

Testing of relationships among spatial accessibility, property characteristics and property value

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Abstract: A novel hedonic model based on spatial accessibility is proposed. This model changes the traditional planar hedonic model from two dimensional to three dimensional (3D). A 3D model through space syntax and quantum geographic information system platform was developed. Then, this model was tested through an analysis of 174 residential areas in Tianjin's central district. Accordingly, the impact of 3D location characteristics on the property value was examined. The results suggest a positive correlation between spatial accessibility and property value on a city-wide scale. Mass transit may exert negative influences, such as traffic noise and air pollution. On submarket scales, the property value may be influenced by urban functions, historical background, and street layout. The negative correlation between the bedroom number and price reflects a higher real estate market investment value in the Heping District and the high demand for small and medium-sized houses in the Hongqiao and Hedong Districts. This study provides insights for improving neighborhood plans and housing design, and policy making concerned with promoting balanced progress of social, economic, and spatial priorities.

Key words: hedonic model; space syntax; spatial accessibility; house price

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China's booming housing market over the past 20 years is inextricably linked to urbanization. Urbanization levels are expected to reach approximately 75% in 2050 regardless of population policies and the GDP growth rate. To a certain extent, property values reflect urban economics and affect population and talent flow across the city. Thus, the distribution of property values has become an important basis for housing studies^[1-3]. Since the 21st century, China's urban housing market has changed from facing an "amount problem" to a "structural problem". Hence, the total supply of urban housing

has been meeting needs, while the structure requires transformation, as reflected in the unbalanced spatial characteristics of central urban areas. The main reason is that urban internal reconstruction and external expansion are simultaneously advancing, resulting in the spatial and social differentiation of the urban housing market in China. In this sense, to understand the spatial and social differentiation of urban housing and provide helpful implications for housing planning policies, a study that integrates up-to-date empirical study results on China's urban housing market is required.

Indeed, the housing environment is always an important factor in house price differentials due to its slow-changing nature. A large amount of research used hedonic models to explain the internal relationship between commodity prices and characteristics, focusing on the specific characteristics of the housing environment, such as the social and environmental features of the neighborhood, architectural design, and location characteristics. In terms of property externalities, a large volume of literature has considered the Euclidean distance of the central business district, highway exits, railway stations, shopping centers, and suburban employment centers^[4-5]. However, a hedonic model is limited when capturing all factors influencing housing prices^[6]. In particular, the street layout determines the traffic form and convenience of the population flow. Accordingly, this paper extends these propositions about geographical locations, compares the two accessibility expressions of the Euclidean distance and street layout, and provides a credible reference for people's housing market choice preferences.

Spatial accessibility is a quantitative expression of how easy it is for residents to reach a spatial node, overcoming resistances such as distance, travel time, and cost. Space syntax is a theory of quantifying spatial accessibility parameters to measure and identify changes in urban morphology^[7]. Areas with high spatial accessibility tend to attract retail and commercial functions, hence increasing the economic value of the surrounding housing market. In the past few decades, research on the correlation between housing prices and the urban street layout has gradually emerged, with the theoretical framework mainly based on the basic idea of public-product-revealed preferences, such as street networks and urban form, as public prod-

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ucts that affect consumer preferences for property values^[8]. Although studies have started to explore the relationship between the topological structure of street networks and property value on a small scale or public transportation, there exists little consensus on how spatial accessibility should be combined with traditional housing location characteristics for applied housing studies.

Under this circumstance, the aims of this article are twofold: First, we address the weaknesses of the traditional hedonic model to identify geographical location characteristics and propose spatial accessibility as the complementary location characteristic. Secondly, we develop a new model to empirically lay out our idea by comparing it with the traditional hedonic model and case study. The submarket division of China's housing market usually uses the pre-delimited geographical boundary as the spatial unit. Based on this background, we undertake an experiment using a case study of Tianjin, China, the central urban area of which contains six housing submarkets delimited by administrative districts. Our study addresses two research hypothesis: 1) Extra spatial accessibility variables improve the interpretation ability of traditional planar feature models. 2) The hedonic model with spatial accessibility variables can verify the spatial differentiation characteristics of property values in spatial submarkets.

