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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 dependent 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 **1. Introduction**

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

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

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

31

32 **2. Literature review**

33 Metro transit has been a consistent factor in creating a diversity of urban forms ([Smith, 1986](#);
34 [Li et al., 2010](#)). From the simple linear shape of Baltimore and Mumbai to the advanced circle-
35 radial shape of Beijing and London, and the more recent grid network of Guangzhou and Shenzhen,
36 the typologies of the metro system and urban development are closely connected ([Angel, 2012](#)).
37 In the 1980s, large cities like Hong Kong and Singapore were developing their metro transit
38 systems with high-density residential neighborhood already in place ([Smith, 1986](#); [Yang et al.,](#)
39 [2016](#)). In the 2000s, many large cities were developing and/or expanding extensive metro transit
40 networks simultaneously with urban expansion and re-intensification.

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

46 The most studied dimensions include accessibility to transport facility (Hess and Almeida, 2007;
47 Cao, 2009; Yang, 2010; Wang et al., 2011; Ma et al., 2015; Yang et al., 2016; Dong, 2017; Guan,
48 2018), neighborhood typologies (Wang and Chai, 2009; Feng et al., 2013; Zhao, 2014; Guan and
49 Rowe, 2016), and built environment characteristics (Pan et al., 2009; Srinivasan, 2010; Yang and
50 Chen, 2014).

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

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

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

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

77 In the Chinese circumstance, two C's are added to reflect local conditions: compactness
78 measured by overall conservative building footprints that are less invasive of the surrounding
79 environment, and connectivity measured by spatial proximity, physical closeness, and distance to
80 culture (Guan and Rowe, 2016). Population density is a key determinant for property development
81 and land value (Peiser, 1989; Yang, 2010; Zhao, 2014; Guan and Rowe, 2016). It is often regulated
82 through zoning ordinances and planning policies which impose limits on building density as
83 measured by floor area ratios (FAR). In Shanghai, most of the recent developments have FARs
84 higher than 2.0. Some high-rise development can reach 10 or even higher. Chinese cities, in general,
85 also have larger block-sizes and neighborhood size. The implications of the number of residential
86 units in each neighborhood and the site area have not yet been thoroughly studied (Wang and Zhou,
87 2017). Large developments can attract retail, commercial, and other public amenities. On the other
88 hand, the scarcity of available large land parcels can potentially push larger development projects
89 to the outskirts with reduced metro accessibility and longer travel time to city centers. In recent
90 years, homogeneous building typologies in large development projects have received a large

91 amount of criticism. In response, mixed-use developments are encouraged. Different types of
92 neighborhoods can have far-reaching effects on property values. Neighborhoods can be
93 categorized by binary variables such as location (urban versus suburban), density (high versus low),
94 and year built (old versus new) (Handy et al., 2005). In China, neighborhoods are also often
95 classified by their historical context (work unit versus non-work unit), social-economic class
96 (market versus welfare), and spatial configurations (conventional versus modern) (Wang et al.,
97 2011).

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

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

133

134 **3. Methodology**

135 **3.1. Neighborhood selection**

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

157

158 **3.2. Statistical Analysis**

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

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

180
$$V_{ij} = \mu_j + \varepsilon_{ij} \quad \text{Eq. (1)}$$

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

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

$$192 \quad F_{ij} = a_i * b_j + e_{ij}, i=1 \text{ to } n, j=1 \text{ to } p \quad \text{Eq. (2)}$$

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

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

$$200 \quad \rho_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_j x_j + \mu \quad \text{Eq. (3)}$$

201 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
202 variables, $j=1$ to 28; u is the error term.

