Accessibility, urban form, and property value: A study of Pudong, Shanghai

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Abstract

The effects of metro system development and urban form on housing prices are highly depend on the spatial temporal conditions of the urban neighborhoods. However, scholars have not yet comprehensively examined these interactions at a neighborhood-scale. This study assesses metro access, urban form, and property value at both district- and neighborhood-levels. The study area is Pudong, Shanghai where metro system development has coincided with rapid urban growth. Two hundred and seventy-nine neighborhoods from 13 districts of Shanghai are randomly selected for the district-level investigation and 31 neighborhoods from Pudong are selected for neighborhood-level investigation. The analysis of variance shows that metro access is more positively correlated to property price in Pudong than other districts. The Pearson correlation, principle component, and ordinary least square regression analyses show that while accessibility attributes have positive influence on housing prices, neighborhood characteristics also exhibit pronounced impact on property price change over time. The present study extends our knowledge on how metro system development interacts with land use efficiency and discusses planning policies that correspond to different stages of development.

Keywords

Urban form; urban neighborhood; accessibility; property value; metro system; Shanghai

1. Introduction

Rapid transit, especially metro systems, have influenced urban growth and property values, producing a diversity of urban forms and city patterns (Smith, 1986). Some of the resulting spatial forms are more environmentally sustainable by inspiring low-carbon travel, promoting land use efficiency, and encouraging building type diversity. Further investigations on the interactions of metro accessibility, urban form, and property value are in urgent need to address the challenges associated with global urbanization (The World Bank, 2010).

Previous studies recognize that metro systems have significant impact on urban forms and formations (Pan et al., 2009; Srinivasan, 2010). In the past century, transportation systems have dramatically changed urban landscapes (Smith, 1986), especially metro systems which interact with market forces and inform land use policies in the long run. Scholars have studied the relationship between metro system accessibility and residential neighborhood property values in a variety of context (Hess and Almeida, 2007; Dong, 2017). Most researchers conclude that property values go up as neighborhoods get closer to metro stops (Pan, 2013; Zhong and Li, 2016). However, the relationship between neighborhood-scale urban form and metro transit is less conclusive and the question of how neighborhood-scale urban form and metro system accessibility interact with property values has not been thoroughly explored (Pan et al., 2009; Yang et al., 2016). For example, if the property value of an existing neighborhood, conveniently located near metro stops, is high, should future neighborhood developments be denser and/or more diverse? A number of physical, social, and economic variables should be considered regarding land use planning, metro system investment, and real property development (Cao, 2009; Yang, 2010; Wang and Zhou, 2017).

This study aims to investigate the interactions among metro system accessibility, residential property value, and neighborhood-scale urban form by answering the following question: What urban planning strategies can promote more efficient urban spatial structure? The next section briefly reviews the current literature on accessibility, property value, and urban form. The methodology section addresses explanatory variables. The results section presents our findings. The first discussion section focuses on accessibility and urban form and policy implications. The second discussion section focuses on the jobs-housing relationship, public service, and sustainable urban spatial structure. The conclusion section presents caveats and recaps the key contributions.

2. Literature review

Metro transit has been a consistent factor in creating a diversity of urban forms (Smith, 1986; Li et al., 2010). From the simple linear shape of Baltimore and Mumbai to the advanced circle-radial shape of Beijing and London, and the more recent grid network of Guangzhou and Shenzhen, the typologies of the metro system and urban development are closely connected (Angel, 2012). In the 1980s, large cities like Hong Kong and Singapore were developing their metro transit systems with high-density residential neighborhood already in place (Smith, 1986; Yang et al., 2016). In the 2000s, many large cities were developing and/or expanding extensive metro transit networks simultaneously with urban expansion and re-intensification.

In China, the superimposed and the concurrently-developed metro systems co-exist in large cities like Beijing and Shanghai (the former means a metro system was established after rapid urban expansions and the latter means both happened at the same time). This special circumstance having to do with the stage of development during which the metro system was built produces spatial conditions and urban forms that respond to metro system accessibility and property values.

The most studied dimensions include accessibility to transport facility (Hess and Almeida, 2007; Cao, 2009; Yang, 2010; Wang et al., 2011; Ma et al., 2015; Yang et al., 2016; Dong, 2017; Guan, 2018), neighborhood typologies (Wang and Chai, 2009; Feng et al., 2013; Zhao, 2014; Guan and Rowe, 2016), and built environment characteristics (Pan et al., 2009; Srinivasan, 2010; Yang and Chen, 2014).

Historically, accessibility to transport facility was a determinant of land development and economic growth (Smith, 1986). Bus service, including Bus Rapid Transit (BRT), light rail, and street cars are all traffic-dependent and the lack of long term stability means that they aren't suitable to be a "catalyst of development" in Chinese cities (Smith, 1986; Pan et al., 2009). Metro systems, on the other hand, can support Transit Oriented Development (TOD) that attracts investment and population because of its long-term stability and operational efficiency (Yang et al., 2016; Dong, 2017).

Many cities in China have observed this changing relationship between accessibility and urban form (Pan et al., 2009). Accessibility to existing metro stops, especially in high density areas, can produce robust ridership and reduce ongoing expenses (Yang et al., 2016). On the other hand, access to future proposed metro stations can change urban development patterns through land use right transfer and potential increases in local government revenues (Yang, 2010). Under the pro-growth policy of the National Development and Reform Commission (NDRC), the metro stations proposed and under construction are continuing to reshape the urban form of Chinese cities. Distance to the closest station and time traveled to city centers are both critical concerns. For example, living closer to a metro station can significantly change people's travel behavior (Wang and Zhou, 2017).

Other studies reveal that proximity to city centers via metro have stronger influence on travel behavior than land use patterns (Ma et al., 2015). Accessibility to employment is often considered in studies of the Chinese urban built environment (Yang et al., 2012). In recent years, low job accessibility has been observed in some parts of major Chinese cities such as Beijing (Yang, 2006) and Shanghai (Pan et al., 2009) due to suburbanization and increase in car ownership. The resulting longer commute time has encouraged people to live closer to metro stations (Yang et al., 2016).

In developed countries, neighborhood characteristics can be summarized into five D's: density of residential population, diversity of land use, design of urban block, distance to public transit, and destination of access (Ewing and Cervero, 2010; Cervero 2013).

In the Chinese circumstance, two C's are added to reflect local conditions: compactness measured by overall conservative building footprints that are less invasive of the surrounding environment, and connectivity measured by spatial proximity, physical closeness, and distance to culture (Guan and Rowe, 2016). Population density is a key determinant for property development and land value (Peiser, 1989; Yang, 2010; Zhao, 2014; Guan and Rowe, 2016). It is often regulated through zoning ordinances and planning policies which impose limits on building density as measured by floor area ratios (FAR). In Shanghai, most of the recent developments have FARs higher than 2.0. Some high-rise development can reach 10 or even higher. Chinese cities, in general, also have larger block-sizes and neighborhood size. The implications of the number of residential units in each neighborhood and the site area have not yet been thoroughly studied (Wang and Zhou, 2017). Large developments can attract retail, commercial, and other public amenities. On the other hand, the scarcity of available large land parcels can potentially push larger development projects to the outskirts with reduced metro accessibility and longer travel time to city centers. In recent years, homogeneous building typologies in large development projects have received a large amount of criticism. In response, mixed-use developments are encouraged. Different types of neighborhoods can have far-reaching effects on property values. Neighborhoods can be categorized by binary variables such as location (urban versus suburban), density (high versus low), and year built (old versus new) (Handy et al., 2005). In China, neighborhoods are also often classified by their historical context (work unit versus non-work unit), social-economic class (market versus welfare), and spatial configurations (conventional versus modern) (Wang et al., 2011).

Built environment characteristics including urban amenities, educational institutions, and public services are all important concerns for housing prices. In China, urban amenities are provided best in the inner-city areas (Zhao et al., 2011). Schools, fresh food markets, hospitals, child care, and senior housing all contribute to a positive proximity premium. These facilities often attract relatively high-income population (Zhao et al., 2011). With a cultural heritage of placing high value on education, housing prices go up in top school districts. Convenient access to fresh food markets, an important component of Chinese urban residence since the post-reform period, has been challenged by continuous urban expansion. However, the growing concern about the health benefits of food and the highly consolidated fresh food e-commerce have re-boosted consumer demand. As health issues become a growing concern, hospitals, especially those ranked as “first-class grade three”, are in short supply and tend to attract senior living communities close by. The changing population pyramid and the change of one-child policy both contribute to increasing demand for facilities such as child care and senior housing. By Chinese cultural standards, certain facilities create negative proximity premiums. To name a few, chemical factories, trash dumpsters, and waste disposal are all non-desirables.

