more highly valued by home buyers. Length of Walkable Roads and Walk Score are no longer significant in both models.

Before-during-after models. Table 5 shows Models 5, 6 and 7, estimated using data on single-family transactions in Renton for the time periods of before, during and after the BTOD, respectively. The adjusted R-squares range from 0.45 for Model 5 to 0.6 for Model 6. With smaller samples drawn from different time periods, the regression results have more inconsistencies across the models. For example, among the physical characteristics variables, number of bathrooms shows a statistically significant positive relationship with sales price only for the middle time period, whereas number of bedrooms is significantly related to sales price only for the last time period and the coefficient is now positive.

Most location factors are no longer significantly associated with the dependent variable. Distance to lake is significant for the middle period only, whereas view and number of bus stops is significant for the last time period only. Distance to river is

Table 5. Outcomes of regression Models 5, 6 and 7.

Variables	Model 5 – Before BTOD		Model 6 – During BTOD		Model 7 – After BTOD	
	Coefficients	z-val	Coefficients	z-val	Coefficients	z-val
Physical Characteristics						
Lot Size	4.834***	2.640	−0.174	−0.219	2.411**	2.091
Total Finished Area	83.479***	3.845	66.834***	8.276	65.343***	6.400
Total Basement Area	47.003***	3.098	31.716***	3.899	25.345***	2.580
Number of Bedrooms	−7860.699	−0.741	729.390	0.144	13,761.84**	2.213
Number of Bathrooms	−13,941.29	−0.738	22,245.17**	2.291	−13,260.32	−1.380
Number of Fireplaces	25,976.02**	2.331	7302.068	1.273	23,970.76***	3.362
Age	−1309.575***	−2.933	−211.115	−0.962	−818.420***	−3.516
Condition	−2086.458	−0.153	9390.24	1.201	16,890.59**	2.292
TOD Characteristics						
Transit Centre Distance	10.120	1.038	−17.296***	−3.860	−9.895*	−1.942
Land Use Mixture	−5171.876	−0.116	−5831.891	−0.270	37,982.21	1.467
Commercial Land Distance	12.323	0.781	15.208*	1.889	12.754	1.387
Length of Walkable Road	2.557	1.040	−0.164	−0.146	−0.037	−0.026
Walk Score	−140.457	−0.154	−801.888	−1.633	−61.219	−0.119
Other Location Characteristics						
Number of Bus Stops	−3973.355	−1.330	515.402	0.344	−3259.941*	−1.931
Highway Distance	−5.272	−1.032	−1.125	−0.410	−3.682	−1.130
River Distance	−20.383***	−2.816	2.228	0.750	0.971	0.241
Park Distance	1.105	0.099	−9.088	−1.525	2.221	0.326
Lake Distance	2.605	0.706	−3.879**	−2.247	−1.761	−0.827
View	6462.174	0.269	8067.464	0.587	27,342.63*	1.707
Traffic Noise	−23822.9	−1.119	−9206.499	−0.774	−12,483.67	−1.010
Neighbourhood Socio-Economic Characteristics						
Percent White Residents	−30,198.25	−0.639	6999.247	0.331	−34,608.9	−1.281
Median Household Income	0.381	0.939	0.236	1.307	0.502**	2.263
School Quality	−577.567	−0.090	4961.26*	1.714	548.417	0.140
W-Inflated Sales Price	−0.083	−0.798	0.443***	10.480	0.128**	1.961
(Constant)	221,531.9*	1.774	116,196.2*	1.848	124,092.2*	1.678
R^2		0.45		0.60		0.56
Lag coeff. (Rho)		−0.083		0.443		0.129
N		196		660		382

Estimates are marked with level of significance (* < 0.1, ** < 0.05, *** < 0.01).

significant for the before BTOD period only, with a negative coefficient that is not consistent with those in Models 1 and 2. Among the neighbourhood socio-economic variables, median household income is statistically highly significant after BTOD, with an expected positive coefficient. School quality is marginally significant for the during BTOD period only, with the expected positive effect.