203

204 **3.3. Attribute selection**

205 As mentioned earlier, metro systems can be the catalyst of development supporting TOD and
206 producing high compactness in urban form (Diao et al., 2017; Guan, 2017; Zhu and Diao, 2016).
207 Thus, capturing property price increases attributable to metro accessibility is a key factor to
208 understand sustainable neighborhood configuration (Diao, 2015). In addition, access to city
209 centers, employment centers, and other transit facilities should also be considered. Moreover, a
210 temporal dimension should be added to the discussion of property price, urban form, and
211 accessibility. Therefore, multiple year prices and price changes are incorporated into this research.
212 Moreover, not all urban form characteristics affect property price and access in the same way (Diao
213 and Ferreira, 2010). Some attributes represent the conditions of external environments and others
214 are internal structure of the built environment. In this research, 28 attributes were collected for the
215 31 neighborhoods selected in Pudong. The definitions of the attributes are listed in **Table 1**. The
216 price data are collected from online real estate open source platforms (www.fang.com). The
217 accessibility attributes are calculated using time-distance analysis (time to centers and distance to
218 stations) and counted using ArcGIS analysis (bus, high-rise office, and commercial). The location
219 of the high-rise office and commercial buildings are collected by the authors. The urban form
220 attributes are acquired from both online real estate platforms and spatial analysis conducted by the
221 authors. The attributes can be divided into the following categories: price (p), accessibility (a), and
222 urban form. Urban form can be subdivided into form of surrounding environment (e) and built
223 condition of the neighborhood (n). Price includes five variables: average resale price in 2012 (p1),
224 2017 (p2), 5-year price change from 2012 to 2017 (p3), 1-year price change (p4), and 1-month
225 price change (p5). Accessibility includes seven variables: time to the city center (a1), distance to
226 the closest metro station (a2), the number of current metro stations within 1km radius (a3), the

227 number of future planned metro stations within 1km radius (a4), bus stops within 1km radius (a5),
228 high-rise office buildings (a6), and commercial enterprise (a7). Environmental variables include
229 the number of non-desirable facilities (e1), kindergartens (e2), schools (e3), colleges (e4), level of
230 security (e5), hospitals and clinics (e6), public services (e7), banks (e8), fresh food markets (e9),
231 parks within 500m (e10). Neighborhood variables include neighborhood types (n1), building types
232 (n2), density (n3), green space (n4), year built (n5), property management (n6), the number of
233 residential units (n7), nearby residential neighborhoods (n8), parking per unit (n9), neighborhood
234 entry gates (n10), and site area (n11).

235 **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 1 month	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 Environment	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 neighborhood 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