In general, Chinese urbanization has distinct features compared with its western counterpart. Understanding the interactions among metro access, urban form, and property value needs not only to establish statistical associations but also to recognize the evolution of urban growth and neighborhood development. As Boarnet (2011) describes, it is fundamental to understand how a community's built environment has been developed in a specific way. The late 1980s marked the beginning of Chinese cities' rapid urbanization. Most of the urban neighborhoods inherited a *work unit* type of spatial configuration, a place of employment and residency. A common work unit has its own schools, shops, post offices, and other services. In the 1990s and early 2000s, economic growth was accompanied by a huge surge of metro system development: Shanghai (1993), Guangzhou (1997), Dalian (2002), Wuhan (2004), and Nanjing (2005) all established their metro systems. Together with the reopening of the metro systems in Beijing and Tianjin, major Chinese cities were experiencing reorganizations of the jobs-housing relationship. The market-oriented property developments were replacing traditional work unit neighborhoods. In cities where existing population density is high, accessibility to job and residential location choice create the underlying conditions for equilibrium of jobs-housing balance or nonequilibrium of spatial mismatch. By 2016, backed by the NDRC, 30 cities in mainland China have metro systems under operation and over 40 smaller cities with population between 1.5 to 3 million have received approval and financial support from the central government to develop metro systems. This is a critical moment for rapidly urbanizing Chinese cities to find balance between rapid transit investment and urban growth.

3. Methodology

3.1. Neighborhood selection

The main objective of this study is to discover the distribution pattern of neighborhood property value and metro access and then to apply urban form variables to explain the differences. In China, urban areas are divided into district (Qu), sub-district (Jiedao), and residential communities (Shequ), from large to small. Each residential community is composed of multiple residential neighborhoods (Xiaoqu). A neighborhood is regarded as the smallest division or a micro-district. A neighborhood often covers one or more urban blocks, built by a single developer, enclosed by walls or fences with guarded gates, and has its own neighborhood association. Our study area includes 13 districts of Shanghai that are accessible by metro lines. There are 10 central districts - Huangpu, Xuhui, Changning, Putuo, Zhabei, Yangpu, Jiang'an, Luwan, Hongkou, and Pudong (Zhabei and Luwan have been merged to Jing'an and Huangpu respectively) and 3 outer districts – Baoshan, Minhang, and Jiading. 279 neighborhoods are randomly selected for the study based on the location of metro stations. The random selection applies a computer-aided random sampling process involving the subsequent steps: In each district, those sub-districts served by metro are identified. For example, in Pudong District, 20 out of 31 sub-districts are identified. In each sub-district, all neighborhoods are assigned unique numbers. For example, in the Century Park Jiedao of Pudong District, 112 neighborhoods are labeled with numbers and put into the random sampling process. Initially, 35 neighborhoods are assigned to each of the 13 districts, which make the total amount to 455 neighborhoods. After the random sampling, ineligible neighborhoods are eliminated either because of insufficient data or limited number of residential unit transactions. After elimination, the total number is brought down to 279. The number of selected neighborhoods for each district ranges from 17 in Jiading to 31 in Pudong.

3.2. Statistical Analysis

A series of statistical analyses were applied including analysis of variance (ANOVA), pairwise correlation analysis, principle component analysis (PCA), and ordinary least square (OLS) hedonic regression analysis. We first employed the one-way ANOVA model, providing statistical inference for comparing multiple group means, to test the average resale residential property price and accessibility to metro station by district. As one of the most useful techniques in statistical inference introduced by Ronald Fisher, ANOVA has been applied as an exploratory tool to explain observations (Montgomery, 2001). We then applied a pairwise correlation test to reveal the associations among variables and if statistical data reduction is necessary. The Pearson test is adopted because it measures the linear correlation between two variables and provides an unbiased estimate when the adjusted correlation coefficient is used (Corder and Foreman, 2014). In addition, the Spearman test (1904) is adopted to assess monotonic relationships for non-linear relationships (Corder and Foreman, 2014). Furthermore, the OLS and PCA analysis were applied to understand how accessibility affects residential property price and to reveal how the internal structure of urban form and access can best explain the variance in price. PCA is selected for this study also because of its integration with Geographic Information System (GIS) in recent years (Petrisor et al., 2011).

First, analysis of variance is performed to reveal the different relationships between property value and metro accessibility at the district level. One-way ANOVA models were applied to test the differences among group means. Model 1 compares the average resale prices among the 13 districts. Model 2 compares access from residential property to city centers by metro. Model 3 compares the ratio of price over access by districts, which measures the relationship between price and access. Model 4 compares access by price and district. The formula can be written as:

$$V_{ij} = \mu_j + \varepsilon_{ij} \qquad \text{Eq. (1)}$$

where μ_j = mean of the jth population, $\mu_j = \mu + \tau_j$, μ is the overall mean of the combined populations, τ_j is the deviation of the group mean from the overall mean, and ε_{ij} is the random error term. The ANOVA tests reveal that neighborhoods in Pudong display different distribution patterns compared to other districts, which leads to further neighborhood-scale investigation of Pudong.

A pairwise correlation test is performed among the selected attributes using Pearson's correlation test. Spearman's correlation test is also applied to variables with ordinal numbers. The high correlations among the variables necessitate statistical data reduction. PCA methodology was adopted to inspect the underlying data structure and to produce a series of uncorrelated linear combinations of the variables that contain most of the variance. The formula is shown as the following:

$$F_{ij} = a_i * b_j + e_{ij}, \text{ i=1 to n, j=1 to p} \qquad \text{Eq. (2)}$$

where F_{ij} are the elements of the matrix F, a_i (scores) and b_j (loadings) are f-vectors of parameters, and e_{ij} are independent homoscedastic residuals. A resampling method called Bootstrapping was also performed to test the stability of the results.

The PCA tests constructed a smaller set of important factor variables. These variables were then applied to the OLS hedonic regression models. The purpose of the regression analysis is to find out which of the factors can explain the dependent variable – price and price change. The formula is presented as the following:

$$\rho_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_j x_j + \mu \qquad \text{Eq. (3)}$$

where ρ_i is the price at a point in time and price change over time, i=1 to 5; x_j is the explanatory variables, j=1 to 28; u is the error term.

3.3. Attribute selection

As mentioned earlier, metro systems can be the catalyst of development supporting TOD and producing high compactness in urban form (Diao et al., 2017; Guan, 2017; Zhu and Diao, 2016). Thus, capturing property price increases attributable to metro accessibility is a key factor to understand sustainable neighborhood configuration (Diao, 2015). In addition, access to city centers, employment centers, and other transit facilities should also be considered. Moreover, a temporal dimension should be added to the discussion of property price, urban form, and accessibility. Therefore, multiple year prices and price changes are incorporated into this research. Moreover, not all urban form characteristics affect property price and access in the same way (Diao and Ferreira, 2010). Some attributes represent the conditions of external environments and others are internal structure of the built environment. In this research, 28 attributes were collected for the 31 neighborhoods selected in Pudong. The definitions of the attributes are listed in **Table 1**. The price data are collected from online real estate open source platforms (www.fang.com). The accessibility attributes are calculated using time-distance analysis (time to centers and distance to stations) and counted using ArcGIS analysis (bus, high-rise office, and commercial). The location of the high-rise office and commercial buildings are collected by the authors. The urban form attributes are acquired from both online real estate platforms and spatial analysis conducted by the authors. The attributes can be divided into the following categories: price (p), accessibility (a), and urban form. Urban form can be subdivided into form of surrounding environment (e) and built condition of the neighborhood (n). Price includes five variables: average resale price in 2012 (p1), 2017 (p2), 5-year price change from 2012 to 2017 (p3), 1-year price change (p4), and 1-month price change (p5). Accessibility includes seven variables: time to the city center (a1), distance to the closest metro station (a2), the number of current metro stations within 1km radius (a3), the number of future planned metro stations within 1km radius (a4), bus stops within 1km radius (a5), high-rise office buildings (a6), and commercial enterprise (a7). Environmental variables include the number of non-desirable facilities (e1), kindergartens (e2), schools (e3), colleges (e4), level of security (e5), hospitals and clinics (e6), public services (e7), banks (e8), fresh food markets (e9), parks within 500m (e10). Neighborhood variables include neighborhood types (n1), building types (n2), density (n3), green space (n4), year built (n5), property management (n6), the number of residential units (n7), nearby residential neighborhoods (n8), parking per unit (n9), neighborhood entry gates (n10), and site area (n11).

Table 1. Definitions of the 28 attributes.

