Does bus accessibility affect property prices?

(submitted to *Cities* for publication consideration)

Abstract: Existing studies have yet reached consistent conclusions on the accessibility benefits of buses. Most existing studies have been conducted in the context of the West, where the rate of bus usage is generally low. In this study, we used a database of 22,586 secondhand residential properties in 358 residential estates in Xiamen, China to develop four hedonic pricing models (one standard, three Box-Cox transformed) and two spatial econometric models to quantify the effects of bus accessibility on property prices and analyze how the introduction of spatial econometric models would influence estimates of such benefits. Our findings are as follows. (1) Distance to bus stops is positively correlated with property prices. This finding is in contrast with the findings of mainstream research (or conventional wisdom). The average price of a property within 500 meters of a bus stop is 0.5% higher than that of other properities, all else being equal. (2) Bus travel times to essential destinations significantly influences housing prices. (3) The spatial econometric models that account for spatial autocorrelation outperform the traditional hedonic pricing models. Robustness check analysis further guarantees the plausibility of this study.

Keywords: property price, bus, local accessibility, regional accessibility, hedonic pricing model, spatial autocorrelation, urban China

1. Introduction

Public transportation has the potential to reduce automobile dependence, redress numerous vexing contemporary urban problems (e.g., traffic congestion, air pollution, greenhouse gases, diminishing urban ecological amenities) and to facilitate high-density and mixed land-use development patterns (Zhao, 2010, 2014). Accordingly, developing an attractive, accessible, and affordable public transport system that meets the needs of transit users is imperative for sustainable development (Batty et al, 2015). However, an inherent drawback of most transit systems is that they only provides stop-to-stop services instead of door-to-door services. Thus, distance to the stop or station affects residents' travel mode choice. If the distance to a transit stop or station exceeds a certain threshold, then residents may not even consider traveling by transit (Krygsman et al., 2004). That is, people would often turn to a private car (as long as they can afford it) when decent transit services are inaccessible.

Public transport is more suitable for high-density and compact cities, particularly those in developing countries. However, in many cities in several developed countries (e.g., the United States, Canada, Australia, and New Zealand), driving is the primary means of transportation and only a small proportion of people use public transportation (Department of Transportation, 2011; Szeto et al., 2017; Wong et al., 2017, 2018; Yang, 2018b). By contrast, in several Asian cities (e.g., Hong Kong, Seoul, Singapore, Tokyo, and Shanghai), density is overwhelmingly high, mixed land use is common, the rate of transit patronage is fairly high, and the population exhibits a strong residential preference for the downtown or its vicinities. Similarly, many European cities (e.g., Prague, Munich, Vienna, Paris, London, and Stockholm) have moderate-to-high density and high percentage of transit use, with substantial complementary relationships among rapid transit and bus transit networks and advanced transport development (Shyr et al., 2017). In terms of public transport mode share, these European cities straddle Asian transit-dependent cities and North American/Oceanian car-dominant cities. For example, the public transport mode share in London is approximately 44% compared with 90% in Hong Kong and 16% in Sydney (Land Transport Authority, 2012). The success of the European public transport lies in "a coordinated package of mutually supportive policies" (Buehler and Pucher, 2012, p. 541).

In China, the average transit usage across cities is 10 times than that of the United States (Zhang, 2007), while only 35 cities owned an urban rail transit as of 2017. By 2020, the total number of cities in Mainland China that will own a rail transit system will reach 50 (National Development and Reform Commission, 2016). At present, traditional buses serve as the most popular transit option in most of the cities ("bus-served cities" for shorthand hereafter). In stark contrast with car-dominant cities, bus- served cities often have a well-developed and relatively dense transit network (Zhao and Li, 2017) and offer relatively frequent, convenient, secure, affordable, and reliable bus services that serve large geographical areas. Moreover, bus stops are often closer to residences compared with railway and bus rapid transit (BRT) stations. That is, buses generally require low access time. Thus, the significance of buses in Urban China is more visible than that in car-dominant cities.

After marketization, housing in Urban China has become a commodity distinguished by a variety of attributes (e.g., size, age, and distance to the city center), many of which have been claimed to affect its price. In bus-served cities, buses play a crucial role in residents' lives. As such, accessibility to bus services and accessibility to amenities (e.g., city centers, shops, and schools, by bus services) by bus (i.e., "bus accessibility") presumably affect housing prices. Residents may be willing to pay high prices for properties with good bus accessibility, which is expected to be translated to price premiums.

The capitalization effect of the bus accessibility could be significant, though unlike fixed guideway transit options (e.g., railway, commuter rail, high-speed rail, and BRT) which have the potential to guide urban expansion and development, explicitly shape the urban form and considerably serve a wide array of urban-planning objectives. Nevertheless, previous studies have yielded mixed and even conflicting results. Koutsopoulos (1977) indicated that a few bus routes in the United States cannot offer price premiums. Hess and Almeida (2007, p. 1043) explained that "most bus routes lack the permanence of fixed infrastructure." Vuchic (2002), Cervero and Kang (2011), and Pang and Jiao (2015) argued that regular buses cannot provide capitalization effects and induce land development. So et al. (1997) indicated that buses have difficulty in offering appreciable accessibility benefits in Hong Kong. Cao and Hough (2012) and Wen and Tao (2015) showed that the impact of proximity to bus routes is even negative within 1/8 mile or 1 km in a small urban area of the United States or Hangzhou, China, respectively. These results contrast starkly with the findings of Ibeas et al. (2012) and Wang et al. (2015) in medium-sized cities of Spain and the United Kingdom, respectively. In light of the above, we attempt to answer the following question: *Can buses provide appreciable accessibility benefits in bus-served cities? If yes, how much are the benefits?*

The bus accessibility can be viewed as a special case of "transit accessibility" that consists of two components, namely, local and regional accessibility (Rodríguez and Targa, 2004). Local accessibility measures the ease of access and depends on built environment factors (e.g., proximity to transit stops and routes). By contrast, regional accessibility measures travel cost (time, distance or monetary cost) to potential destinations or available opportunities or activities within a pre-defined travel time and is dictated by good transportation links to trip attractions (Rodríguez and Targa, 2004).

Extensive and thorough studies on the effects of transit accessibility on housing prices have been conducted in the Western context, particularly car-dominant cities therein, where transit accessibility may not be valued similarly as bus-served cities. In comparison, only very few studies have looked at capitalization benefits of local/regional bus accessibility in bus-served cities. Moreover, the majority of the existing studies focus on the valuation of either local or regional transit accessibility, but rarely both. Furthermore, only a few studies have incorporated spatial econometric techniques, which appear to provide an overall better performance than the models have not considered spatial effects (LeSage and Pace, 2009).