237 **4. Results and analysis**

238 **4.1 Analysis of variance in Shanghai**

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

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

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

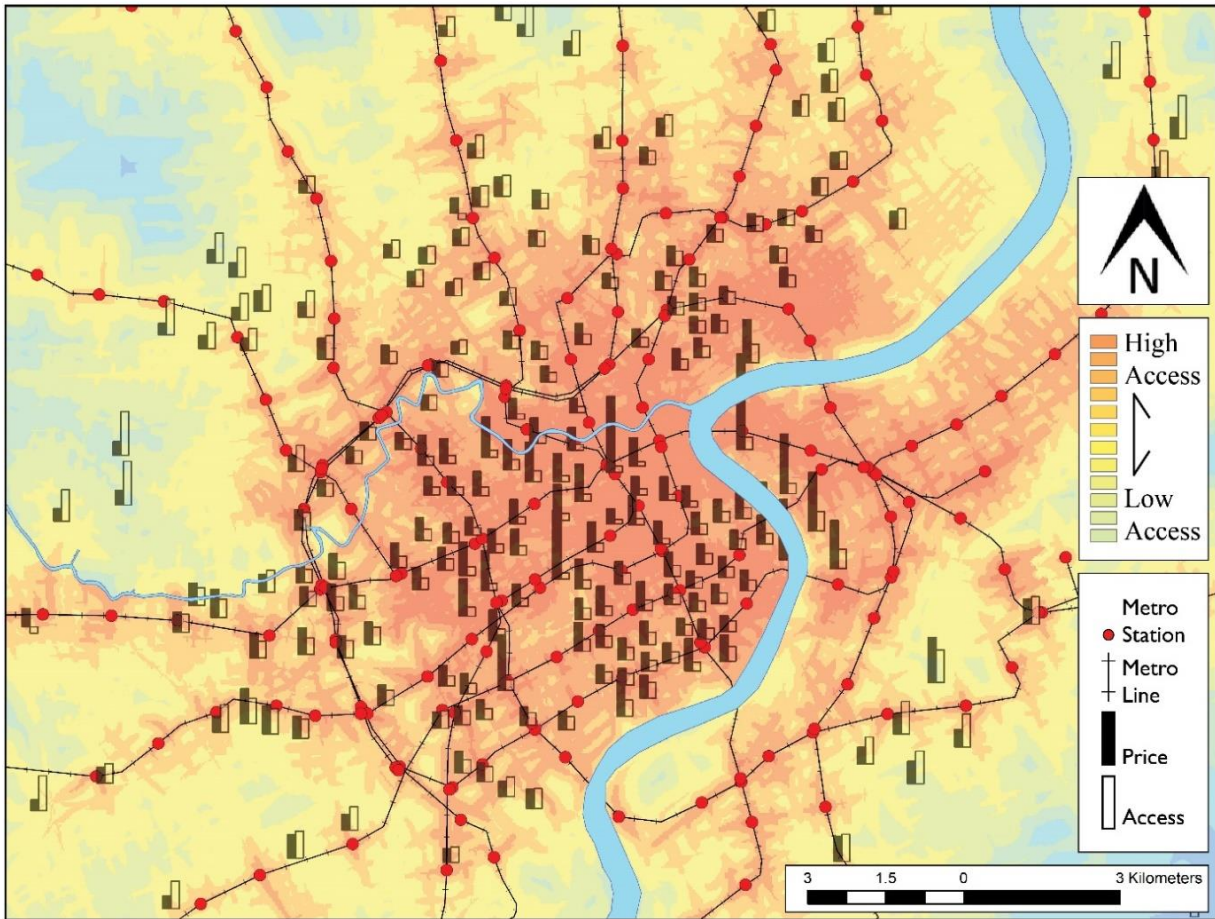
Model		Partial SS	df	F	Prob>F	R-squared	Adj.
1 Price	District	2.46E+10	12	11.21	0.0000	0.3360	0.3060
2 Access	District	4226.19	12	33.18	0.0000	0.5995	0.5814
3 Price/Access	District	175.48	12	43.78	0.0000	0.6639	0.6487
4 Access	Price, District	6492.83	221	3.01	0.0000	0.9210	0.6146
	Price	2266.64	209	1.11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