Category		Variable	Definition
Price	P1	Average Price (2012)	The average resale price of the selected neighborhoods in 2012
	P2	Average Price (2017)	The average resale price of the selected neighborhoods in 2017
	P3	Price Change 5 years	The average resale price difference between 2012 and 2017
	p4	Price Change 1 year	The average resale price difference between 2016 and 2017
	p5	Price Change 1month	The average resale price difference within one month in 2017
Accessibility	a1	Time to Centers	Travel time to city centers (minute)
	a2	Dist. to Station (km)	Distance to the closest metro station
	a3	Current Station 1km	The number of existing metro stations within 1km radius
	a4	Future Station 1km	The number of future planned metro stations within 1km radius
	a5	Bus 1km	The number of existing bus stops within 1km radius
	a6	High-rise Office	The number of high-rise offices within 500m radius
	a7	Com.	The number of commercial buildings within 500m radius
Urban Form - Surrounding Enviornment	e1	Non Desir.	The number of non desirable facilities within 500m radius
	e2	Kindergarten	The number of kindergartens within 500m radius
	e3	School	The number of schools within 1km radius
	e4	College	The number of colleges within 1km radius
	e5	Secur.	The level of security system installed
	e6	Hosp. Clinic	The number of hospitals and clinics within 1km radius
	e7	Social Serv.	The number of social service facilities within 1km radius
	e8	Bank	The number of banks within 1km radius
	e9	Fresh Food	The number of fresh food markets within 1km radius
	e10	Park (500m)	The number of parks within 500m radius
Urban Form - Built Condition of the Neighborhood	n1	Neigh. Type	The variety of neighborhood typologies in the abutting area
	n2	Build Type	Types of buildings based on spatial form and functionality
	n3	Density (FAR)	Building density based on floor area ratio
	n4	Green Space	Percentage of green and open space
	n5	Year Built	The year that the neighorhood is first developed
	n6	Prop. Fee (RMB)	Property management fee per month in Chinese Yuan
	n7	Resi. Units	The number of residential units
	n8	Nearby Reside. Comm.	The number of residential community within 1km radius
	n9	Parking	The number of parking space per residential unit
	n10	Main Gates	The number of gates
	n11	Site Area (ha)	The area of land in hectare

4. Results and analysis

4.1 Analysis of variance in Shanghai

Figure 1 shows the spatial distribution of the 279 selected neighborhoods in Shanghai. The black bar represents price and white bar represents access. Visual inspections show that black bars are higher than white bars in the inner districts while the opposite happens in the outer districts. The explanation can be that property prices are higher in the inner districts and residential property developments are more influenced by TOD in the outer districts. Further investigations were performed to reveal the relationship between property price and metro accessibility using the analysis of variance (ANOVA) models.

Table 2 summarizes the results of the ANOVA models. Model 1, 2, and 3 exhibit high values for the F-test, which means price, travel time, and the ratio of price over access by district all produce good fits. The results of model 4 show that only districts show high variation that is statistically significant. It means districts at different development stages have different levels of accessibility to city centers. To unfold which district appears to have the most consistent price to access relationship, the underlying regression coefficients were examined. The regressions show that Pudong, the baseline group, has the largest variation of price to access relationship and the longest access time to the city centers, see **Table 3**. The next step is to further investigate why and how neighborhoods developed in Pudong districts are different from other districts in Shanghai.

Table 2. Access, price, and district (ANOVA test).

Model		Partial SS	df	F	Prob>F	R-squared	Adj.
1 Price	District	2.46E+10	12	11.21	0.0000	0.3360	0.3060
2 Access	District	4226.19	12	33.18	0.0000	0.5995	0.5814
3 Price/Access	District	175.48	12	43.78	0.0000	0.6639	0.6487
4 Access	Price, District	6492.83	221	3.01	0.0000	0.9210	0.6146
	Price	2266.64	209	1.11	0.3277		
	District	495.26	12	4.22	0.0001		
	Residual	557.07	57				
	Total	7049.90	278				

Table 3. Access and district (ANOVA test).

District	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Pudong	0 (base)					
Huangpu	-12.989	2.183	-5.95	0.0000	-17.3600	-8.6189
Xuhui	-10.320	2.064	-5.00	0.0000	-14.4529	-6.1878
Changning	-11.117	2.415	-4.60	0.0000	-15.9524	-6.2821
Putuo	-10.685	2.110	-5.06	0.0000	-14.9105	-6.4597
Zhabei	-12.086	2.131	-5.67	0.0000	-16.3541	-7.8179
Yangpu	-11.919	2.016	-5.91	0.0000	-15.9560	-7.8829
Jing'an	-12.497	2.928	-4.27	0.0000	-18.3602	-6.6335
Luwan	-12.383	2.204	-5.62	0.0000	-16.7962	-7.9703
Baoshan	-8.727	2.278	-3.83	0.0000	-13.2900	-4.1650
Minhang	-11.167	2.436	-4.58	0.0000	-16.0450	-6.2898
Hongkou	-11.970	2.017	-5.93	0.0000	-16.0092	-7.9300
Jiading	-10.447	3.731	-2.80	0.0070	-17.9186	-2.9763
_cons	26.307	4.868	5.40	0.0000	16.5603	36.0546

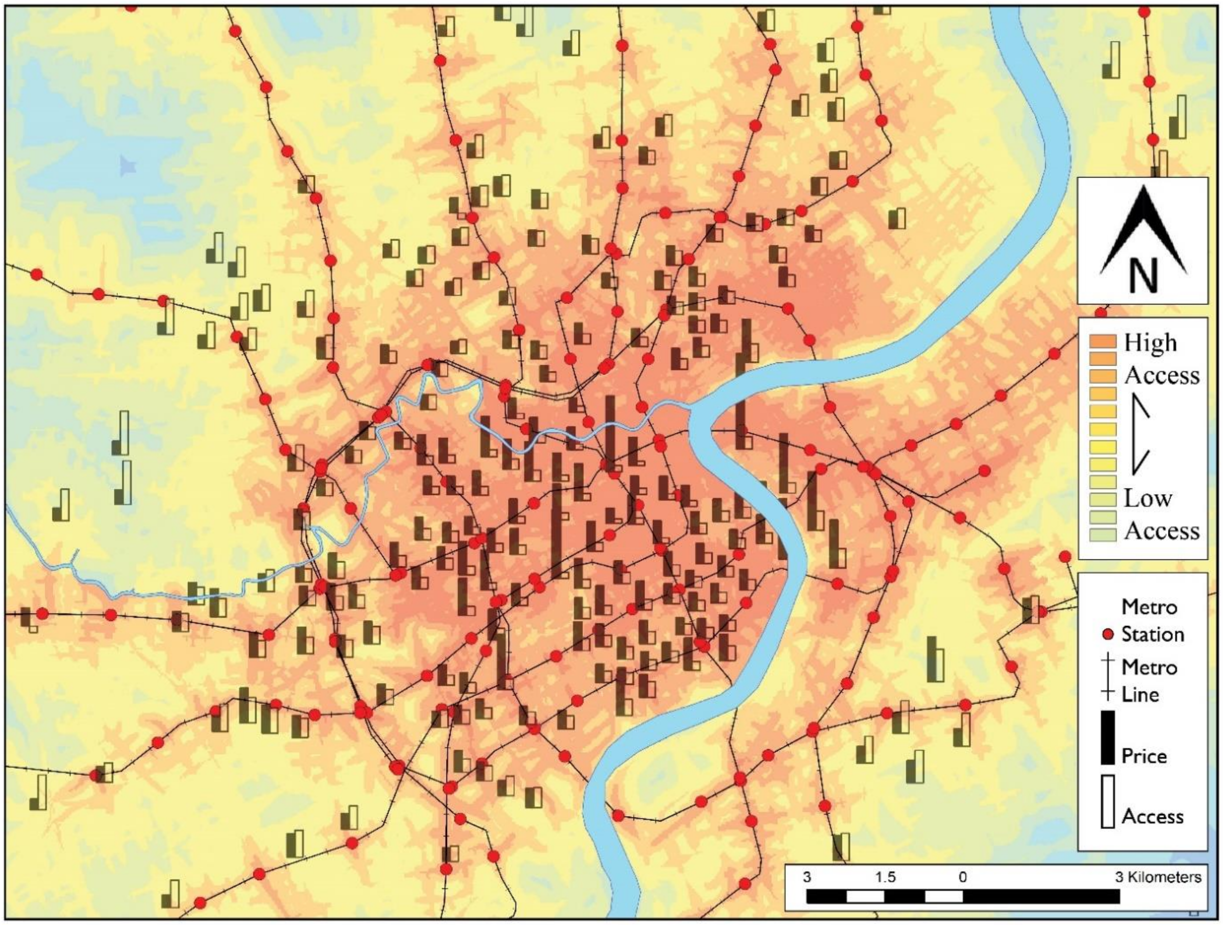

Figure 1. Metro access and property price of the 279 selected neighborhoods in Shanghai. The unit for property price is Chinese RMB (ranging from 8,700 to 160,000) and the unit for metro access is minutes (ranging from 0 to 90).

4.2 Correlation between variables in Pudong

An OLS hedonic regression model is introduced to understand neighborhood development and metro access in the Pudong District. **Figure 2** shows the location of neighborhoods in relation to the existing metro stations and metro lines. **Table 4** shows the correlation matrix of the 28 explanatory variables. The explanatory variables with statistically significant p-value at the 0.01 level are marked with asterisk (*). Based on the covariance coefficients, a few pairs stand out:

Short-term price change and future stations; price and job access; price and urban form; job access and urban form; metro access and neighborhood size; public services and bus access; density and access. In sum, these observations articulate the spatial characteristics of price, accessibility, and urban form in Pudong.