The current study focuses on capitalization effects of the bus accessibility and adopts a set of hedonic pricing models to test whether or not the bus accessibility exerts effects on housing prices. The main contributions are as follows: (1) *adding an empirical study in Urban China on the value of the bus accessibility and* *supplementing the current literature*; (2) *gaining a profound and thorough understanding of the benefits offered by local and regional bus accessibility*; (3) *comparing the performances of a pre-specified functional form and three Box-Cox regression models and two spatial econometric models about the value of the bus accessibility*; and (4) *offering insights for the implementation of value capture schemes of financing bus investments*.

The remainder of this paper is organized as follows. Section 2 reviews the related literature, which positions this study in the ongoing debate on the transit accessibility capitalization effects and highlights its potential contributions. Section 3 introduces the standard hedonic pricing models, Box-Cox transformation, and spatial econometric methods. Section 4 describes the case study area, data, and variables. Section 5 presents the modeling results. Section 6 presents the conclusion and identifies avenues for future research.

2. Literature Review

The literature pertinent to our analysis includes the studies on the two-component transit accessibility metrics and effects of the local and regional transit accessibility on property values. As a whole, how the bus accessibility affects property values has not been well studied. Few existing studies on this topic have produced mixed and even conflicting results and/or findings. .

2.1. Two-component transit accessibility metrics

Accessibility is a well-known concept in the fields of transportation, geography, and urban planning. There are numerous accessibility definitions, as well as the related metrics. Transit accessibility includes two components, namely, the local accessibility (i.e., ease of obtaining access to a transit stop or station) and the regional accessibility (i.e., where a resident can arrive within a specified distance or time threshold by transit) (Rodríguez and Targa, 2004). Table 1 shows that selected studies have presented dissimilar terminologies that can be used interchangeably for the same concept.

Table 1

Different terminologies for local and regional transit accessibility

Local accessibility	**Regional accessibility**	**Source**
local accessibility	network transit accessibility	Hillman and Pool (1997)
access	accessibility	Murray et al. (1998); Chowdhury et al. (2016)
convenience (便利性)	connectivity (通达性)	Wang et al. (2013)
accessibility to transit	accessibility by transit	Moniruzzaman and Páez (2012); Xu et al. (2015); Boisjoly and El-Geneidy (2016)
access	locational accessibility	Geurs and Van Wee (2004)
transit accessibility	the accessibility of a transit system	Xu et al. (2016)

On the one hand, the local accessibility is defined by physical (or built environment) factors (e.g., spatial configuration of transit stops) and the related metrics include "the distance to the transit station, the length and width of the walking connector, the behavior of passenger influenced by the walking time, and the level of service of the transit facility" (Xu, 2015, p. 56). On the other hand, the regional accessibility concerns the convenience of accomplishing specific activities (e.g., shopping, healthcare) by transit and the related factors include "travel time (or distance), transfer number, fare cost and headway" (Xu, 2015, p. 56).

Physical access to a transit stop or station is a necessary but insufficient condition for enjoying the transit accessibility benefits (Armstrong and Rodríguez, 2006). Another requirement is that transit services should competitively connect the stops or stations near potential destinations (Armstrong and Rodríguez, 2006).

2.2 Local and regional transit accessibility and property values

Table 2 presents the results of selected studies which have analyzed how transit accessibility influences property values based on hedonic pricing models. The accessibility benefits of fixed guideway transit modes (i.e., high-speed rail, light/heavy railway, and BRT) have been involved in the heated discussion and intensively documented, predominately because they have substantial policy relevance or implications. A relatively consistent (though still inconclusive) relationship has been identified. Most studies found that proximity to a fixed guideway transit mode offers economic advantages. However, a few studies indicated insignificant and even negative effects. In general, the price premiums offered by the commuter rail and high-speed rail accessibility are the largest, followed by that of railway or BRT. Moreover, the impact magnitude of transit accessibility varies with the quality of service provided by stations (e.g., the service converge and network connectivity) and demographic characteristics of the neighborhood.

The capitalization effect of the regional transit accessibility has been substantially under-investigated compared with that of the local transit accessibility. Only a handful of the existing studies have simultaneously investigated both components of transit accessibility (e.g., Rodríguez and Targa, 2004; Armstrong and Rodríguez, 2006; Debrezion et al., 2011). Furthermore, very few studies have incorporated spatial econometric techniques.

Comparatively, limited attention has been paid to the bus accessibility in car-dominant cities, possibly because of its negligible role. Most studies have not separately addressed the effects of the bus accessibility on housing prices (e.g., So et al., 1997; Wen et al., 2014, 2017; Wen and Tao, 2015), and very few have aimed at specifically looking at the bus accessibility. No consistent relationship was observed in a handful of the bus accessibility studies and mixed, even conflicting conclusions were drawn. The majority of studies have suggested that the bus accessibility is insufficient to increase property prices (e.g., So et al., 1997), while a few more recent studies have identified either the positive (e.g., Ibeas et al., 2012) or negative (e.g., Cao and Hough. 2012; Wen and Tao, 2015) effects.

The role of both components of the bus accessibility in determining property values should be better understood. Nonetheless, the typically existing literature has overlooked the regional bus accessibility. To the best of our knowledge, no research has completely investigated the effects of both components of the bus accessibility. Accordingly, we aim to provide empirical evidence for the nature of the bus accessibility's values in Urban China, where bus-dependent cities dominate.

Table 2

Property value results of selected hedonic studies

Reference	**Data, Site**	**Local accessibility's effect**	**Regional accessibility's effect**	**Spatial econometric model**
High Speed Railway				
Andersson et al. (2010)	1550 property sales in Tainan in 2007	marginal or negligible effects	-	No
Andersson et al. (2012)	5745 property sales in five small metropolitan areas of Taiwan in 2007, 10,368 in Taipei and Kaohsiung regions in 2008	elasticity ranging from -0.04 to -0.18 in 6 out of 7 metropolitan areas, but no effects in one region	-	No
Light/heavy Railway				
Gatzlaff and Smith (1993)	912 property sales in Miami between 1971 and 1990	no evidence of appreciable effects	-	No
Landis et al. (1995)	232 and 1,131 property sales in San Mateo County and Sacramento City in the second quarter of 1990	heavy/light rail does not contribute to housing prices in San Mateo County/Sacramento City	-	No
So et al. (1997)	1,234 property sales in Hong Kong in 1991	premium of 3.2% for a location within 1km of a station	-	No
Bowes and Ihlanfeldt (2001)	22,388 sales of single-family homes in Atlanta during 1991 and 1994	premium ranging from 2.4% to 3.5% depending on the distance from 1/4 mile to 3 miles	-	No
Armstrong and Rodríguez (2006)	1,860 property sales in Eastern Massachusetts in the fourth quarter of 1992 and first quarter of 1993	inconsistent findings: premium of 10.1% for a location within 1/2 mile of a station or no appreciable effects	no evidence of appreciable effects	No