1 Materials and Methods

1.1 Research area

The research area is the central district of Tianjin. The central district of Tianjin includes the Heping, Nankai, Hexi, Hedong, Hebei, and Hongqiao Districts, which are administrative districts divided according to different urban functions, locations, and historical backgrounds. The road network of the central district presents the shape of an inner ring, indicating a strong core structure. From the core area to the outside, the density of the road network decreases, and the block scale gradually increases. This type of circular changed road network resulted in different levels and spatial differentiation of urban accessibility. Moreover, the housing type and property value differ across the city. The central districts of Tianjin can represent a type of Chinese city that is quickly expanding with real estate booms in the last 20 years.

1.2 Data

The datasets come from several sources. First, the street layout data were obtained from Google Maps. Second, the housing prices were gathered from a real estate information website using web crawler software to get text information in the web source code. We included only residential communities that are located in residential areas containing houses rather than offices or factories, whose housing prices are available. We excluded villas, affordable housing, and apartments for commercial use.

We took the average housing price per square meter (HPPSM) of each residential community on the real estate market in January 2020 to represent the property value. We randomly selected 174 residential communities from six administrative regions of Tianjin central district as samples to establish the traditional planer hedonic model (TP-HM) and spatial accessibility hedonic model (SA-HM). Fig.1 shows the spatial distribution of the HPPSM estimated by these communities.

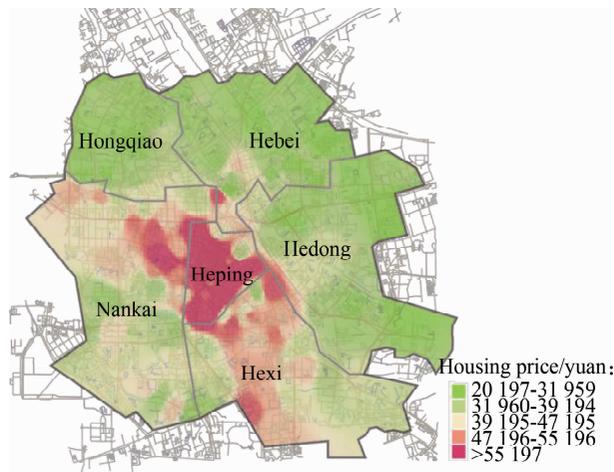


Fig. 1 Average housing price distribution

1.3 Measuring spatial accessibility

Two core parameters in space syntax were chosen as spatial accessibility indicators: The integration degree measures the potential of an element to attract arriving traffic, whereas the choice degree measures the potential of an element to attract crossing traffic^[9-10]. The two indicators are complementary and can comprehensively express the spatial accessibility potential of a spatial point in the study area. The space syntax literature and measures contain global and local analyses, reflecting the difference between long- and short-distance travels in spatial systems.

Based on the inner road network of the Tianjin central district, a depth map was used to calculate the space syntax parameters of the spatial network form, with 500, 1 500, 3 000, 5 000 m, and global N m (the entire network) as the search radius, reflecting traffic crossing and traffic walkthrough accessibility. In this section, the derived formulas are presented, which show the total depth and its relationship with the integration and choice degree^[11]. It is a basic formula in the space syntax theory which has been widely used. We assume that different search radii correspond to different transportation modes used by socioeconomic groups. Therefore, we can evaluate the centrality of the housing location and its corresponding spatial accessibility.

1.4 Quantifying property characteristics

Much research has been devoted to quantifying property

characteristics, with commonly reported measures, including the distance to urban facilities, floor level, landscapes, and housing age^[12]. For instance, the types of properties in China are usually classified by the number of bedrooms. It is basically proportional to the size of the property. The number of bathrooms and kitchens also matches it, which better reflects the basic layout of the property. Hence, in this study, we selected the bedroom number to determine property structure characteristics. Given that the hedonic model uses variables from three features, i. e., structure, location, and neighborhood, we identified seven variables with quantitative values and representativeness (see Tab. 1).