256

257 **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

258



259

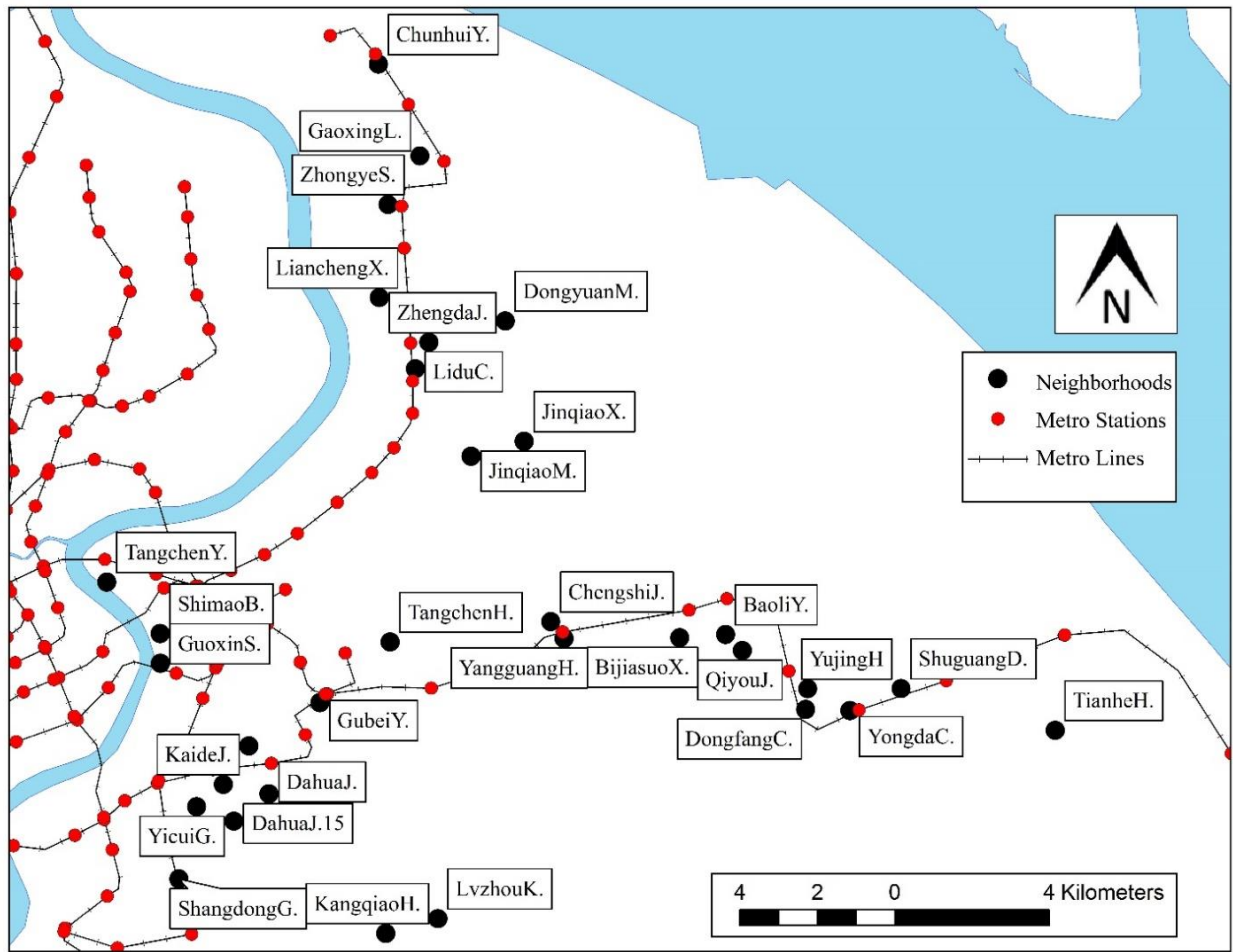
260 **Figure 1.** Metro access and property price of the 279 selected neighborhoods in Shanghai. The
 261 unit for property price is Chinese RMB (ranging from 8,700 to 160,000) and the unit for metro
 262 access is minutes (ranging from 0 to 90).

263

264 **4.2 Correlation between variables in Pudong**

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

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



274
 275 **Figure 2.** Locations of the 31 neighborhoods in Pudong District.

Table 4. Pairwise correlation coefficients matrix.

	Ave. Price 2012	Ave. Price 2017	Price Change 5-years	Price Change 1-year	Price Change 1-month	Time to Centers Mins	Dist. to Metro km	Current Station <1km	Future Station <1km	Bus Stop <1km	High-rise Office	Commer.	Non Desir.	Kinderg.	School	College	Security
	p1	p2	p3	p4	p5	a1	a2	a3	a4	a5	a6	a7	e1	e2	e3	e4	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	0.201	0.338	0.494*	1.000					
a7	0.514*	0.466*	-0.308	0.033	0.174	-0.347	-0.088	0.109	-0.318	-0.081	-0.131	-0.349	1.000				
e1	-0.113	-0.124	-0.022	0.075	0.096	0.034	-0.212	0.031	-0.168	0.005	0.013	0.119	0.084	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	0.071	-0.329	-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	0.510*	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	Social Service	Bank	Fresh Food 500m	Park	Neighb. Type	Build Type	Density (FAR)	Green Space	Year Built RMB	Prop. Fee	Resi. Units	Nearby Resid.	Parking	Main Gates	Site Area Hectre
	e6	e7	e8	e9	e10	n1	n2	n3	n4	n5	n6	n7	n8	n9	n10	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