Debrezion et al. (2011)	40,326, 17,772 and 5,997 property sales in Amsterdam, Rotterdam, Enschede during 1996 and 2001	elasticity of -0.009 and -0.020 in Amsterdam and Enschede, but no evidence of appreciable effects in Rotterdam	positive effects in Amsterdam and Enschede, but not Rotterdam	No
Shyr et al. (2013)	4,068 and 2,999 property sales in Taipei and Kaohsiung in 2008, 5,291 property sales in Hong Kong in the third and fourth quarters of 2008	elasticity of -0.016, -0.044, -0.072 in Hong Kong, Taipei, Kaohsiung	-	No
Kim (2016)	3,385 subterranean housing rents in Beijing between October 2012 and September 2013	elasticity of around -0.015	-	No
BRT				
Rodríguez and Targa (2004)	494 property rents in Bogota in 2001	premium of 6.8-9.3% for every 5min walking time	no evidence of appreciable effects	Yes
Perdomo Calvo (2017)	206 and 488 observations of Bogota in 2006 and 2008, and 431 observations in Barranquilla in 2011	elasticity of -0.010	-	Yes
Pang and Jiao (2015)	272 and 282 property sales along BRT1 and BRT3 in Beijing in 2012	premium of 5.35% for a location within 5-10 minutes' walking distance of a BRT1 station, but no evidence of appreciable effects of BRT3	-	No
Bus				
So et al. (1997)	1,234 property sales in 7 housing estates in Hong Kong during 1991	no appreciable effects	-	No
Zheng and Kahn	900 new housing projects in	inconsistent findings: premium of 5.1%	-	No

(2008)	Beijing	to 7.9% for every km or no appreciable effects		
Cao and Hough (2012)	369 property rents in Fargo in 2007	discount of $18.41/month for a location within 1/8 mile of a bus route	-	No
Ibeas et al. (2012)	1,562 property asking prices in Santander in June 2009	inconsistent findings: either premium of 1.4-2.2% for every bus route within 0.4 km or no appreciable effects	-	Yes
Wen et al. (2014)	609 property sales in Hangzhou in May 2012	no evidence of appreciable effects	-	Yes
Wen and Tao (2015)	229, 340 and 649 property sales in Hangzhou in 2003, 2008 and 2011	premium of 0.3% for every bus route within 1 km in 2003, no evidence of appreciable effects in 2008, discount of 0.1% for every bus route within 1 km in 2011	-	Yes
Wen et al. (2017)	660 residential community observations in Hangzhou from June 2011 to May 2013	no evidence of appreciable effects	-	Yes

3. Methods

3.1 Standard hedonic pricing model

The hedonic pricing model assumes that property prices can be decomposed into the component prices of a bundle of attributes (Rosen, 1974). This model is an efficient tool to empirically assess the determinant factors (e.g., structural features, accessibility levels, and neighborhood amenities) on the prices of heterogeneous properties, such as residential real estate (Boscacci et al., 2017; Law, 2017). The standard (or basic) hedonic pricing model is an ordinary least squares (OLS) regression of the natural log of housing price (*Y*) on the set of value-bearing attributes (*X*s). The mathematical expression is as follows:

$$Y = X\beta + \varepsilon ,$$

where β is a vector of regression coefficients and ε is the remainder term that represents all the unmeasured effects.

3.2 Box-Cox transformation

The Box-Cox transformation, a nonlinear regression technique, is capable of detecting nonlinearity in model parameters and choose among alternative functional forms for a better model specification. Box-Cox models have many specifications, such as the simple left-hand-side (LHS), simple both-side, and separate both-side models.

The simple LHS Box-Cox model can be written as

$$Y^{(\lambda)} = X\beta + \varepsilon ,$$

where $Y^{(\lambda)} = (Y^{\lambda} - 1)/\lambda$ for $\lambda \neq 0$, whereas $Y^{(\lambda)} = \ln Y$ for $\lambda = 0$.

The simple both-side Box-Cox model can be written as

$$Y^{(\lambda)} = X^{(\lambda)}\beta + \varepsilon ,$$

where $Y^{(\lambda)} = (Y^{\lambda} - 1)/\lambda$, $X^{(\lambda)} = (X^{\lambda} - 1)/\lambda$ for $\lambda \neq 0$, whereas $Y^{(\lambda)} = \ln Y$, $X^{(\lambda)} = \ln X$ for $\lambda = 0$.

The most general specification, namely, the separate both-side Box-Cox model (a.k.a. each-side Box-Cox transformed model), can be written as

$$Y^{(\lambda)} = X^{(\theta)}\beta + \varepsilon ,$$

where $Y^{(\lambda)} = (Y^{\lambda} - 1)/\lambda$ for $\lambda \neq 0$, $X^{(\theta)} = (X^{\theta} - 1)/\theta$ for $\theta \neq 0$, whereas $Y^{(\lambda)} = \ln Y$ for $\lambda = 0$, $X^{(\theta)} = \ln X$ for $\theta = 0$.

3.3 Spatial econometric models

Spatial autocorrelation (or spatial dependence) can be deemed as “the co-variation of variables within a geo-space” (Li et al., 2011, p. 443). The possible explanations include spatial externality, external force, and spatial interaction (LeSage and Pace, 2009; Wong et al., 2013). Spatial autocorrelation has been properly incorporated into hedonic analysis using spatial econometric models in a host of property valuation and urban economics literature (Krause and Bitter, 2012).

The traditional OLS regression is subject to several assumptions that are likely to be violated with spatial statistics. The spatial lag model (SLM) and spatial error model (SEM) are the two celebrated methods that take account of spatial dependence (Anselin, 1988).

3.3.1 Spatial lag model

The SLM accounts for endogenous interaction effects among the predicted variable (Jun and Kim, 2017), which can be written as

$$Y = \rho WY + X\beta + \varepsilon,$$

where W is a spatial weight matrix that specifies the assumed spatial structure and contains the information on the neighborhood structure for each property location, WY is the spatially lagged predicted variable and ρ is the spatial dependence parameter. If $\rho = 0$, the SLM is a standard hedonic pricing model.

3.3.2 Spatial error model

The SEM deals with spatial autocorrelation in remainder terms, which can be written as

$$\begin{gathered} Y = X\beta + \varepsilon \\ \varepsilon = \rho W\varepsilon + u' \end{gathered}$$

where u' is a remainder term assumed to be uncorrelated with other observations' remainder term. Similar to the SLM, if $\rho = 0$, the SEM is a standard hedonic pricing model.