Tab. 1 Variables measuring property characteristics

Dimension	Variables	Abbr.	Measure
Structure	Bedroom number	BN	Average bedroom numbers in a residential community
	Floor number	FN	Average floor height of residential buildings, high (> 18), middle (6-18), and low (<6) are assigned 3, 2, and 1, respectively
	Housing age	HA	Number of years from the residential community development to 2020
Location	Administrative region	AR	Administrative area of the Tianjin central district, numbered 1-6
	Distance to the subway station	LN_DSS	Natural log of the Euclidean distance to the subway station
Neighborhood	Distance to the hospital	LN_DH	Natural log of the distance to the hospital
	Ratio of green space	RGS	Ratio of green space to the total area of the residential community

1.5 Statistical analysis and modeling

Taking the HPPSM as the dependent variable, we compared two sets of hedonic models to address the first research question. We first used the TP-HM with classical characteristic house price variables as the independent variables. We then added spatial accessibility variables to the independent variables to follow the SA-HM. To address the second research question, we divided the 174 residential communities into six groups according to their administrative regions and established the SA-HM of each group to explore the differences across submarkets. The hedonic price model employed in this study is specified in the following general form:

$$P_i = a_i + \beta_1 S_i + \beta_2 L_i + \beta_3 N_i + \beta_4 A_i + \varepsilon_i$$

where P_i is the residential property price (HPPSM); S_i is property structural attributes; L_i is property planar location attributes; N_i is property planar neighborhood attrib-

utes; A_i is spatial accessibility metrics at different radii; and ε_i is a random error term.

There are 7 independent variables in the TP-HM and 15 independent variables in the SA-HM. We conducted a number of tests, including F-statistics, R^2 , and standard errors, to ensure that the assumptions of hedonic models are not violated. The variance inflation factors of the variables are all fewer than 10, which indicates that multicollinearity is not a problem. The rationality was determined by adjusting the R^2 value of the linear regression analysis of the SPSS software.

2 Results

2.1 Space syntax analysis results

The integration degree shows a strong spatial clustering feature: The local integration with a radius of 500 m shows a multicore clustering mode with more local accessibility sub-cores (see Fig. 2). With the increase in the search radius, the integration illustrates a trend of clustering from the inside out, and the accessibility gradually decreases from the inside out. The spatially accessible core is the central business district of Tianjin, located in the Heping District. As shown in Fig. 3, a choice degree analysis with a low metrical radius highlights the old historic centers located in the Heping Historical Block. A high metrical radius highlights the modern urban centers and main route network. The global axial choice degree

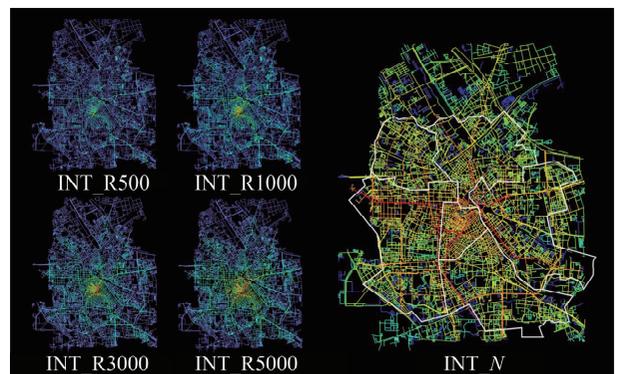


Fig. 2 Segment angular integration

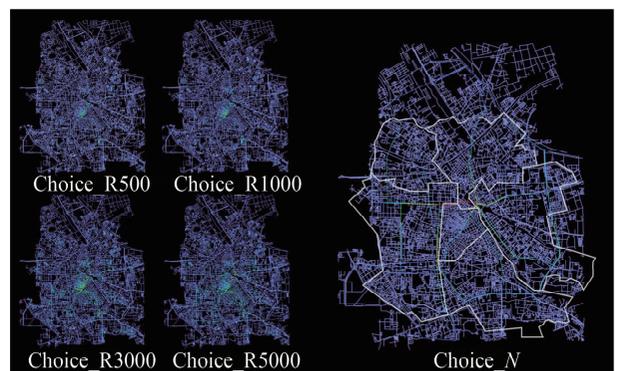


Fig. 3 Segment angular choice

(Choice_{*N*}) shows that high-value segments correspond to the main traffic arteries.

2.2 Comparative analysis of the TP-HM and SA-HM

Tab.2 shows the coefficients and t-statistics of the TP-HM and SA-HM. Compared with the TP-HM, including spatial accessibility variables (*A_i*) as explanatory variables improves the interpretation. The results of the TP-HM show that LN_DH and AR have the expected strong positive correlation with the property value, whereas BN and RGS have a negative correlation with the property value. The results of the SA-HM show that AR and INT_R3000 have a strong positive correlation with the property value. SA-HM shows that after adding spatial network accessibility variables, the adjusted *R*² increased from 0.184 to 0.633, so the degree of interpretation increased by about 3 times.