280 4.3 Factor identification using PCA

281 **Table 5** summarizes the loadings of the PCA tests. The loading coefficients lower than -0.25
282 or higher than 0.25 are in bold. Loadings with statistically significant p-value at the 0.1, 0.05, and
283 0.01 levels are marked with one, two, and three asterisks respectively. Factor 1 shows high
284 coefficients for the number of high-rise office buildings and housing density. Factor 1 can be called
285 “*jobs-housing relationship*”. It represents the balance between accessibility to job opportunity and
286 housing supply. In addition, commercial properties, quality of property management, and number
287 of parking space per unit also exhibit high coefficients. The correlation analysis shows high
288 positive associations between access to office and access to commercial as well as between density
289 and parking. The property management variable reveals that in the jobs-housing relationship, not
290 only the quantity of housing but also the quality of property maintenance matters.

291 Factor 2 shows high coefficients for travel time to the closest metro station and the size of the
292 residential neighborhoods. The latter is represented by the number of residential units and site
293 areas. Factor 2 can be called “size and *access to existing metro station*”. Factor 3 is significant for
294 the future planned metro stations and the (un)availability of public services such as post offices,
295 public libraries, and civic centers. Factor 3 shows that the public service facilities are lagging
296 behind public transit planning as a consequence of the government-led (State Council) “planning
297 in advance” policy that prioritizes infrastructure development. In addition, level of security is also
298 important. Security, often operated by private contractors, can contribute to public safety and
299 emergency management. The positive correlation of security with factor 3 shows that the future
300 planned metro stations are closer to neighborhoods where high security levels are provided. These
301 neighborhoods are characterized by being recently built, high end, and often gated. Factor 3 can
302 be called “*public service and access to planned metro station*”. Since Factors 2 and 3 are only

303 correlated with accessibility to a low to medium extent, the accessibility variables have been tested
304 directly in the hedonic analysis. The coefficients are shown in **Figure 3**. The results show for
305 property price in both 2012 and 2017, high-rise office and commercial are the two most positively
306 correlated variables; for short term price change (one year and one month), future planned stations
307 are the most negatively correlated variables. The results reinforce the PCA analysis: First, more
308 value or benefit can be captured in the future in regard to *access to planned metro station*. Second,
309 access to employment (office and commercial) are the most influential variables.

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

320 **Table 6** shows the variation explained by the PCA. Among the 28 factors, the top 6 factors
321 together explained more than 64% of the variation in the original data. The top 9 factors explained
322 78.6% of the variation. Factor 7 to 28 each explain less than 5 percent of the variation and are thus
323 eliminated from further discussion. The eigenvalue trendline flattens out after factor 6, which also
324 confirms the importance of factors 1 to 6. **Figure 3** shows the scree plot of PCA eigenvalues and
325 the 95% confidence interval.

326 **Table 5a.** Variable coefficient of the PCA.

Variables	Factor 1 Jobs-Housing Relationship		Factor 2 Size Access to Metro E.		Factor 3 Social Service Access to Metro P.	
	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

327

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

329 **Table 5b.** Variable coefficient of the PCA.

Variables	Factor 4 Typology		Factor 5 Public Amenity		Factor 6 Environment Proximity	
	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 Commercial	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

330

331 **Table 5c.** Variable coefficient of the PCA.