4. Data

4.1 Site

Our site is Xiamen Island (Figure 1), the central city of Xiamen. Xiamen is located on the southeast coast of China. Up to the end of 2016, the city has a permanent population of 3.92 million, with an administrative area of 1,699 km^2 (Xiamen Statistics Bureau, 2017). Xiamen Island is the central city of Xiamen until now, with an administrative area of approximately 130 km^2 and consists of two urban districts, namely, Siming and Huli Districts. Zhongshan Road Area is normally viewed as the traditional city center.

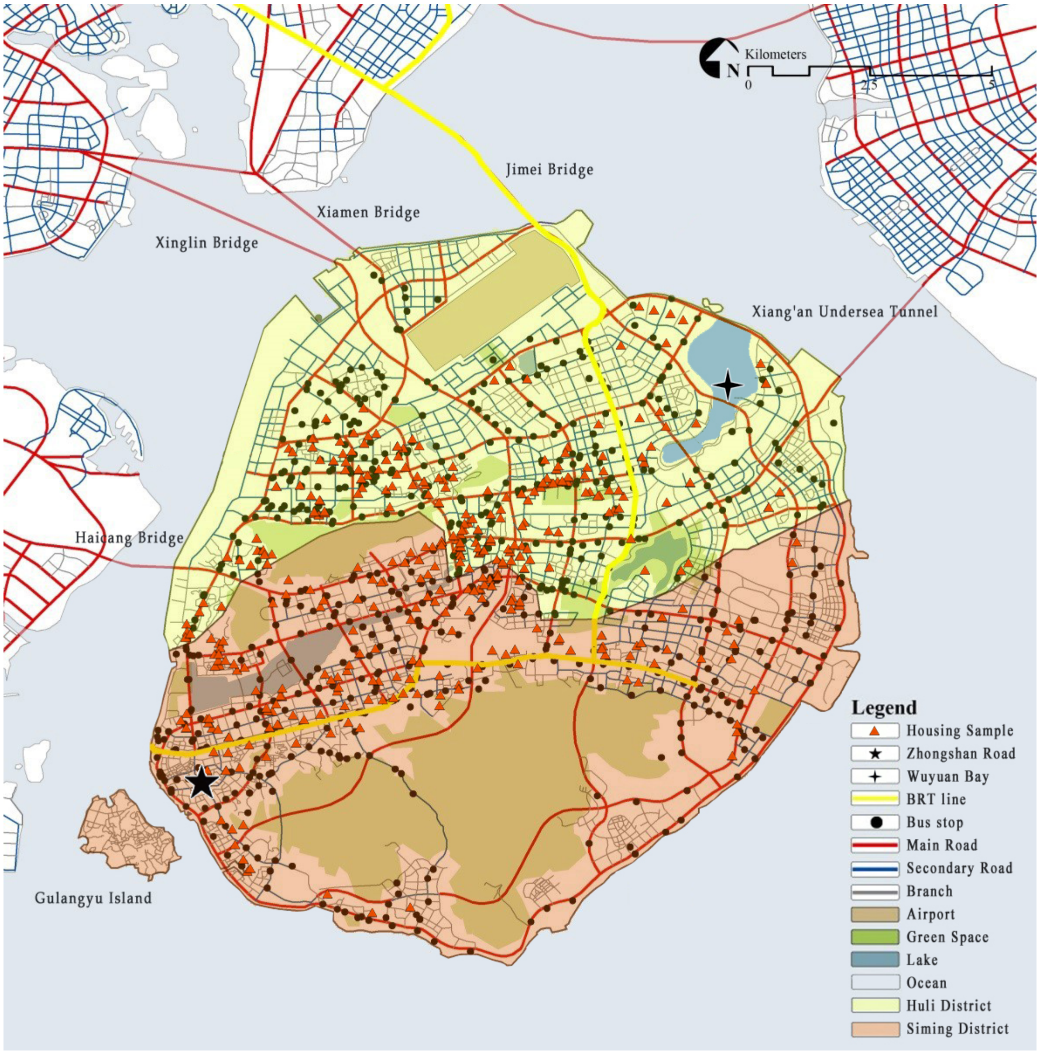

Figure 1. The location of housing unit samples in Xiamen Island.

The reasons for choosing Xiamen Island for this study are as follows. First, the missing (or omitted) variable bias is a major limitation of the traditional hedonic pricing model. As Brasington (2003) indicates, a feasible method accounting for this is to focus on a narrow area, in which numerous confounders have already been properly controlled. In this regard, Xiamen Island is a tractable laboratory for hedonic pricing analysis (Yang et al., 2016; Yang, 2018a). Second, Xiamen Island has extremely low car usage and a high rate of bus usage. Private cars and buses account for 9.3% and 31.7%, respectively, of the trips of city dwellers (Zhou et al., 2011). Although BRT is a good competitor of buses, only three lines are available and serve a small area of Xiamen Island and constitute only 12.25% of all local transit trips (Xiamen Transport Bureau, 2015). As such, bus is the most crucial transit mode for the local residents. Last, many substitutes for traditional buses (e.g., railway) are unavailable on Xiamen Island.

4.2 Data

The data on 22,586 secondhand (pre-owned) residential properties in 358 multi- or high-story condominium complexes (or residential estates) were crawled in late March 2017 from *Soufang.com*, one of the largest on-line real estate agency websites in China. To date, condominium units have dominated urban China's nascent housing sector, with a market share of over 95% (Wu et al., 2014). Note that we confined our samples to secondhand housing units for comparability but without considering newly built properties, particularly because of the following three reasons. First, developers' pricing behaviors make the determination of newly built housing price vastly different from that of secondhand property price (Wu et al., 2014). Second, prices of newly built housing are easily affected by policy intervention, such as the home-purchase restriction that was started in Beijing in May 2010 and implemented in Xiamen in August 2010 (Du and Zhang, 2015). Lastly and most importantly, the substantially developed Xiamen Island currently lacks newly built residential districts. The last newly built residential district is *Jianfa Yangxi*, which was open for sale at the end of 2016. As Figure 1 shows, our samples are spatially distributed quite evenly within the island, except the northwest dominated by industries and the southern and eastern coastal areas adjacent to the 48-km-long Island Ring Road (环岛路) where residential projects are normally prohibited. In addition, apart from collecting housing samples, a workable GIS framework was built. Coordinate data from government websites or Google Earth (e.g., amenities, BRT stations, and bus stops and routes) were collected.