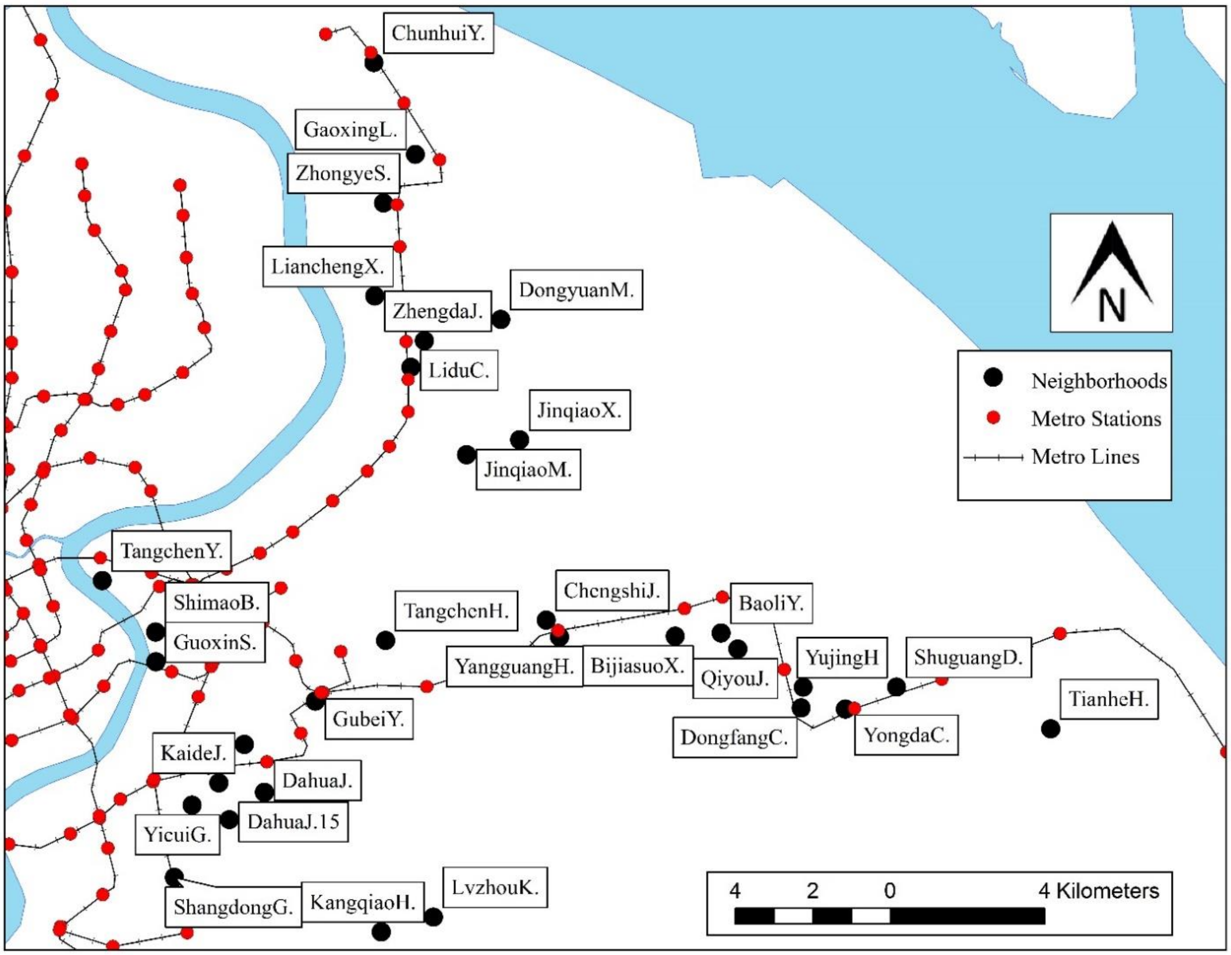

Figure 2. Locations of the 31 neighborhoods in Pudong District.

Table 4. Pairwise correlation coefficients matrix.

	Ave. Price 2012 p1	Ave. Price 2017 p2	Price Change 5-years p3	Price Change 1-year p4	Price Change 1-month p5	Time to Centers Mins a1	Dist. to Metro km a2	Current Station <1km a3	Future Station <1km a4	Bus Stop <1km a5	High-rise Office a6	Commer. a7	Non Desir. e1	Kinderg. e2	School e3	College e4	Security e5
p1	1.000																
p2	**0.920***	1.000															
p3	**-0.561***	-0.299	1.000														
p4	0.347	0.395	-0.112	1.000													
p5	0.425	**0.458***	-0.027	**0.760***	1.000												
a1	**-0.474***	**-0.524***	0.130	-0.364	-0.210	1.000											
a2	-0.072	-0.193	-0.216	-0.214	-0.079	**0.744***	1.000										
a3	-0.008	0.130	0.124	-0.079	-0.288	-0.378	**-0.545***	1.000									
a4	0.063	0.049	-0.181	**-0.546***	**-0.511***	0.236	0.395	0.188	1.000								
a5	-0.052	-0.134	0.097	0.105	0.061	-0.203	0.002	-0.123	-0.051	1.000							
a6	**0.852***	**0.724***	-0.374	0.181	0.351	-0.403	-0.054	-0.130	-0.018	0.003	1.000						
a7	**0.514***	**0.466***	-0.308	0.033	0.174	-0.347	-0.088	0.109	0.201	0.338	**0.494***	1.000					
e1	-0.113	-0.124	-0.022	0.075	0.096	0.034	-0.212	0.031	-0.318	-0.081	-0.131	-0.349	1.000				
e2	0.012	-0.148	-0.202	-0.372	-0.319	-0.003	-0.053	0.030	0.023	0.050	0.243	0.119	0.084	1.000			
e3	0.297	0.253	0.155	-0.132	0.184	-0.267	-0.248	-0.040	-0.025	0.172	**0.599***	0.416	-0.163	0.450	1.000		
e4	-0.112	-0.204	-0.106	-0.180	-0.126	0.223	0.173	-0.168	0.005	0.013	-0.035	-0.141	**0.472***	-0.022	-0.136	1.000	
e5	0.345	0.305	-0.184	-0.027	0.030	0.084	0.184	0.000	0.371	-0.329	0.365	-0.083	-0.184	0.073	0.185	0.080	1.000
e6	-0.085	-0.116	0.247	-0.096	-0.069	0.009	-0.022	-0.142	0.073	**0.510***	0.034	0.284	-0.328	0.010	0.374	-0.046	-0.080
e7	-0.059	-0.117	0.297	-0.046	0.117	-0.120	-0.233	-0.119	-0.202	0.419	0.201	0.321	-0.154	0.226	**0.498***	-0.012	-0.185
e8	0.111	0.044	-0.042	-0.055	-0.036	-0.024	0.022	0.083	-0.075	0.183	0.227	0.258	-0.251	0.241	0.300	0.183	0.071
e9	-0.024	0.020	0.039	-0.085	0.002	-0.087	-0.102	0.163	-0.187	-0.088	-0.113	0.137	-0.160	-0.215	-0.224	0.016	-0.199
e10	0.121	0.105	0.017	-0.209	-0.158	0.058	0.156	-0.056	0.050	0.183	0.197	0.005	0.060	0.134	0.038	-0.012	-0.132
n1	0.219	0.220	-0.253	0.036	-0.029	-0.235	0.092	-0.128	0.034	0.119	0.048	0.160	-0.216	-0.169	-0.225	-0.188	-0.205
n2	-0.179	-0.180	-0.042	-0.031	0.045	-0.135	0.049	-0.348	-0.127	0.121	-0.195	-0.148	0.072	-0.049	-0.124	-0.321	-0.305
n3	**0.674***	**0.694***	-0.144	0.195	0.184	-0.398	-0.149	0.292	0.169	0.045	**0.695***	**0.460***	-0.204	-0.058	0.400	-0.221	0.334
n4	0.293	0.128	-0.210	0.024	0.235	0.035	0.128	-0.171	-0.086	0.171	0.389	0.365	-0.022	0.342	0.235	-0.117	-0.231
n5	-0.158	-0.242	-0.026	-0.242	-0.107	0.276	0.398	-0.338	0.122	0.218	0.066	-0.069	0.090	0.359	0.245	0.365	0.146
n6	**0.849***	**0.818***	-0.368	0.178	0.225	-0.326	-0.119	0.033	0.170	-0.060	**0.678***	0.346	-0.144	-0.114	0.251	-0.123	0.370
n7	-0.067	-0.154	-0.055	-0.257	-0.076	0.433	**0.651***	-0.401	0.328	0.132	0.046	0.117	-0.067	0.072	0.069	0.185	0.083
n8	-0.165	-0.128	0.367	-0.063	-0.100	-0.132	-0.114	-0.080	-0.120	0.077	-0.084	-0.158	-0.048	0.038	0.163	0.083	-0.015
n9	**0.775***	**0.797***	-0.362	0.447	0.427	-0.313	-0.110	0.023	0.005	-0.147	**0.598***	0.340	-0.030	-0.183	0.220	-0.110	0.369
n10	-0.152	-0.118	0.138	-0.131	-0.004	-0.205	-0.156	-0.233	-0.298	0.007	0.015	-0.076	-0.023	0.302	0.200	-0.016	0.033
n11	-0.016	-0.098	-0.185	-0.408	-0.278	0.446	**0.542***	-0.403	0.387	-0.054	0.008	0.168	-0.125	0.241	0.018	0.258	0.115

Table 4. (Continue)