Most importantly, the distance to transit centre variable shows the expected effects for the three time periods: it is not significant for the time period before BTOD with a negative coefficient, but is significant during and after BTOD with positive coefficients. In other words, these longitudinal models indicate that the accessibility benefits of the transit centre became significant and capitalised once the BTOD was initiated, and have remained significant in the time period after the BTOD was completed. As for the other TOD characteristics, land use mixture and length of walkable roads are not significant, whereas distance to commercial land use is marginally significant during BTOD with a positive coefficient. These results are largely consistent with those of Models 3 and 4.

Conclusions

This article examines the effects of bus transit-oriented development on the market values of single-family residential properties located nearby. Using data on four completed BTODs in King County, Seattle metropolitan area, the Hedonic price analysis finds considerable housing price premiums created by this particular type of transit-oriented development. More specifically, results of the cross-sectional pooled analysis show that the price premiums are positively related to proximity to transit centre. The regression models, whether with a continuous variable of distance to transit centre or two dummy distance variables, reveal that sales prices for properties located within 0.5 mile of the transit centre are 3–5 percent higher than otherwise similar houses located farther than 1.0 mile from the transit centre.

The longitudinal analysis, which is more sophisticated methodologically but much more limited in terms of data, confirms the existence of housing price premiums created by the BTOD in the case of Renton. The estimated magnitude of the price premiums, which was obtained through two sets of longitudinal regression models, is larger than 10 percent.

Overall, the measured price premiums resulting from proximity to transit centre are broadly consistent with those reported in the existing literature (Andersson et al., 2010; Cervero and Duncan, 2002; Cervero and Kang, 2011; Ma et al., 2014; McDonald and Osuji, 1995; Mathur and Ferrell, 2013; Rodriguez and Mojica, 2009). The improved transit accessibility associated with the BTOD has created substantial land values which are capitalised by residential properties located nearby. However, our regression models do not produce consistent findings with respect to the relationships between the sales prices of single-family residential properties and the other TOD characteristics.

The key finding reported in this article – that BTOD creates substantial price premiums for single-family properties located nearby – has important policy implications. The most important implication is that for Seattle and other cities relying on an extensive bus system for public transportation provision, BTOD can be a viable approach to generating additional local tax revenues while advancing sustainability. Given that most cities do not have a metro or light rail system, BTOD will likely become a common practice. Our research also shows that combining cross-sectional and longitudinal analyses is a promising methodological approach for understanding the effects of BTOD on residential property value.

Much future research is required to fill remaining knowledge gaps and inform the future practice of BTOD. One limitation of this study is that the empirical analysis employs current data on land use and locational and neighbourhood socio-economic characteristics as explanatory variables for sales prices in different time periods. Future analysis should strive to match historical housing transaction data with historical GIS and socio-economic data. Another limitation of this study is that the longitudinal analysis relies on a single case of BTOD, which is quite limited in terms of sample size and generalisability. Future effort should aim to gather more cases and data for this kind of analysis. Yet another limitation is that in some of these case examples, most noticeably Northgate, BTOD is adjacent to a large shopping mall, and hence the measured price premiums may include positive effects of access to the shopping mall. Future studies should aim to clearly isolate the effects of BTOD through more sophisticated research design. Finally, the current article has not sufficiently addressed some obviously questionable results, such as the insignificant coefficients for land use mixture and inconsistent coefficients for walk core. Future work should go one level deeper in investigating unexpected and inconsistent regression results based on richer information about the context.