4.3 Variables

Table 3 presents the descriptive statistics of housing characteristics in our housing dataset. A total of seven variables were used to quantify the local and regional bus accessibility. The quantification was consistent with the broad definitions of accessibility. In evaluating the regional bus accessibility, the key issue is to identify the potentially contributory destinations. The destinations concerned herein include Zhongshan Road, Wuyuan Bay, the sea, shopping centers, and primary schools. The regional bus accessibility variables, reflected by the bus travel time, are measured in a publicly accessible website, *Gaode Map*. The trip origin is set as the centroid of the residential estate of a property. Notably, in *Gaode Map* framework, first/last-mile (or origin-to-stop/stop-to-destination) times are not included.

Similar to many Chinese cities, Xiamen is dominated by large-scale gated residential districts, where bus services are prohibited from entering. Many bus stops located outside residential districts are readily available based on the observation that the average number of bus stops within 0.5 km is 6.37. People do not necessarily go to the nearest bus stop but select the stop with their desired bus routing/schedule. As such, we used "cumulative opportunity" measures to reflect local bus accessibility rather than time distance to the nearest bus stop, which represents "nearest opportunity." Moreover, Ryan (1999) argued that the capitalization benefits of a transportation mode's accessibility should be considered relative to other alternatives. Therefore, we controlled for BRT accessibility using the road network distance to the closest BRT station from a property. Furthermore, it is worth noting that we did not directly include the variable of number of bedrooms, which has been widely used in western hedonic literature, because its effect tends to overlap with floor area, resulting in the occurrence of multi-collinearity (So et al., 1997). Instead, we introduced bedroom dummies to impart higher flexibility, following the suggestion of Malpezzi (2003). The Pearson's coefficients associated with floor area and bedroom dummies in our data are less than 0.67. Last, the neighborhood herein is defined as traffic analysis zone (TAZ), a small area unit. There are 335 TAZ in the small context.

Table 3

Descriptive statistics of the housing dataset (N=22,586)

Variable	**Description**	**Mean**	**Std. Dev**
Control Variables			
Size	Floor area (m^2)	135.12	71.01
Age	-	10.33	5.91
Building height	Number of stories	20.11	11.66
Bedroom2-	Dummy variable, 1 for a property with 1 or 2 bedrooms, 0 otherwise	0.26	0.44
Bedroom3	Dummy variable, 1 for a property with 3 bedrooms, 0 otherwise	0.40	0.49
Bedroom4+	Dummy variable, 1 for a property with 4 or more bedrooms, 0 otherwise	0.34	0.48
Local environment	Dummy variable, 1 for a property in the residential district with good environment, 0 otherwise	0.64	0.48
Population density	Neighborhood fixed-effects variable (1000 residents/km^2)	16.80	9.60
Employment density	Neighborhood fixed-effects variable (1000 jobs/km^2)	15.98	16.29
School quality	Dummy variable, 1 for a property within the attendance zone of a high-quality school, 0 otherwise	0.13	0.33
Water body	Dummy variable, 1 for a property within 0.2 km of a body of water, 0 otherwise	0.10	0.29
BRT access	Road network distance (or transportation distance) to the closest BRT station (km)	2.02	1.45
Adjacency to elevated roads	Dummy variable, 1 for a property within 0.5 km of elevated roads, 0 otherwise	0.23	0.42
Explanatory variables: the local bus accessibility (to-bus accessibility)			
#Stop	Number of bus stops within a 0.5 km crow-fly distance from the residential estate's centroid	6.37	4.03
#Route	Number of bus routes within a 0.5 km crow-fly distance from the residential district's	22.17	17.05

	centroid		
Explanatory variables: the regional bus accessibility (by-bus accessibility)			
Zhongshan Road	Bus travel time to Zhongshan Road (min)	25.77	10.80
Wuyuan Bay	Bus travel time to Wuyuan Bay, an emerging city center (min)	15.87	9.35
Sea	Bus travel time to sea (min)	9.57	4.93
Primary school	Bus travel time to the closest primary school (min)	4.99	3.28
Shopping center	Bus travel time to the closest shopping center (min)	4.48	2.77

5. Results

5.1. OLS regression and Box-Cox transformation

A pairwise correlation analysis was performed to identify associations that exist between regressors. #Route was removed from all model specifications to avoid multi-collinearity for the regression analysis because of the extremely high positive correlation between #Stop and #Route (Pearson’s coefficient = 0.78). The estimation of hedonic pricing functions comprises four different model specifications (see Table 4). The double-log OLS model modified the dependent and independent variables by a natural log transformation and used the OLS method to calculate the coefficient associated with each variable. Note that in the double-log and Box-Cox models, seven variables (bedroom3, bedroom4+, local environment, school quality, water body, adjacency to elevated roads, #stop) were not transformed because they are not definitely positive.

All the four specifications show fairly satisfactory model fit. The both-side and one-side Box-Cox models show slightly higher goodness-of-fit than the OLS model. In addition, the variance inflation factor is extremely small (substantially below 10) for all variables (not reported herein). Moreover, all variables are significant at the 5% level and the signs of all coefficients are consistent with our expectations. All the Box-Cox transformation parameters are significantly different from 0 at the 1% level, thereby illustrating the nonlinearity in the model parameters. Compared with the pre-specified double-log function, which is very simple and easy to interpret, the Box-Cox transformed specifications improve the remainder term distribution, considerably fit the data, but increase the interpretation complexity.

Table 4

Regression results of OLS and Box-Cox transformed models

Variable	**OLS model (double-log)**		**Simple LHS Box-Cox model**		**Simple both-side Box-Cox model**		**Separate both-side Box-Cox model**	
	Coefficient	**t-statistic**	**Coefficient**	**t-statistic**	**Coefficient**	**t-statistic**	**Coefficient**	**t-statistic**
Size	0.905**	192.80	0.024**	167.26	1.055**	195.36	0.347**	196.47
Age	-0.107**	-40.84	-0.089**	-47.76	-0.174**	-43.65	-0.112**	-47.01
Building height	0.056**	21.41	0.014**	16.88	0.068**	18.39	0.031**	16.78
Bedroom3	0.063**	15.48	1.133**	62.66	0.098**	13.85	0.152**	26.57
Bedroom4+	0.130**	23.07	1.557**	63.43	0.213**	21.58	0.216**	26.86
Local environment	0.161**	31.79	0.778**	29.99	0.272**	30.55	0.228**	30.82
Population density	-0.049**	-13.22	-0.011**	-10.36	-0.068**	-13.24	-0.035**	-13.75
Employment density	0.040**	24.45	0.008**	13.17	0.066**	25.98	0.037**	25.03
School quality	0.081**	17.47	0.340**	14.54	0.137**	16.88	0.100**	14.80
Water body	0.010*	1.97	0.283**	11.24	0.021**	2.34	0.025**	3.35
BRT access	-0.108**	-40.09	-0.330**	-43.31	-0.201**	-41.68	-0.174**	-45.29
Adjacency to elevated roads	-0.106**	-17.29	-0.329**	-12.88	-0.199**	-18.45	-0.167**	-19.20
#Stop	0.004**	5.42	0.028**	8.07	0.007**	5.59	0.008**	8.06
Zhongshan Road	-0.059**	-12.05	-0.021**	-7.73	-0.080**	-11.14	-0.040**	-10.14
Wuyuan Bay	-0.042**	-18.11	-0.013**	-4.27	-0.064**	-16.73	-0.032**	-12.58
Sea	-0.080**	-28.70	-0.099**	-42.10	-0.139**	-32.56	-0.099**	-39.82
Primary school	-0.018**	-8.01	-0.042**	-14.94	-0.038**	-10.33	-0.036**	-14.62
Shopping center	-0.026**	-12.13	-0.014**	-4.37	-0.038**	-10.64	-0.017**	-6.84
Constant	2.590**	82.88	13.987**	109.69	3.314**	67.47	5.127**	148.71
λ	-	-	0.239**	41.33	0.088**	15.40	0.062**	10.87
θ	-	-	-	-	-	-	0.279**	31.99