	Hospt. Clinic e6	Social Service e7	Bank e8	Fresh Food 500m e9	Park e10	Neighb. Type n1	Build Type n2	Density (FAR) n3	Green Space n4	Year Built RMB n5	Prop. Fee n6	Resi. Units n7	Nearby Resid. n8	Parking n9	Main Gates n10	Site Area Hectre n11
e6	1.000															
e7	**0.635***	1.000														
e8	**0.501***	0.419	1.000													
e9	0.154	0.146	0.245	1.000												
e10	-0.042	0.017	0.134	-0.158	1.000											
n1	-0.160	-0.388	-0.193	0.163	0.223	1.000										
n2	-0.197	-0.256	**-0.540***	-0.094	0.099	0.454	1.000									
n3	0.065	0.112	0.066	-0.026	0.138	0.016	-0.309	1.000								
n4	0.147	0.355	0.248	0.032	0.216	0.070	-0.024	-0.041	1.000							
n5	0.242	0.170	0.328	-0.099	0.075	-0.383	-0.026	-0.098	-0.102	1.000						
n6	0.111	-0.021	0.151	-0.041	0.299	0.143	-0.262	**0.624***	0.129	-0.173	1.000					
n7	-0.017	0.034	-0.129	-0.151	0.069	0.116	0.098	-0.072	0.221	0.174	-0.208	1.000				
n8	0.167	0.240	-0.037	-0.026	-0.308	-0.122	0.132	-0.130	-0.069	-0.057	-0.216	0.128	1.000			
n9	-0.088	-0.152	0.154	-0.105	0.077	0.051	-0.253	**0.587***	-0.040	-0.035	**0.773***	-0.219	-0.312	1.000		
n10	-0.117	0.057	-0.050	-0.081	0.005	0.265	0.420	-0.215	-0.052	-0.020	-0.289	0.067	0.327	-0.326	1.000	
n11	0.095	-0.011	0.107	-0.061	0.076	0.150	-0.028	-0.257	0.224	0.154	-0.034	**0.731***	0.075	-0.071	0.039	1.000

4.3 Factor identification using PCA

Table 5 summarizes the loadings of the PCA tests. The loading coefficients lower than -0.25 or higher than 0.25 are in bold. Loadings with statistically significant p-value at the 0.1, 0.05, and 0.01 levels are marked with one, two, and three asterisks respectively. Factor 1 shows high coefficients for the number of high-rise office buildings and housing density. Factor 1 can be called "*jobs-housing relationship*". It represents the balance between accessibility to job opportunity and housing supply. In addition, commercial properties, quality of property management, and number of parking space per unit also exhibit high coefficients. The correlation analysis shows high positive associations between access to office and access to commercial as well as between density and parking. The property management variable reveals that in the jobs-housing relationship, not only the quantity of housing but also the quality of property maintenance matters.

Factor 2 shows high coefficients for travel time to the closest metro station and the size of the residential neighborhoods. The latter is represented by the number of residential units and site areas. Factor 2 can be called "size and *access to existing metro station*". Factor 3 is significant for the future planned metro stations and the (un)availability of public services such as post offices, public libraries, and civic centers. Factor 3 shows that the public service facilities are lagging behind public transit planning as a consequence of the government-led (State Council) "planning in advance" policy that prioritizes infrastructure development. In addition, level of security is also important. Security, often operated by private contractors, can contribute to public safety and emergency management. The positive correlation of security with factor 3 shows that the future planned metro stations are closer to neighborhoods where high security levels are provided. These neighborhoods are characterized by being recently built, high end, and often gated. Factor 3 can be called "*public service and access to planned metro station*". Since Factors 2 and 3 are only correlated with accessibility to a low to medium extent, the accessibility variables have been tested directly in the hedonic analysis. The coefficients are shown in **Figure 3**. The results show for property price in both 2012 and 2017, high-rise office and commercial are the two most positively correlated variables; for short term price change (one year and one month), future planned stations are the most negatively correlated variables. The results reinforce the PCA analysis: First, more value or benefit can be captured in the future in regard to *access to planned metro station*. Second, access to employment (office and commercial) are the most influential variables.

Factor 4 has high coefficients for neighborhood type and building type. Both are related to the typology of neighborhoods. Factor 4 can be called "*typology*". Factor 5 has high coefficients for fresh food markets, kindergartens, and non-desirable facilities. It can be called "*public amenity*". Factor 6 has high coefficients for parks and nearby residential communities. It can be called "*environment proximity*". Similar to factor 5, factors 7, 8, and 9 have high coefficients for kindergartens, fresh food markets, non-desirable facilities. Together, these three factors are called "*public amenity*". Factor 9 also has high coefficients for residential units, which has been covered by factor 2. **Table 5c** shows that these three factors are only correlated with environmental variables to a low extent. However, they certainly reinforce the collective influence of environmental proximity on property value.

Table 6 shows the variation explained by the PCA. Among the 28 factors, the top 6 factors together explained more than 64% of the variation in the original data. The top 9 factors explained 78.6% of the variation. Factor 7 to 28 each explain less than 5 percent of the variation and are thus eliminated from further discussion. The eigenvalue trendline flattens out after factor 6, which also confirms the importance of factors 1 to 6. **Figure 3** shows the scree plot of PCA eigenvalues and the 95% confidence interval.

Table 5a. Variable coefficient of the PCA.

		Factor 1 Jobs-Housing Relationship		Factor 2 Size Access to Metro E.		Factor 3 Social Service Access to Metro P.	
	Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value
a1	Time to Centers	-0.2543	0.3330	0.2771	0.3450	0.1689	0.6170
a2	Dist. to Station (km)	-0.1646	0.6190	**0.3499**	**0.2550**	0.2690	0.4600
a3	Current Station <1km	0.1173	0.6550	-0.2770	0.1120	-0.0110	0.9750
a4	Future Station <1km	0.0218	0.9210	0.1690	0.5910	**0.2959**	**0.1880**
a5	Bus <1km	0.0787	0.6940	0.1424	0.6340	-0.2647	0.2660
a6	High-rise Office	**0.3665 *****	**0.0020**	0.0930	0.7900	0.1024	0.6860
a7	Commercial	**0.3027 ****	**0.0240**	0.1109	0.7050	-0.0382	0.8860
e1	Non Desirable	-0.1361	0.3780	-0.1035	0.6150	-0.0298	0.9130
e2	Kindergarten	0.0664	0.7540	0.1925	0.3710	-0.1547	0.5670
e3	School	0.2925	0.1040	0.1636	0.6090	-0.1686	0.5060
e4	College	-0.1052	0.5620	0.1517	0.4370	0.0269	0.9330
e5	Security	0.1210	0.5150	0.0770	0.8230	**0.3021**	**0.1950**
e6	Hospital and Clinic	0.1560	0.5140	0.2163	0.4850	-0.2575	0.3560
e7	Social Service	0.1809	0.4610	0.1895	0.6440	**-0.3782** *	**0.0970**
e8	Bank	0.2031	0.3340	0.1974	0.4610	-0.1501	0.6300
e9	Fresh Food	0.0133	0.9280	-0.0778	0.6840	-0.1125	0.6180
e10	Park <500m	0.0653	0.6530	0.0853	0.6410	0.0771	0.7530
n1	Neighborhood Type	-0.0290	0.8720	-0.0860	0.7380	0.0996	0.8210
n2	Building Type	-0.1920	0.2390	-0.0809	0.7740	-0.0775	0.8490
n3	Density (FAR)	**0.3609 *****	**0.0010**	-0.0619	0.8630	0.1629	0.3980
n4	Green Space	0.1171	0.5750	0.1958	0.3520	-0.1156	0.6990
n5	Year Built	-0.0221	0.9370	0.2991	0.0440	-0.0422	0.9090
n6	Property Fee ($)	**0.3423 *****	**0.0090**	-0.0393	0.9200	0.2469	0.1830
n7	Residential Units	-0.1178	0.7150	**0.3548 ***	**0.0650**	0.1216	0.7600
n8	Nearby Resid. Comm.	-0.0650	0.6720	0.0342	0.9000	-0.2364	0.1720
n9	Parking	**0.3044 ***	**0.0540**	-0.0817	0.8330	0.2797	0.1290
n10	Main Gates	-0.0836	0.6040	0.0000	1.0000	-0.2146	0.4590
n11	Site Area (h)	-0.0883	0.7910	**0.3673 ****	**0.0470**	0.1421	0.7150

Note: *** 99% confidence level; ** 95% confidence level; * 90% confidence level

Table 5b. Variable coefficient of the PCA.