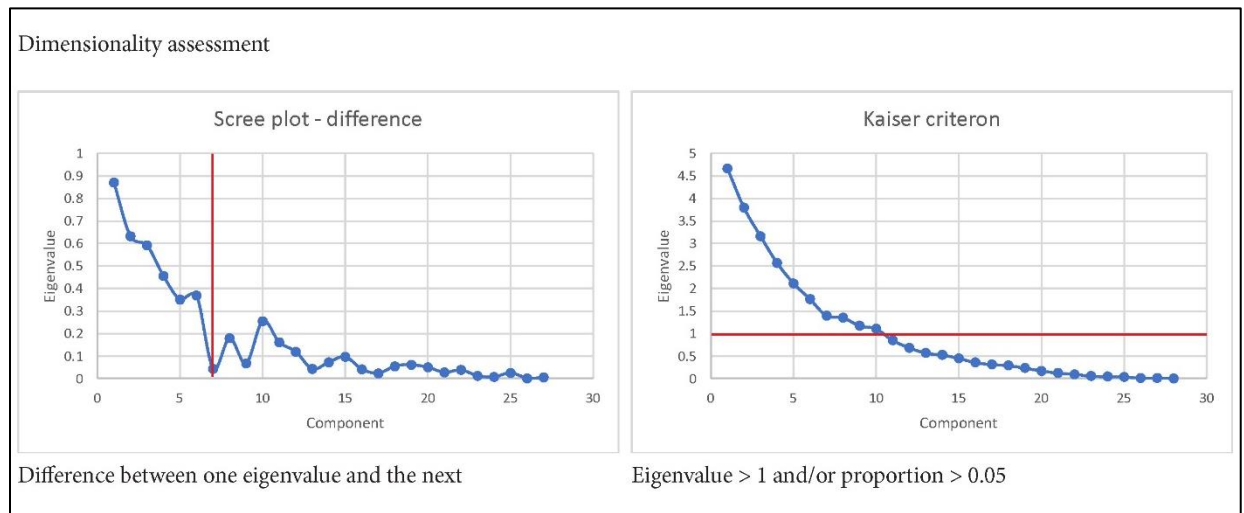
		Factor 7		Factor 8		Factor 9	
		Public Amenity		Public Amenity		Public Amenity	
Variables		Coef.	P-value	Coef.	P-value	Coef.	P-value
a1	Time to Centers	0.0552	0.8600	-0.0268	0.9510	-0.1253	0.8810
a2	Dist. to Station (km)	-0.1083	0.6620	-0.0299	0.9620	-0.1136	0.6840
a3	Current Station <1km	0.4675	0.5450	-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	Commercial	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

332

333 **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

334



335

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

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

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

345 Model 2 regresses on the average price in 2017. Factor 1 “*jobs-housing relationship*” and factor
346 3 “*public service plus access to planned metro*” are statistically significant at the 0.001 level. The
347 average resale price in 2017 can be understood as a function of jobs-housing balance and access
348 to metro stations plus public service.

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

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

355 In both models 1 and 2, jobs-housing relationship appears to be statistically significant. In this
356 study, it is the most important factor influencing housing prices at a point in time. Jobs-housing
357 balance has been the source of heated debates in the international context ([Guiliano and Small,](#)
358 [1993](#); [Peng, 1997](#)) as well as in China ([Wang and Chai, 2009](#); [Zhou, 2014](#)). [Cervero \(1989\)](#)
359 indicates that jobs-housing imbalance can cause higher vehicle miles traveled (VMT) and larger
360 percentage of motorized travel mode. [Weitz et al. \(2003\)](#) states that jobs-housing balance is a