Performance statistics				
R-squared	0.9086	0.8921	0.9098	0.9130
Adjusted R-squared	0.9086	0.8920	0.9097	0.9129

Notes: ** significant at the 1% level, * significant at the 5% level.

5.2. Spatial regression

A Moran's I test using the normality approach was conducted to test the spatial effects. The corresponding result implies that the spatial distribution of housing prices is not completely random and offers strong evidence of spatial autocorrelation existence (p-value < 0.05). The estimation of the coefficient associated with each variable is based on the maximum likelihood method. Table 5 displays the results of two spatial econometric models and shows that both alternatives accounting for spatial autocorrelation, nested with the OLS model, did outperform the OLS model, as reflected by a few model performance indicators. Furthermore, SEM with heteroscedasticity-corrected error estimates outperforms SLM. This result indicates that the SEM specification is the preferred approach to accounting for spatial autocorrelation for our data. That is, the dominating feature in the data is the spillover effects in the residuals.

In the SLM, the spatial dependence parameter ρ is positive and significantly different from 0. The positive sign implies the existence of adjacency effect, while the statistical significance indicates that the assumed spatial structure is representative of the existing spatial structure (Osland, 2010). The price of a property did affect the prices of other nearby properties because the market prices of properties are often set based on the price information of nearby houses (Cohen and Coughlin, 2008; Osland, 2010). All but one variables are significant at the 1% level. In the SEM, the statistical significance of ρ indicates the presence of spatial dependence in residuals. Moreover, the significance levels, signs, and magnitude of coefficient estimates are considerably similar in the two spatial econometric methods. All variables are significant at the 1% level.

Table 5

Regression results of the SLM and SEM

Variable	**SLM**		**SEM**	
	coefficient	**t-statistic**	**coefficient**	**t-statistic**
Size	0.900^{**}	192.75	0.885^{**}	207.83
Age	-0.104^{**}	-40.01	-0.135^{**}	-31.92
Building height	0.051^{**}	19.63	0.017^{**}	5.97
Bedroom3	0.065^{**}	16.04	0.048^{**}	13.97
Bedroom4+	0.130^{**}	23.26	0.087^{**}	18.10
Local environment	0.157^{**}	31.20	0.177^{**}	22.84
Population density	-0.047^{**}	-12.82	-0.057^{**}	-9.75
Employment density	0.040^{**}	24.45	0.034^{**}	12.40
School quality	0.076^{**}	16.56	0.088^{**}	11.88
Water body	0.009^{*}	1.77	0.040^{**}	4.88
BRT access	-0.107^{**}	-40.02	-0.122^{**}	-27.73
Adjacency to elevated roads	-0.108^{**}	-17.70	-0.124^{**}	-12.64
#Stop	0.004^{**}	5.42	0.005^{**}	5.22
Zhongshan Road	-0.063^{**}	-12.85	-0.073^{**}	-9.12
Wuyuan Bay	-0.042^{**}	-18.16	-0.043^{**}	-10.46
Sea	-0.080^{**}	-28.82	-0.080^{**}	-17.90

Primary school	-0.017**	-7.56	-0.025**	-6.63
Shopping center	-0.027**	-12.61	-0.018**	-5.18
Constant	2.564**	82.46	2.925**	72.95
ρ	0.011**	16.79	0.615**	103.73
Performance statistics				
R-squared	0.9098		0.9399	
AIC	-10542.4		-17530.5	
BIC	-10381.9		-17378.0	

Note: ** significant at the 1% level, * significant at the 10% level.

The contribution of all variables was determined to be substantially similar and highly consistent across all six specifications. Nearly all control variables are significant and exhibit the expected sign. In addition, the coefficient associated with age is negative, thereby indicating that older properties are more affordable. A possible explanation is that older properties are generally inferior in quality compared with newer houses. Moreover, the school quality premium is estimated to be 9.2% (= $e^{0.088}$-1). That is, properties located within the attendance zones of high-quality schools (学区房) exhibit 9.2% higher values than properties located outside of these areas, *ceteris paribus*. This outcome is consistent with those of Yang et al. (2018a). Furthermore, the effect of being located within 200 m of a body of water on housing prices has been identified. The coefficient of water body is estimated to be 0.040 in the SEM model. This finding illustrates that properties located within a 200 m buffer of a water body have values that are 4.1% (= $e^{0.040}$-1) higher than properties located outside of this buffer area. Lastly, the property markets on Xiamen Island have been determined to value the BRT access. The BRT access elasticity is estimated to be –0.122 after controlling for the spatial autocorrelation.

The six bus accessibility measures are fairly robust across all model specifications and they are associated with housing prices. The local accessibility measure (#Stop) is statistically significant at the 1% level (even after controlling for spatial autocorrelation) and has a positive sign. This result implies that local bus accessibility is associated with housing values and contradicts the conventional wisdom: buses are insufficient to offer appreciable accessibility benefits. The price effect of a one-unit increase in (or marginal effect of) #Stop is calculated to be 38.35 thousand Yuan by multiplying the corresponding coefficient with the mean property value. Note that this variable also obtains a few of the price effects of #Route variability because of the high multi-collinearity between them. Moreover, the bus regional accessibility to essential destinations (i.e., Zhongshan Road, Wuyuan Bay, the sea, primary school, and shopping center) measured by the bus travel time significantly affects housing prices. Their estimated parameters consistently take negative signs, thereby implying that the houses with good bus regional accessibility exhibit high values. An interesting finding is that close proximity to the sea (elasticity = –0.080) has a slightly higher price premium than proximity to Zhongshan Road (elasticity = –0.073), which is often deemed as the traditional city center. Given the rapid urbanization (500 million population urbanized from 1980 to 2010) and social/economic diversification, the urban spatial structure of numerous Chinese cities has developed from monocentric to polycentric. Xiamen is by no means an exception in this regard: Zhongshan Road has gradually lost the city center status. Moreover, the elasticities of the bus regional accessibility to Wuyuan Bay, primary school, and shopping center are considerably small.