		Factor 4 Typology		Factor 5 Public Amenity		Factor 6 Environment Proximity	
	Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value
a1	Time to Centers	-0.1625	0.5010	-0.0983	0.6650	0.0560	0.7880
a2	Dist. to Station (km)	0.0634	0.8390	-0.1137	0.5570	0.0243	0.9060
a3	Current Station <1km	-0.2029	0.4030	-0.1319	0.6820	-0.1029	0.8090
a4	Future Station <1km	-0.0186	0.9590	-0.1613	0.6520	-0.2761	0.4320
a5	Bus <1km	0.1447	0.6560	-0.1606	0.6010	0.1340	0.7300
a6	High-rise Office	0.1310	0.6340	0.2405	0.2050	0.0678	0.8160
a7	Commecial	0.1855	0.4170	-0.1879	0.4140	-0.0249	0.9300
e1	Non Desirable	-0.1547	0.6770	**0.3179**	**0.4830**	**0.4142**	**0.2620**
e2	Kindergarten	0.0080	0.9830	**0.3341**	**0.1700**	0.0212	0.9670
e3	School	0.0328	0.9200	0.2717	0.1800	-0.1495	0.6180
e4	College	**-0.2732**	**0.2390**	0.1309	0.7390	0.2209	0.5430
e5	Security	-0.1667	0.6650	0.2367	0.5490	**-0.3265**	**0.2710**
e6	Hospital and Clinic	-0.0845	0.8190	-0.2715	0.2420	-0.1009	0.7820
e7	Social Service	-0.0867	0.8080	-0.0677	0.7570	-0.0105	0.9560
e8	Bank	-0.2218	0.3720	-0.1397	0.6380	0.1107	0.7090
e9	Fresh Food	-0.0521	0.8950	**-0.3790** *	**0.0950**	0.0220	0.9650
e10	Park <500m	0.1792	0.4850	0.0288	0.9530	**0.4294**	**0.1110**
n1	Neighborhood Type	**0.4842** **	**0.0140**	-0.1565	0.7380	0.0517	0.8760
n2	Building Type	**0.4390** **	**0.0120**	0.1232	0.7730	-0.0148	0.9620
n3	Density (FAR)	0.0228	0.9110	0.0244	0.8880	-0.0810	0.6330
n4	Green Space	0.1977	0.4140	-0.0507	0.8960	0.2690	0.4430
n5	Year Built	-0.2079	0.4210	0.1768	0.5510	0.1018	0.7730
n6	Property Fee ($)	0.0625	0.8070	0.0051	0.9800	0.1082	0.5590
n7	Residential Units	0.1849	0.4110	0.0048	0.9850	-0.1040	0.6320
n8	Nearby Resid. Comm.	0.0107	0.9740	0.1391	0.7490	**-0.3951**	**0.1630**
n9	Parking	-0.0113	0.9690	0.0739	0.7450	0.1244	0.6040
n10	Main Gates	0.2574	0.5070	**0.3360**	**0.3360**	-0.1938	0.6410
n11	Site Area (h)	0.1211	0.6160	-0.0350	0.8820	-0.0723	0.7800

Table 5c. Variable coefficient of the PCA.

		Factor 7 Public Amenity		Factor 8 Public Amenity		Factor 9 Public Amenity	
	Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value
a1	Time to Centers	0.0552	0.8600	-0.0268	0.9510	-0.1253	0.8810
a2	Dist. to Station (km)	-0.1083	0.6620	-0.0299	0.9620	-0.1136	0.6840
a3	Current Station <1km	0.4675	0.5450	-0.1306	0.9600	0.1067	0.9100
a4	Future Station <1km	0.2356	0.8890	-0.2970	0.8260	0.1278	0.8820
a5	Bus <1km	-0.2144	0.9190	-0.3770	0.7630	0.2243	0.8010
a6	High-rise Office	-0.0564	0.9530	0.1694	0.6300	0.0303	0.9250
a7	Commecial	0.1284	0.7640	0.0520	0.9480	0.2261	0.6480
e1	Non Desirable	0.0179	0.9740	0.0359	0.9500	**0.3701**	**0.1690**
e2	Kindergarten	**0.4771**	**0.2340**	-0.0510	0.9850	-0.1990	0.7470
e3	School	0.0370	0.9430	-0.0858	0.7640	0.0006	0.9990
e4	College	-0.1671	0.9150	0.2688	0.8060	0.3091	0.8210
e5	Security	-0.0816	0.8680	0.0618	0.9140	-0.1726	0.5570
e6	Hospital and Clinic	-0.2400	0.7690	-0.1431	0.9150	-0.0445	0.9030
e7	Social Service	-0.0428	0.8520	0.0047	0.9890	0.0876	0.8900
e8	Bank	0.0231	0.9840	0.1943	0.7080	-0.3427	0.6380
e9	Fresh Food	-0.0329	0.9900	**0.4505**	**0.2470**	-0.1744	0.8210
e10	Park <500m	0.0998	0.9430	-0.2371	0.7440	-0.2053	0.7620
n1	Neighborhood Type	-0.0486	0.9570	0.1509	0.7340	-0.0857	0.9330
n2	Building Type	-0.1553	0.8810	-0.1840	0.8350	-0.0767	0.8220
n3	Density (FAR)	-0.0620	0.9250	-0.1123	0.7880	0.1375	0.5860
n4	Green Space	0.3310	0.7820	0.2051	0.9130	0.0674	0.9540
n5	Year Built	-0.2099	0.8790	-0.2415	0.8440	-0.2152	0.7910
n6	Property Fee ($)	-0.1545	0.6860	0.0616	0.9440	-0.0043	0.9880
n7	Residential Units	0.0553	0.9200	0.0724	0.8940	**0.3327 ***	**0.0710**
n8	Nearby Resid. Comm.	-0.1590	0.8790	0.1699	0.8650	0.2594	0.5270
n9	Parking	-0.2325	0.6290	0.0809	0.9500	-0.0022	0.9950
n10	Main Gates	-0.0190	0.9860	0.1886	0.6830	-0.2473	0.7690
n11	Site Area (h)	0.1415	0.9210	0.2554	0.7560	0.1333	0.7930

Table 6. Factor loading of the PCA

Component		Eigenvalue	Std. Err.	[95% Conf. Interval]		Difference	Proportion	Cumulative
Factor	1	4.6691	1.1860	2.3447	6.9936	0.8715	0.1668	0.1668
Factor	2	3.7976	0.9646	1.9070	5.6882	0.6322	0.1356	0.3024
Factor	3	3.1654	0.8040	1.5896	4.7413	0.5922	0.1131	0.4154
Factor	4	2.5732	0.6536	1.2922	3.8542	0.4556	0.0919	0.5073
Factor	5	2.1176	0.5379	1.0634	3.1718	0.3515	0.0756	0.5830
Factor	6	1.7661	0.4486	0.8869	2.6454	0.3688	0.0631	0.6460
Factor	7	1.3974	0.3549	0.7017	2.0930	0.0445	0.0499	0.6959
Factor	8	1.3529	0.3436	0.6794	2.0264	0.1790	0.0483	0.7443
Factor	9	1.1739	0.2982	0.5895	1.7583	0.0677	0.0419	0.7862

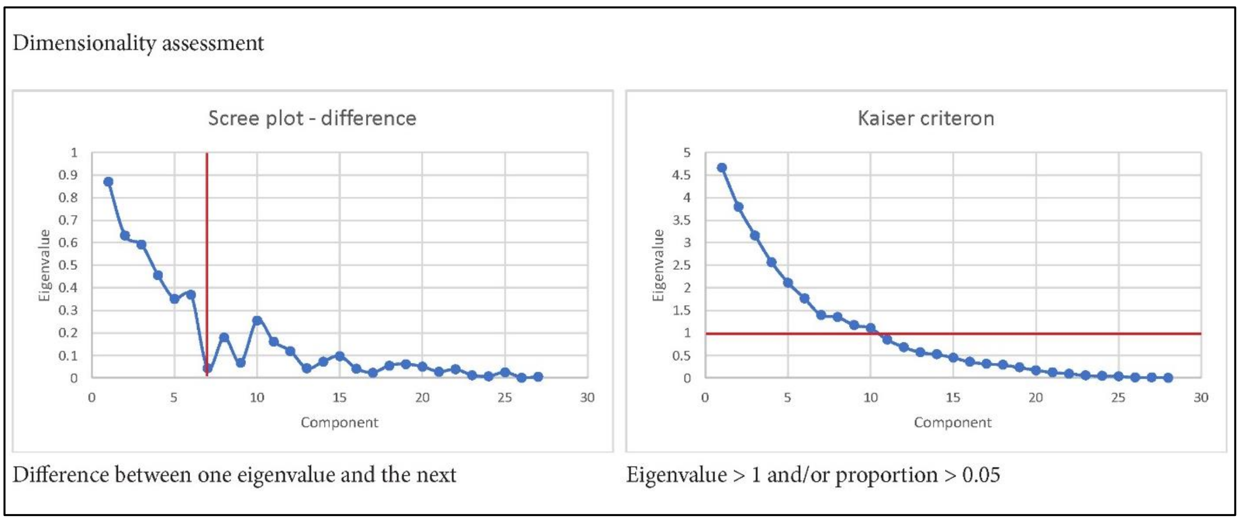

Figure 3. Dimensionality assessment of eigenvalues using scree plot difference and the Kaiser criterion.

5. Metro system accessibility, jobs-housing relationship, and public service

Table 7 summarizes the results from the five regression models on price and price change. Model 1 uses the property price in 2012 as the independent variable. Factor 1 "*jobs-housing relationship*" and factor 3 "*access to metro and public service*" show statistically significant p-values at the 0.001 level. Factor 4 "typology" is also statistically significant at the 0.01 level. The results reveal that the average resale price of neighborhoods in 2012 is a function of jobs-housing balance, access to metro plus public service, and neighborhood typology.

Model 2 regresses on the average price in 2017. Factor 1 "*jobs-housing relationship*" and factor 3 "*public service plus access to planned metro*" are statistically significant at the 0.001 level. The average resale price in 2017 can be understood as a function of jobs-housing balance and access to metro stations plus public service.

Model 3 uses 5-year price change from 2012 to 2017 as the independent variable. The significant factor is factor 3 "*public service plus access to planned metro*" at the 0.05 level. The price change over the last 5 years is a function of access to metro stations plus public service.

Model 4 applies 1-year price change from 2016 to 2017 as the independent variable. Factor 2 "*access to metro plus size*" is significant at the 0.05 level. In this factor, the access to metro focuses on existing stations that are under operation.