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Notes

1. Although the Northgate BTOD was initiated before Calthorpe coined the term 'transit-oriented development' in his 1993 book, it included some of the TOD ideas. Moreover, its subsequent development has been guided by TOD principles.
2. This study focuses on single family homes because there are too few sales of multiple family units in the study areas and because the relevant multiple family units do not have much variation in TOD characteristics. The samples are drawn from within 1.5 miles from the corresponding transit centre based on the considerations that a threshold distance must be specified to make the data processing manageable, and that a distance of 1.5 miles is a reasonable threshold because it is much farther than the normal walking distance and hence beyond much of the accessibility benefits of TOD.
3. Because j is defined for each property, each observation in this study has a uniquely calculated value of land use mixture. The six land use types are results of aggregating the hundreds of distinct land uses in the original data.
4. Some sales records were judged as invalid based on specific criteria, and hence removed from the final samples. Examples of removed records include those with a sales price equal to '0' and those with obvious errors made in recording, such as missing key data items or having an unreasonable sales price.
5. A P-P plot helps to check if the given data set is normally distributed by plotting theoretical data versus observed data. If the data is normally distributed, the result should be nearly a straight line (Wilk and Gnanadesikan, 1968).

References

Alonso W (1964) *Location and Land Use: Toward a General Theory of Land Rent*. Cambridge: Harvard University Press.

Andersson DE, Shyr OF and Fu J (2010) Does high-speed rail accessibility influence residential property prices? Hedonic estimates from southern Taiwan. *Journal of Transport Geography* 18: 166–174.

Anselin L and Rey S (1991) Properties of tests for spatial dependence in linear regression models. *Geographical Analysis* 23(2): 112–131.

Bartholomew K and Ewing R (2011) Hedonic price effects of pedestrian-and transit-oriented development. *Journal of Planning Literature* 26: 18–34.

Bocarejo JP, Portilla I and Pérez MA (2013) Impact of Transmilenio on density, land use, and land value in Bogotá. *Research in Transportation Economics* 40(1): 78–86.

Bowes DR and Ihlanfeldt KR (2001) Identifying the impacts of rail transit stations on residential property values. *Journal of Urban Economics* 50: 1–25.

Calthorpe P (1993) *The Next American Metropolis: Ecology, Community, and the American Dream*. New York: Princeton Architectural Press.

Cervero R (2004) *Transit-oriented Development in the United States: Experiences, Challenges, and Prospects*. Washington, DC: Transportation Research Board.

Cervero R and Duncan M (2002) Transit's value-added effects: Light and commuter rail services and commercial land values. *Transportation Research Record: Journal of the Transportation Research Board* 1805: 8–15.

Cervero R and Kang CD (2011) Bus rapid transit impacts on land uses and land values in Seoul, Korea. *Transport Policy* 18(1): 102–116.

Chen Z and Haynes KE (2015) Impact of high speed rail on housing values: An observation from the Beijing–Shanghai line. *Journal of Transport Geography* 43: 91–100.

Duncan M (2011) The impact of transit-oriented development on housing prices in San Diego, CA. *Urban Studies* 48(1): 101–127.

Ewing R and Cervero R (2010) Travel and the built environment: A meta-analysis. *Journal of the American Planning Association* 76: 265–294.

Fejarang RA (1993) *Impact on Property Values: A Study of the Los Angeles Metro Rail*. Public Transport Planning and Operations. Proceedings of Seminar held at The European Transport, Highways and Planning 21st Summer Annual Meeting (13–17 September, 1993) UMIST, Volume P370.

Frank LD, Andresen MA and Schmid TL (2004) Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine* 27: 87–96.

Frank LD, Sallis JF, Conway TL, et al. (2006) Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association* 72: 75–87.

Gibbons S and Machin S (2005) Valuing rail access using transport innovations. *Journal of Urban Economics* 57(1): 148–169.

Hanson S and Giuliano G (2004) *The Geography of Urban Transportation*. New York: Guilford Press.

Kay AI, Noland RB and DiPetrillo S (2014) Residential property valuations near transit stations with transit-oriented development. *Journal of Transport Geography* 39: 131–140.