5.3. Robustness checks

The preceding results have validated that key variables of interest are extremely robust across all model specifications. With an aim of further verifying coefficient robustness and plausibility, gaining confidence in the performance of key variables, and/or confirming how certain core regression coefficients estimated behave, we decided to conduct three robustness check analyses: (1) removing non-critical core variables to simplify the regression specification. A considerably simple SEM with only three key variables (i.e., size, age, and local environment) and six bus accessibility variables is developed. (2) using the price per meter square as the predicted variable of an SEM so as to remove the dominating role of size in determining the gross price of a property. (3) introducing the independent variables step by step. At Step 1, only structural variables are introduced to an SEM while other variables other than bus accessibility variables are added at Step 2. Finally (Step 3), the formerly included variables and six bus accessibility measures are considered simultaneously.

Table 6 shows the corresponding results. The outcomes of robustness check analysis 1 and 2 show that no evident change in signs and significance levels of all variables and the spatial dependence parameter. Moreover, the goodness-of-fit of the model with the predicted variable of price per meter square is modestly high, comparable to that of a similar study of Zhang and Kahn (2008). In addition, we can see incremental model fit (and thus better model performance) with more contributors included. The full model (see Table 5) outperform the model without bus accessibility measures, which indicates bus accessibility contributes to explaining variation in property prices. Therefore, the main result of this study is robust and plausible and we can infer its structural validity.

Table 6

Results of robustness check analyses

Variable	**Robustness check analysis 1**		**Robustness check analysis 2**		**Robustness check analysis 3 (Step 1)**		**Robustness check analysis 2 (Step 2)**	
	Coefficient	**t-statistic**	**Coefficient**	**t-statistic**	**Coefficient**	**t-statistic**	**Coefficient**	**t-statistic**
Size	0.978**	309.65	-	-	0.714**	153.02	0.652**	119.32
Age	-0.138**	-52.56	-0.126**	-29.98	0.909**	202.14	0.886**	204.30
Building height	-	-	0.018**	6.15	-0.163**	-41.55	-0.121**	-28.50
Bedroom3	-	-	-	-	0.048**	15.39	0.023**	7.84
Bedroom4+	-	-	-	-	0.042**	11.75	0.048**	13.72
Local environment	0.195**	32.66	0.162**	21.03	0.078**	15.34	0.088**	18.05
Population density	-	-	-0.051**	-8.71	-	-	0.166**	30.40
Employment density	-	-	0.035**	12.81	-	-	-0.097**	-19.86
School quality	-	-	0.078**	10.49	-	-	0.036**	13.94
Water body	-	-	0.021**	2.59	-	-	0.149**	19.86
BRT access	-	-	-0.120**	-27.44	-	-	0.102**	12.41
Adjacency to elevated roads	-	-	-0.123**	-12.50	-	-	-0.110**	-25.27
#Stop	0.007**	9.26	0.005**	4.59	-	-	-0.083**	-8.24
Zhongshan Road	-0.185**	-39.70	-0.070**	-8.71	-	-	-	-
Wuyuan Bay	-0.073**	-25.66	-0.043**	-10.64	-	-	-	-
Sea	-0.046**	-19.92	-0.078**	-17.45	-	-	-	-
Primary school	-0.006*	-2.21	-0.024**	-6.34	-	-	-	-

Shopping center	-0.032**	-12.87	-0.024**	-6.96	-	-	-	-
Constant	2.770**	106.64	2.392**	68.01	-	-	-	-
ρ	0.448**	73.28	0.600**	98.51	2.241**	89.49	2.440**	89.33
Performance statistics								
R-squared	0.9133		0.6693		0.9314		0.9374	
AIC	-9761.5		-16813.7		-13544.5		-16297.2	
BIC	-9681.3		-16685.3		-13496.4		-16192.9	

Note: ** significant at the 1% level, * significant at the 5% level.

6. Discussions and Conclusions

Public transport is gaining increasing attention as an imperative, resource-saving, and low-carbon travel mode. In bus-served cities, regular bus accounts for the fairly high proportion of trips. Therefore, the significance of bus to inhabitants in these cities is larger than that in car-dominant cities, and thus bus accessibility may positively affect housing prices. Unlike fixed guideway transit options, which are capable of affecting urban land use and of serving broader urban-planning objectives, the effect of bus on housing prices is rather elusive. Moreover, previous studies have produced mixed, even conflicting results and findings in various settings.

We adopted the two-component modeling approach of the bus accessibility and utilized a set of hedonic pricing models (i.e., one pre-specified OLS model, three Box-Cox regression models, and two spatial econometric models) to empirically estimate the capitalization benefits of bus accessibility in Xiamen, a bus-served city. In sum, our findings are as follows. (1) Housing price variations can be explained by bus accessibility. (2) Local bus accessibility is incorporated into housing prices and residents have a high willingness to pay for this. This result disagrees with the mainstream idea that buses are insufficient to offer appreciable accessibility benefits. We suspect that Xiamen is not an exception and our findings may apply to other bus-dependent cities. In car-dominant cities, people rarely use buses but prefer automobiles; hence, the effects of buses on property values may be inappreciable (Munoz-Raskin, 2010). (3) The regional bus accessibility to essential destinations significantly affects housing prices. (4) Spatial econometric models can provide an improved explanation of price variances, thereby justifying the necessity of spatial econometric methods. Understandably, bus travel times from properties to essential destinations, acting as the regional bus accessibility variables in this study, are at least modestly correlated to physical distances. We also attempted to replace the bus travel time variables with physical-distance-based variables for another econometric model. The modeling result is very similar to that of our reported models, and the local bus accessibility measure (#Stop) remains significant at the 1% level. Moreover, a slight decrease in model fit is found, which, to some extent, justifies our use of regional bus accessibility variables (instead of introducing pure physical distance regressors) and provide some evidence for robustness of local bus accessibility's effect.