In both models 1 and 2, jobs-housing relationship appears to be statistically significant. In this study, it is the most important factor influencing housing prices at a point in time. Jobs-housing balance has been the source of heated debates in the international context (Guiliano and Small, 1993; Peng, 1997) as well as in China (Wang and Chai, 2009; Zhou, 2014). Cervero (1989) indicates that jobs-housing imbalance can cause higher vehicle miles traveled (VMT) and larger percentage of motorized travel mode. Weitz et al. (2003) states that jobs-housing balance is a process readjustment to market failure. In the Chinese circumstance, Wang and Chai (2009) claim that the work unit system has an inherited advantage for achieving better jobs-housing balance. In addition, Zhao et al. (2011) added to the claim that a comprehensive master plan implemented through government intervention can further enhance the housing resource allocation. The counter argument supporting co-location theory claims that the jobs-housing balance can be achieved through market forces (Gordon et al., 1991; Peng, 1997; Hu et al., 2017). Hu et al. (2018) extended the argument that various population groups may be affected differently in large Chinese cities. In Shanghai, where state owned enterprises (SOE) who have a strong hold on work unit type of land ownership coexist with private real estate developers who are maximizing profit by building market price housing, the jobs-housing balance can only be achieved through a competing advocacy of policy from multiple parties involved to align public interests and their own benefits. For example, in recent years, some local SOEs (who own land-use rights) collaborate with private developers (who bring money and development expertise) by forming public-private partnerships (PPP) to take advantage of mezzanine loans in the form of nominal bank debts. The PPP can expedite urban regeneration by providing more housing opportunities while reducing government debts.

Models 1, 2, and 3 all show access to future metro stations as a significant variable for property values. This factor considers future proposed metro stations and those under construction. The high positive coefficients in 2012 and 2017 mean at both points in time, the housing property prices are reflecting the premium of proximity to future metro stations. The negative coefficient for the 5-year price change, on the other hand, means that the premium price is reflected in the market at least 5 years before the metro station start operation and that price premium diminishes from that point on. The underlying reason may be that the initial market price was set too high so that it takes away future price growth potential. When the market functions well, the initial prices are confirmed by transactions, so they show what the market will bear. When the market fails to do so, it may be counted as a market failure.

Comparing access to existing metro stations with access to future proposed metro stations, access to existing metro stations is more influential in the short-term price variation. This can be explained by the fact that short-term decisions are a response to existing welfare while long-term decisions (more than one year) place more value on benefits that can be captured in the future.

Adequate public services such as post offices, public libraries, and banks provide convenient living experiences for residences (Jung et al., 2013). Convenient accessibility to these facilities is also reflected in housing prices (Huang and Tao, 2015). In China, public service facilities are often associated with public space that can be utilized for social activities, for example, group exercise and plaza dance meetup. They are construed as valuable assets to the residents. However, the added value can diminish as public spaces become privatized or the re-intensification of urban space happens.

Table 7. Regression models on price and price change over time.

				Number of observations			31
		Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
P1	Price 2012					R-sqaured	0.8215
Factor 1	**Jobs-Housing Relationship**	10,259.6	1,174.6	8.73	**0.000**	7,835.4	12,683.9
Factor 2	Access to Existing Metro Stations	-824.1	1,302.4	-0.63	0.533	-3,512.2	1,864.0
Factor 3	**Access to Planned Metro Stations**	6,497.7	1,426.6	4.55	**0.000**	3,553.4	9,442.0
Factor 4	**Typology**	4,639.8	1,582.2	2.93	**0.007**	1,374.3	7,905.4
Factor 5	Public Amenity	2,883.7	1,744.2	1.65	0.111	-716.0	6,483.5
Factor 6	Environment Proximity	2,502.6	1,909.8	1.31	0.202	-1,439.1	6,444.3
Cons		39,017.7	2,496.8	15.63	0.000	33,864.6	44,170.9
P2	Price 2017					R-sqaured	0.7853
Factor 1	**Jobs-Housing Relationship**	10,225.3	1,340.0	7.63	**0.000**	7,459.8	12,990.9
Factor 2	Access to Existing Metro Stations	-3,552.3	1,485.8	-2.39	0.025	-6,618.8	-485.8
Factor 3	**Access to Planned Metro Stations**	6,775.6	1,627.4	4.16	**0.000**	3,416.8	10,134.4
Factor 4	Typology	4,234.8	1,805.0	2.35	0.028	509.5	7,960.1
Factor 5	Public Amenity	1,877.8	1,989.7	0.94	0.355	-2,228.7	5,984.4
Factor 6	Environment Proximity	635.3	2,178.7	0.29	0.773	-3,861.3	5,131.9
Cons		65,602.8	2,848.3	23.03	0.000	59,724.2	71,481.5
P3	Price Change 5-years					R-sqaured	0.2985
Factor 1	Jobs-Housing Relationship	-0.0540	0.0487	-1.11	0.279	-0.1545	0.0466
Factor 2	Access to Existing Metro Stations	-0.0239	0.0540	-0.44	0.663	-0.1353	0.0876
Factor 3	**Access to Planned Metro Stations**	-0.1419	0.0592	-2.40	**0.025**	-0.2640	-0.0198
Factor 4	Typology	-0.0745	0.0656	-1.13	0.268	-0.2099	0.0610
Factor 5	Public Amenity	-0.0281	0.0723	-0.39	0.701	-0.1774	0.1212
Factor 6	Environment Proximity	-0.1002	0.0792	-1.27	0.218	-0.2637	0.0633
Cons		0.9326	0.1035	9.01	0.000	0.7189	1.1463
P4	Price Change 1-year					R-sqaured	0.2283
Factor 1	Jobs-Housing Relationship	0.0179	0.0156	1.15	0.261	-0.0142	0.0501
Factor 2	**Access to Existing Metro Stations**	-0.0376	0.0173	-2.18	**0.040**	-0.0732	-0.0019
Factor 3	Access to Planned Metro Stations	-0.0008	0.0189	-0.04	0.966	-0.0398	0.0382
Factor 4	Typology	0.0059	0.0210	0.28	0.782	-0.0374	0.0492
Factor 5	Public Amenity	0.0019	0.0231	0.08	0.934	-0.0458	0.0496
Factor 6	Environment Proximity	0.0247	0.0253	0.98	0.338	-0.0275	0.0770
Cons		0.1190	0.0331	3.60	0.001	0.0507	0.1874
P5	Price Change 1-month					R-sqaured	0.1649
Factor 1	Jobs-Housing Relationship	0.0064	0.0045	1.42	0.168	-0.0029	0.0157
Factor 2	Access to Existing Metro Stations	-0.0038	0.0050	-0.77	0.451	-0.0141	0.0065
Factor 3	Access to Planned Metro Stations	-0.0009	0.0055	-0.16	0.876	-0.0121	0.0104
Factor 4	Typology	0.0043	0.0060	0.72	0.480	-0.0081	0.0168
Factor 5	Public Amenity	0.0044	0.0067	0.65	0.519	-0.0094	0.0181
Factor 6	Environment Proximity	0.0079	0.0073	1.08	0.291	-0.0072	0.0229
Cons		-0.0177	0.0095	-1.86	0.075	-0.0374	0.0020

6. Urban form and urban spatial structure

Monocentric cities (Alonso, 1964) and polycentric cities (Garreau, 1991) have city centers or subcenters where the metro system can effectively connect people to concentrations of employment. Pudong, with a high percentage of within-district commuting trips, resembles a monocentric model. On the other hand, with nine employment centers, Shanghai performs more as a polycentric city. To describe the spatial structure of Shanghai more precisely, it is important to consider the large amount of work unit neighborhoods inherited from the pre-reform era and the dispersion of jobs outside of the employment centers. Angel and Blei (2016) proposed a mosaic of live-work and constrained dispersal model for contemporary cities. Pudong fits the description when considering its urban form and neighborhood development.

Density, one of the most frequently used measures for urban development, is a significant determinant for residential prices in 2012 and 2017. In the US, lower density subdivisions have higher prices; this study finds the reverse in Shanghai. Density in this study represents the maximum capacity of residence accommodated or the as-built condition (not the population density according to zoning). In a rapid urbanizing city, density should be constantly readjusted by policy makers and planning professionals to reflect surrounding environment change, job opportunity distribution, and accessibility improvement. The implementation of density adjustment, to a large extent, is a collective appropriation of the state apparatus and private investors' profit-making. Both neighborhood typology and size come into play as part of the urban land use right reform in China. Neighborhood typology exhibits stronger impact on price in 2012 than in 2017. It echoes the results from previous studies that in the long term mixed-use and diversity of land development are not as significant for Chinese cities as they are for American cities (Srinivasan, 2010). Neighborhood size, including both the land area and the number of residential units, exhibits significant effect on short-term (one year) price variation. To maintain a sustainable spatial structure, density, typology, and size should be further investigated in regard to urban development as well as urban retrofitting policies. More specifically, Pudong should adopt planning strategies that increase job accessibility by introducing higher diversity to accommodate all social classes. Also, Pudong should take into consideration spatial allocation of density to increase the overall compactness and emphasize TOD to balance future planned metro transit to serve not only high-income neighborhoods but also where low- to mid-incomes are clustered.