KCDOT (2010) *Metropolitan Place, Renton TOD Project description*. Available at: http://www.kingcounty.gov/depts/transportation/planning/tod/renton.aspx (accessed 4 September 2017).

KCDOT (2013a) *Redmond Downtown Transit Center and TOD Project Description*. Available at: http://www.kingcounty.gov/depts/transportation/planning/tod/redmond.aspx (accessed 4 September 2017).

KCDOT (2013b) *Transit-oriented development*. Available at: http://www.kingcounty.gov/depts/transportation/planning/tod/northgate.aspx (accessed 4 September 2017).

KCDOT (2013c) *The Village at Overlake Station, Redmond—TOD Project description*. Available at: http://www.kingcounty.gov/depts/transportation/planning/tod/overlake.aspx (accessed 4 September 2017).

Ma L, Ye R and Titheridge H (2014) Capitalization effects of rail transit and bus rapid transit on residential property values in a booming economy: Evidence from Beijing. *Transportation Research Record: Journal of the Transportation Research Board* 2451: 139–148.

McDonald JF and Osuji CI (1995) The effect of anticipated transportation improvement on residential land values. *Regional Science and Urban Economics* 25: 261–278.

Martínez L and Viegas J (2009) Effects of transportation accessibility on residential property values: Hedonic Price Model in the Lisbon, Portugal, metropolitan area. *Transportation Research Record: Journal of the Transportation Research Board* 2115: 127–137.

Mathur S and Ferrell C (2013) Measuring the impact of sub-urban transit-oriented developments on single-family home values. *Transportation Research Part A: Policy and Practice* 47: 42–55.

Meyer MD and Miller EJ (2001) *Urban Transportation Planning: A Decision-Oriented Approach*. New York: McGraw Hill.

Office USGA (2014) *Public Transportation: Multiple Factors Influence Extent of Transit-oriented Development*. Washington, DC: U.S. Government Accountability Office.

Munoz-Raskin R (2010) Walking accessibility to bus rapid transit: Does it affect property values? The case of Bogotá, Colombia. *Transport Policy* 17(2): 72–84.

Rodríguez DA and Mojica CH (2009) Capitalization of BRT network expansions effects into prices of non-expansion areas. *Transportation Research Part A: Policy and Practice* 43(5): 560–571.

Rosen S (1974) Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy* 82: 34–55.

Seo K, Golub A and Kuby M (2014) Combined impacts of highways and light rail transit on residential property values: A spatial hedonic price model for Phoenix, Arizona. *Journal of Transport Geography* 41: 53–62.

Small KA and Verhoef ET (2007) *The Economics of Urban Transportation*. London: Routledge.

Song Y and Knaap G-J (2003) New urbanism and housing values: A disaggregate assessment. *Journal of Urban Economics* 54: 218–238.

Suzuki H, Murakami J, Hong Y-H, et al. (2015) *Financing Transit-Oriented Development with Land Values: Adapting Land Value Capture in Developing Countries*. Washington, DC: World Bank Publications.

Von Thünen JH (1966) *Isolated State: An English Edition of Der Isolierte Staat*. London: Pergamon Press.

Walk Score Methodology (2017) Available at: https://www.walkscore.com/methodology.shtml (accessed 4 September 2017).

Wang Y, Potoglou D, Orford S, et al. (2015) Bus stop, property price and land value tax: A multilevel hedonic analysis with quantile calibration. *Land Use Policy* 42: 381–391.

Wilk MB and Gnanadesikan R (1968) Probability plotting methods for the analysis for the analysis of data. *Biometrika* 55(1): 1–17.

Yan S, Delmelle E and Duncan M (2012) The impact of a new light rail system on single-family property values in Charlotte, North Carolina. *Journal of Transport and Land Use* 5(2).

Zhong H and Li W (2016) Rail transit investment and property values: An old tale retold. *Transport Policy* 51: 33–48.