Tab.2 Coefficient estimates and t-statistics of the TP-HM and SA-HM

Dimension	Variables	TP-HM		SA-HM	
		Pearson coefficient	t-statistic	Pearson coefficient	t-statistic
Structure	BN	-0.247 ***	-3.454	-0.189 ***	-3.639
	FN	0.101	1.416	0.058	1.135
	HA	-0.067	-0.943	-0.110 *	-2.167
Location	AR	-0.343 ***	4.685	0.238 ***	4.446
	LN_DSS	-0.059	-0.784	0.026	0.450
Neighborhood	LN_DH	0.062 *	-0.862	-0.120 *	-2.300
	RGS	-0.071	-0.949	-0.003	-0.062
Spatial accessibility	INT_ <i>N</i>			-0.204 *	-2.496
	INT_R500			0.249	1.447
	INT_R1000			-0.425	-1.395
	INT_R3000			1.438 ***	6.111
	INT_R5000			-0.321	-0.610
	Choice_ <i>N</i>			-0.062	-0.876
	Choice_R500			-0.125	-0.873
	Choice_R1000			-0.063	-0.234
	Choice_R3000			0.027	0.072
	Choice_R5000			-0.027	-0.50
Standard errors		14 658.664		10 229.328	
Adjust <i>R</i> ²		0.184		0.633	
F-statistic		5.281		15.297	

Note: *** *P* < 0.001, significant at the 0.1% level or less (2-tailed); * *P* < 0.1, significant at the 10% level or less (2-tailed).

However, when the search scope was expanded to the maximum (*N*), the integration and property values had a negative correlation, as shown by INT_*N*. The particularity of the Heping District is also reflected in the negative correlation between house prices and the bedroom number. In addition, LN_DSS showed no significant correlation with the property value, whereas LN_DH showed a negative correlation with the property value.

2.3 Spatial differentiation characteristics of property values in submarkets

The analysis results of submarkets show that the *R*² val-

ue is generally higher than SA-HM of the city range (for submarket models, the *R*² value ranges from 0.713 to 0.89). The standard error of the equation reflects the significant spatial variability of the variable price structure of the urban housing market, with Hedong and Hongqiao having the lowest values and Heping and Nankai having the highest. Overall, the spatial accessibility variables have little correlation with submarkets, but they have a greater impact on housing prices in Hedong. There was no significant correlation between spatial accessibility and property values in Heping. In the Heping District, with the highest average house prices (63 368 yuan), only BN and PVPSM had a significant negative correlation (*p* < 0.01). The *R*² value of submarkets remains high (0.526-0.837), indicating a strong spatial differentiation in the whole Tianjin central district. Heping, Hongqiao, and Hedong all show a strong negative correlation with BN. Interestingly, Heping has the highest average house prices in Tianjin, whereas Hongqiao and Hedong have the lowest average house prices. In addition, among the submarkets, only Hongqiao in several submarkets showed consumer dependence on the subway station location (*p* < 0.01). The closer to the subway station, the higher the house prices, which is consistent with the previous space syntax analysis. The Hongqiao submarket's potential to attract traffic (INT_*N*) and cross-traffic (Choice_*N*) was the lowest among the six submarkets.

3 Discussion

3.1 Central district level

The property value is closely related to spatial accessibility. High-integration-degree areas in Heping are historic blocks, which in the past give pedestrians priority, thus providing high pedestrian accessibility. Housing age has a strong negative correlation with the property value, which conforms to the general buyer logic. In terms of accessibility variables, within a radius of 3 000 m, high accessibility contributes to a high property value. This condition suggests that buyers are willing to pay more for a better location with good accessibility and low travel costs. The novel hedonic model analysis results show that the convenient spatial point of mass transportation does not bring about a clear house price increase. This finding can be explained by the fact that due to the impact of noise, the housing value may fall by 3%-10%. Positive externalities brought by traffic convenience cannot compensate for negative externalities, such as noise and pollution brought by traffic, when spatial accessibility is good.

Based on the location and neighborhood dimension results, more than 90% of our samples have at least one subway station within a 1 km radius. Hence, the distance to subway stations may not be the main factor affecting

purchasers. This is because the subway has been a popular form of public transportation in central Tianjin.