To summarize, there are three general planning strategies can be applied to promote sustainable urban spatial structure. First, enhance jobs-housing balance. This strategy should include promoting collaborations between public and private entities, introducing financial strategies such as nominal bank debts, and encouraging the mosaic live-work or cellular type model to constrain dispersal. Second, balance access to metro stations. This strategy not only considers the development stage variations among districts but also the density distribution around future planned metro stations. In particular, under the current "planning in advance" policy, the zoning ordinance and spatial plans of density distribution should reflect the public transit plan, both short term and long term. Third, use public space to reorganize the spatial planning of neighborhoods. The gravitational effect of social amenities can be applied to cultivate social capital, civic aspiration, and public participation. To be more specific, neighborhood design of different typologies should all provide convenient access to facilities.

7. Conclusion

In a market-oriented economy, urban form and accessibility interact with property value. To achieve a sustainable and more efficient urban spatial structure, residential housing price variation can be analyzed to understand variables of accessibility and urban form. This study shows that access to job, access to existing and future metro stations, access to public service, neighborhood density and size, and neighborhood typology are all influential factors. Especially jobs-housing balance and metro accessibility are the two key components to maintain a functionally efficient, economically viable, and socially equitable urban spatial environment at the neighborhood scale.

The limitations of this study include not differentiating the status of metro stations (transfer versus non-transfer stations), quality of school district, and property management structure. In sum, urban development policies, zoning ordinances, and rapid transit investment should align with the spatial distribution of jobs, public amenities, neighborhood density, size, and typology, in order to achieve a sustainable urban spatial structure.

References

Angel, S., Parent, J., Civco, D. L., & Blei, a. M. (2012). Atlas of urban expansion. *Choice Reviews Online*, *50*(3), 397.

Angel, S., & Blei, A. M. (2016). The spatial structure of American cities: The great majority of workplaces are no longer in CBDs, employment sub-centers, or live-work communities. *Cities*, *51*, 21–35.

Boarnet, M. G. (2011). A broader context for land use and travel behavior, and a research agenda. *Journal of the American Planning Association*, *77*(3), 197–213.

Cao, X. (Jason), Mokhtarian, P. L., & Handy, S. L. (2009). The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research Part A: Policy and Practice*, *43*(5), 548–559.

Cervero, R. (1996). Jobs-Housing Balance Revisited: Trends and Impacts in the San Francisco Bay Area. *Journal of the American Planning Association*, *62*(4), 492–511.

Cervero, R. and Day, J. (2008). Suburbanization and transit-oriented development in China. *Transport Policy*, 15(5), 315-323.

Chen, S., Claramunt, C., & Ray, C. (2014). A spatio-temporal modelling approach for the study of the connectivity and accessibility of the Guangzhou metropolitan network. *Journal of Transport Geography*, *36*, 12–23.

Corder, G.W., and Foreman, D.I. (2014). *Nonparametric Statistics: A Step-by-Step Approach*, John Wiley & Sons, Hoboken, New Jersey.

Diao, M. and Ferreira, J. (2010). Residential property values and the built environment: Empirical Study in the Boston, Massachusetts, metropolitan area. *Transportation Research Record: Journal of the Transportation Research Board*, 2174, 138-147.

Diao, M. (2015). Selectivity, spatial autocorrelation, and the valuation of transit accessibility. *Urban Studies*, 52(1), 159-177.

Diao, M., Leonard, D., and Sing, T.F. (2017). Spatial-difference-in-differences models for impact of new mass rapid transit line on private housing values. *Regional Science and Urban Economics*, 67, 64-77.

Dong, H. (2017). Rail-transit-induced gentrification and the affordability paradox of TOD. *Journal of Transport Geography*, *63*, 1–10.

Feng, J., Dijst, M., Prillwitz, J., & Wissink, B. (2013). Travel Time and Distance in International Perspective: A Comparison between Nanjing (China) and the Randstad (The Netherlands). *Urban Studies*, *50*(November), 2993–3010.

Guan, C. and Rowe, P.G. (2016). The concept of urban intensity and China's townization policy: Cases from Zhejiang Province. *Cities*, *55*, 22–41.

Guan, C. and Rowe, P.G. (2018). In pursuit of a well-balanced network of cities and towns: A case study of the Changjiang Delta Region in China. Environment and Planning B: Urban Analytics and City Science.

Guan, C. (2018) Spatial distribution of high-rise buildings and its relationship to public transit development in Shanghai. *Transport Policy*. In press.

Haixiao Pan, Qing Shen, & Ming Zhang. (2009). Influence of Urban Form on Travel Behaviour in Four Neighbourhoods of Shanghai. *Urban Studies*, *46*(2), 275–294.

Handy, S., Cao, X., & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment*, *10*(6), 427–444.

Hess, D. B., & Almeida, T. M. (2007). Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York. *Urban Studies*, *44*(5–6), 1041–1068.

Hu, L, Fan, Y, and Sun, T (2017) Spatial or socioeconomic inequality? Job accessibility changes for low- and high-education population in Beijing, China. *Cities*, 66, 23-33.

Hu, L, Sun, T, and Wang, L (2018) Evolving urban spatial structure and commuting patterns: A case study of Beijing, China. *Transportation Research Part D: Transport and Environment*, 59, 11-22.

Huang, Y., & Tao, R. (2015). Housing migrants in Chinese cities: current status and policy design. *Environment and Planning C: Government and Policy*, *33*(3), 640–660.

Jung, S., Huynh, D., & Rowe, P. G. (2013). The pattern of foreign property investment in Vietnam: The apartment market in Ho Chi Minh City. *Habitat International*, *39*, 105–113.

Li, J., Walker, J. L., Srinivasan, S., & Anderson, W. P. (2010). Modeling Private Car Ownership in China: Investigation of Urban Form Impact Across Megacities. *Ransportation Research Record: Journal of the Transportation Research Board*, (2193), 76–84.

Ma, J., Liu, Z., & Chai, Y. (2015). The impact of urban form on CO2 emission from work and non-work trips: The case of Beijing, China. *Habitat International*, *47*, 1–10.

Montgomery, D. (2001). *Design and Analysis of Experiments* (5th ed.). New York: Wiley.

Pan, Q. (2013). The impacts of an urban light rail system on residential property values: A case study of the Houston METRORail transit line. *Transportation Planning and Technology*, *36*(2), 145–169.

Pan, H., Shen, Q., & Zhang, M. (2009). Influence of Urban Form on Travel Behaviour in Four Neighbourhoods of Shanghai. *Urban Studies*, *46*(2), 275–294.

Peiser, R. B. (1989). Density and Urban Sprawl. *Land Economics*, 65, 193-204.

Petrisor, A., Ianos, I., Iurea, D., and Vaidianu, M. (2012). Applications of principal component analysis integrated with GIS. *Procedia Environmental Sciences*, 14, 247-256.

Smith, W. (1986). Interactions between transportation and high-rise, high-density living. *Ekistics*, 53(320/321), 336-344.

Srinivasan, S. (2010). Linking Travel Behavior and Location in Chengdu, China: Geographically Weighted Approach. *Transportation Research Record*: *Journal of the Transportation Research Board*, (2193), 85–95.

Wang, D., & Chai, Y. (2009). The jobs-housing relationship and commuting in Beijing, China: the legacy of Danwei. *Journal of Transport Geography*, *17*(1), 30–38.

Wang, D., Chai, Y., & Li, F. (2011). Built environment diversities and activity-travel behaviour variations in Beijing, China. *Journal of Transport Geography*, *19*(6), 1173–1186.

Wang, D., & Zhou, M. (2017). The built environment and travel behavior in urban China: A literature review. *Transportation Research Part D: Transport and Environment*, *52*, 574–585.

Wang, E., Song, J., & Xu, T. (2011). From "spatial bond" to "spatial mismatch": An assessment of changing jobs-housing relationship in Beijing. *Habitat International*, *35*(2), 398–409.

World Bank (2010). *Cities and climate change: An urgent agenda*. Urban Development Series. Washington, D.C. The International Bank for Reconstruction and Development/The World Bank.

Yang, J. (2010). Spatial and Social Characteristics of Urban Transportation in Beijing. *Transportation Research Record: Journal of the Transportation Research Board*, *2193*, 59–67.

Yang, J., Chen, J., Le, X., & Zhang, Q. (2016). Density-oriented versus development-oriented transit investment: Decoding metro station location selection in Shenzhen. *Transport Policy*, *51*, 93–102.

Yang, J., Shen, Q., Shen, J., & He, C. (2012). Transport Impacts of Clustered Development in Beijing: Compact Development versus Overconcentration. *Urban Studies*, *49*(6), 1315–1331.

Yang, Z. and Chen, J. (2014). *Housing Affordability and Housing Policy in Urban China*. Springer.

Zhao, P. (2014). The Impact of the Built Environment on Bicycle Commuting: Evidence from Beijing. *Urban Studies*, *51*(5), 1019–1037.

Zhao, P., Lu, B., & Roo, G. de. (2011). Impact of the jobs-housing balance on urban commuting in Beijing in the transformation era. *Journal of Transport Geography*, *19*(1), 59–69.

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

Zhu, Y. and Diao, M. (2016). The impacts of urban Mass Rapid Transit lines on the density and mobility of high-income households: A case study of Singapore. *Transport Policy*, 51, 70-80.

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