361 process readjustment to market failure. In the Chinese circumstance, Wang and Chai (2009) claim
362 that the work unit system has an inherited advantage for achieving better jobs-housing balance. In
363 addition, Zhao et al. (2011) added to the claim that a comprehensive master plan implemented
364 through government intervention can further enhance the housing resource allocation. The counter
365 argument supporting co-location theory claims that the jobs-housing balance can be achieved
366 through market forces (Gordon et al., 1991; Peng, 1997; Hu et al., 2017). Hu et al. (2018) extended
367 the argument that various population groups may be affected differently in large Chinese cities. In
368 Shanghai, where state owned enterprises (SOE) who have a strong hold on work unit type of land
369 ownership coexist with private real estate developers who are maximizing profit by building
370 market price housing, the jobs-housing balance can only be achieved through a competing
371 advocacy of policy from multiple parties involved to align public interests and their own benefits.
372 For example, in recent years, some local SOEs (who own land-use rights) collaborate with private
373 developers (who bring money and development expertise) by forming public-private partnerships
374 (PPP) to take advantage of mezzanine loans in the form of nominal bank debts. The PPP can
375 expedite urban regeneration by providing more housing opportunities while reducing government
376 debts.

377 Models 1, 2, and 3 all show access to future metro stations as a significant variable for property
378 values. This factor considers future proposed metro stations and those under construction. The
379 high positive coefficients in 2012 and 2017 mean at both points in time, the housing property prices
380 are reflecting the premium of proximity to future metro stations. The negative coefficient for the
381 5-year price change, on the other hand, means that the premium price is reflected in the market at
382 least 5 years before the metro station start operation and that price premium diminishes from that
383 point on. The underlying reason may be that the initial market price was set too high so that it takes

384 away future price growth potential. When the market functions well, the initial prices are
385 confirmed by transactions, so they show what the market will bear. When the market fails to do
386 so, it may be counted as a market failure.

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

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

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

		Coef.	Std. Err.	t	P> t	Number of observations	31
P1	Price 2012					R-squared	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-squared	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-squared	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-squared	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-squared	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

400 **6. Urban form and urban spatial structure**

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

410 Density, one of the most frequently used measures for urban development, is a significant
411 determinant for residential prices in 2012 and 2017. In the US, lower density subdivisions have
412 higher prices; this study finds the reverse in Shanghai. Density in this study represents the
413 maximum capacity of residence accommodated or the as-built condition (not the population
414 density according to zoning). In a rapid urbanizing city, density should be constantly readjusted
415 by policy makers and planning professionals to reflect surrounding environment change, job
416 opportunity distribution, and accessibility improvement. The implementation of density
417 adjustment, to a large extent, is a collective appropriation of the state apparatus and private
418 investors' profit-making. Both neighborhood typology and size come into play as part of the urban
419 land use right reform in China. Neighborhood typology exhibits stronger impact on price in 2012
420 than in 2017. It echoes the results from previous studies that in the long term mixed-use and
421 diversity of land development are not as significant for Chinese cities as they are for American
422 cities (Srinivasan, 2010). Neighborhood size, including both the land area and the number of

423 residential units, exhibits significant effect on short-term (one year) price variation. To maintain a
424 sustainable spatial structure, density, typology, and size should be further investigated in regard to
425 urban development as well as urban retrofitting policies. More specifically, Pudong should adopt
426 planning strategies that increase job accessibility by introducing higher diversity to accommodate
427 all social classes. Also, Pudong should take into consideration spatial allocation of density to
428 increase the overall compactness and emphasize TOD to balance future planned metro transit to
429 serve not only high-income neighborhoods but also where low- to mid-incomes are clustered.

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

442

443 **7. Conclusion**

444 In a market-oriented economy, urban form and accessibility interact with property value. To
445 achieve a sustainable and more efficient urban spatial structure, residential housing price variation

446 can be analyzed to understand variables of accessibility and urban form. This study shows that
447 access to job, access to existing and future metro stations, access to public service, neighborhood
448 density and size, and neighborhood typology are all influential factors. Especially jobs-housing
449 balance and metro accessibility are the two key components to maintain a functionally efficient,
450 economically viable, and socially equitable urban spatial environment at the neighborhood scale.

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

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