Accessibility enhancement because of public investment in bus infrastructure is determined to increase housing values. However, residents in Urban China can freely enjoy the benefits of bus service improvements because of institutional limitations (e.g., lack of property tax). In the foreseeable future, municipal governments could attempt to formulate policy measures to recoup property price increments due to infrastructure provision to cover, at least a portion of, the infrastructure cost, which is currently covered by a single tool, namely, land's lease revenue. Nonetheless, this financial tool may be inappropriate, particularly for redeveloped land. Methods of obtaining these increments for revenue-generating should be extensively discussed and explored in the immediate future.

Investment in bus services can enhance accessibility and has repercussions on property prices. Two possible explanations of the bus accessibility's substantial effects in bus-dependent cities are as follows. (1) Outstanding bus service quality, including reliable, efficient, secure, affordable, and frequent services, well-developed and sophisticated transport network, and considerable spatial and temporal coverage. These favorable and desirable characteristics collectively contribute to high bus ridership (31.7% in Xiamen, as compared to 3.6% in Germany and 1.4% in the United States. see Buehler and Pucher, 2012). (2) Intra-regional variability arises from differential accessibility to and by bus services.

Chinese and other Asian transit-dependent cities have been traditionally characterized by high-density, mixed land uses, pedestrian-oriented urban design, low rates of car ownership, and high levels of transit usage. This situation continues to be the case even in the most highly developed Asian cities, such as Hong Kong, Tokyo, and Seoul. However, many current land development strategies in China (e.g., gigantic housing projects, isolated superblock development enveloped by wide streets, single-use industrial zones, and new development zones) emphasize the spatial separation of land uses (or specialized land-use pattern). The change from *danwei*-dominant, organically evolved, mixed-use urban form to car-oriented, large-scale land-use pattern can be clearly identified (Cervero, 2013). The substantially complex underlying reasons for this development are as follows: establishment of many new development zones on farmland that could be acquired more easily and cheaply, pro-growth local governments that oversupplied industrial land, and urban public finance that relied heavily on profits of leasing state-owned land, to name a few (for more details, see Wei et al., 2009; Wu, 2015; Zhou et al., 2016). Such development pattern leads to immense travel distances, enlarged travel footprints, and declining attractiveness for bus travel. Improved coordination of transportation and land use has become overwhelmingly indispensable at the current stage of economic development. Cervero (2013, p. 7) explained such concerns as “whatever progress [developed countries] make in reducing greenhouse, gas emissions (GHG) and fuel consumption will be quickly eclipsed if rapidly growing countries like India, China, and Brazil continue to mimic American-style patterns of suburbanization, car ownership, and travel.”

Since 2011, the Ministry of Transport of China has initiated to fund many cities for building transit metropolises (公交都市) (Ministry of Transport, 2011). Xiamen was selected as one such city. The continuous implementation of transit-enhancing policy measures in the coming years will enable bus services to possibly improve further, thereby possibly decreasing the intra-regional variability in bus accessibility. The operation of the metro, expansion of BRT, and widespread use of bicycle-sharing services would enable buses to gradually serve minimal transportation demands and lose ground to other transit options, thereby suggesting that its role and significance would decline. The argument of Shyr et al. (2013) based on the comparison of cross-sectional hedonic models in three cities (i.e., Hong Kong, Taipei, and Kaohsiung) indicated that the price premium induced by transit accessibility could diminish as urban transit accessibility increase. We feel that in the preceding circumstances (i.e., declining attractiveness of bus travel and decreased intra-regional variability in bus accessibility), the bus accessibility price premiums would be gradually decreased and even diminished eventually. Accordingly, a rigorous and sophisticated before-after (or ex-post) or longitudinal study is recommended in future research to test the two hypotheses. Furthermore, a host of databases in China are proprietary (owned by either governments or corporations) and thus inaccessible to the general public (Yang et al., 2018b). Given data unavailability, some potentially influencing variables (e.g., income, education level, the crime rate of the neighborhood, sea view) were excluded. We can explore the contribution of these variables in the future research. Lastly, the definition of neighborhood herein is based on the TAZ. However, neighborhood is a vague concept in China case. More neighborhood definition methods even with Chinese characteristics (e.g., Wu, 1992) can be explored, if with sufficient data.

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APPENDIX

See Tables A1 and A2

Table A1

Correlation matrix variable codes

Variable	**Code**
Size (log)	C1
Age (log)	C2
Building height (log)	C3
Bedroom3	C4
Bedroom4+	C5
Local environment	C6
Population density (log)	C7
Employment density (log)	C8
School quality	C9
Water body	C10
BRT access	C11
Adjacency to elevated roads	C12
#Stop	E1
Zhongshan Road	E2
Wuyuan Bay	E3
Sea	E4
Primary school	E5
Shopping center	E6

Table A2

Correlation matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	E1	E2	E3	E4	E5	E6
C1	1.00																	
C2	-0.36	1.00																
C3	0.32	-0.58	1.00															
C4	-0.04	0.14	-0.13	1.00														
C5	0.67	-0.27	0.25	-0.59	1.00													
C6	0.42	-0.43	0.28	-0.06	0.29	1.00												
C7	-0.32	0.34	-0.25	0.05	-0.25	-0.37	1.00											
C8	-0.38	0.67	-0.32	0.11	-0.32	-0.49	0.62	1.00										
C9	0.12	-0.01	0.14	-0.02	0.06	-0.09	0.28	0.24	1.00									
C10	0.14	-0.01	0.05	0.04	0.03	0.07	-0.19	-0.06	0.02	1.00								
C11	-0.02	0.15	-0.28	0.02	-0.01	-0.05	-0.27	-0.04	-0.09	0.06	1.00							
C12	-0.04	0.00	0.12	0.01	-0.04	-0.10	0.32	0.19	0.15	-0.15	-0.81	1.00						
E1	-0.36	0.44	-0.20	0.07	-0.26	-0.79	0.48	0.61	0.22	-0.16	-0.11	0.33	1.00					
E2	0.06	-0.24	-0.05	-0.01	0.06	0.19	-0.53	-0.52	-0.44	0.05	0.35	-0.44	-0.42	1.00				
E3	-0.19	0.41	-0.14	-0.01	-0.11	-0.28	0.56	0.57	0.27	-0.35	-0.12	0.27	0.48	-0.67	1.00			
E4	-0.30	0.06	-0.16	0.04	-0.24	-0.28	0.60	0.33	0.01	-0.20	-0.24	0.17	0.23	0.04	0.22	1.00		
E5	0.15	-0.37	0.22	-0.03	0.11	0.25	-0.41	-0.44	-0.29	-0.03	-0.03	-0.04	-0.27	0.42	-0.25	-0.05	1.00	
E6	0.31	-0.31	0.20	-0.02	0.16	0.46	-0.20	-0.42	-0.02	-0.01	-0.05	0.01	-0.37	0.18	-0.08	-0.09	0.31	1.00