3.2 Submarket level

Based on the correlation between spatial accessibility variables and submarket housing prices, Hedong's housing market is special. Its average house prices were the lowest in 2019 (24 979 yuan), and it includes urban functional arrangements and infrastructure that are not fully constructed. This finding indicates that the relationship between spatial accessibility and property socioeconomic characteristics is strong. In these areas, people with less disposable income and car ownership are highly dependent on public transportation. In contrast, private car users are less sensitive to pedestrian accessibility and public transportation facilities, which is supported by the correlation results for the Heping District. Heping submarkets retain their historical blocks under the protection of the government. Although the average bedroom number and housing area are lower than those in other submarkets due to the superior geographical location and rich historical background, the prices of houses are always extremely high. Furthermore, Heping is the economic and political center of Tianjin. Although its area is only 21% of the central city area, 70% of the main roads directly or indirectly pass through the area. This example clearly shows the local impact and importance of accessibility. According to previous studies, the standard error of the model is low at the submarket level as the level of statistical variability is reduced. In addition, the results of submarkets R^2 show that the fitted equation can effectively explain changes in dependent variables. With the division of urban areas, it is possible to find more localized effects.

In addition, the correlation between other variables and property values and their coefficient values are different, increasing the complexity at the submarket level. Previous studies have argued that the bedroom number is directly proportional to the property value, regardless of the purchase price or rental price. However, our results show that the situation is more complex given different urban functions and submarket backgrounds. A negative correlation exists between the bedroom number and the prices in the administrative region with the highest and lowest average house prices. This finding may indicate two different situations in which the property value is affected by BN. In the case of Heping, as a housing market with well-established infrastructure and high-value historic properties, fewer bedrooms usually indicate that the houses were built in the early stages of urban development. Under special protection and trading policies, these houses tend to have walkable access to historical blocks and represent a high real estate market investment value. However, for areas with low socioeconomic status, such

as Hongqiao and Hedong, more bedrooms mean that the housing area is relatively large and the housing is too expensive to afford, highlighting the high demand for small- and medium-sized houses in such areas.

The dependence of people with low socioeconomic status on subway transportation is a significant indicator of the strong demand for public transportation. Some studies have shown that low-income people tend to walk or cycle, with low monetary expenditures, but the speed is low and comfort is poor. With the gradual expansion of China's construction land scale in recent years, public transport such as subways and buses has become the main means of long-distance travel for low-income people. This conclusion can be confirmed by the housing market of the Hongqiao District (lowest average house price); its submarket's potential to attract traffic and cross-traffic is the lowest among the six submarkets. These variables are combined with a spatial accessibility analysis to better understand the complexity of the housing market, thus increasing the level of further analysis.

4 Conclusions

1) The TP-HM and SA-HM results show that the bedroom number and distance to hospitals have a negative impact on the property value, whereas spatial accessibility has little significance in explaining changes in the property value on a city scale. Moreover, the influencing factors of the property value vary across submarkets. For instance, only areas with underdeveloped street traffic and low socioeconomic status show sensitivity to subway station locations.

2) Urban spatial accessibility, as a public product, is the intervention of urban planning in the housing market. Decision makers should optimize the structure of the urban spatial network, which allows for the adjustment and control of property prices in the region, and the impact of spatial accessibility on the housing market should be considered.

3) From the perspective of the market economy, this study is still in the initial stage of evaluating the structural road characteristics. Although the evaluation results of quantitative methods were obtained, for accuracy, other interference factors should be excluded, and more control variables should be considered.

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空间可达性、住宅特征与房产价格之间的关系检验

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摘要:为明确空间可达性、房产特征与房产之间的关系,提出了基于空间可达性的新特征模型,使传统的平面特征模型从二维尺度转向三维尺度.通过空间句法与 QGIS 平台构建了三维特征模型,对天津市市中心 174 个居住区的分析结果验证了三维空面特征对房产价格的影响关系.结果表明,市级尺度的空间可达性与房价呈正相关,但公共交通带来的噪音与空间污染可能会产生负外部性.在行政区划尺度,房产价格受到城市功能、历史背景与街道布局的影响较为显著,如卧室数量与房价之间呈现的负相关关系分别体现出和平区房地产市场的高投资价值与红桥区、河东区对中小型住宅的高需求.研究结果可为改善住宅设计、社区规划以及城市发展战略提供决策依据,促进社会、经济与空间的平衡发展.

关键词:特征模型;空间句法;空间可达性;房产价格

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