Spatial Distribution of Influence Factors of Residential Land Price in Cangzhou City Based on GWR Model

Hongjie Liu¹, Yuan Meng¹ and Jing Ma¹
¹ Urban Construction School, Beijing City University, Beijing, 101399, China

Abstract. This paper mainly takes Cangzhou City as an example to study spatial distribution of influence factors of residential land price, in order to deeply understand the driving factors of the spatial heterogeneity of residential land price in Cangzhou City. Based on the GWR model, the analysis of the influence factors of residential land price shows that the urban center has a significant positive impact on land prices, that is, the closer to the city center, the higher the land price is. The main roads, schools, and parks have different positive impacts on residential land prices, and there are large spatial differences in the degree of influence of various factors. The canal has a negative impact on residential land prices, that is, the closer to the canal, the lower the land price, mainly due to the existence of villages in city on both sides of the canal, which has a certain inhibitory effect on land prices. The impact of hospitals on residential land prices is not regular in spatial distribution.

1. Introduction
In recent years, urban residential land prices have shown an upward trend nationwide, and there are many factors that form this trend. However, specific to a certain city, the land price presents different spatial correlation and heterogeneity, and many scholars pay attention to the spatial distribution and influence factors of residential land price within the city. The GWR (Geographically Weighted Regression) model, has been widely used in the study of land price influence factors. The GWR model can overcome the limitations of the traditional regression model, and perform statistical analysis from a spatial perspective to describe the functional relationship between the research objects more accurately.

Brunsdon C et al. studied the difference between expansion model in spatial statistics and GWR model, using linear expansion model, nonlinear expansion model and GWR model to study spatial difference. The results show that GWR model reflects spatial difference more accurately. Platt R V applied global regression model and GWR model to study the functional relationship between Landscape fragmentation and Urban Growth Boundary density, based on land use data from 1985 to 1999. The results show that GWR model explains spatial variation more accurately. Gao Xiaolu et al. applied global regression model and GWR model to study influence factors of real estate price. The results show that there is a complementary effect between the two model in identifying land parcel correlated variables and area correlated variables. Luo Ganghui et al. applied the GWR model to analyze the impact of parcel area on urban residential land price, and showed the results in a visual space through GIS method. The results show that there is a large spatial difference in the impact of parcel area on residential land price. Li Zhi et al. applied the GWR model to study the spatial distribution of the influence factors of residential land price in Nanjing. The results show that the GWR model has a good estimate of the spatial variation of land price influence factors. At present, the research areas of domestic scholars are mainly concentrated in large cities such as provincial capitals,
however, the spatial distribution and influence factors of residential land prices in small and medium-sized cities are relatively limited. Based on this, this paper mainly takes Cangzhou City as an example to study spatial distribution of influence factors of residential land price, in order to deeply understand the driving factors of the spatial heterogeneity of residential land price in Cangzhou City, enrich the research case of land economics from the method and practice, and provide a powerful reference for land management in similar areas.

2. Research area overview and basic data

2.1. Overview of the study area
Cangzhou City is located in the southeast of Hebei Province, in the center of the Bohai Bay. It is located between 115°06′ and 117°08′ east longitude and between 37°04′ and 38°09′ north latitude. It is only 200 km away from Beijing. It is one of the economic open areas and open coastal cities defined by the State Council. Since 2007, the land market in Cangzhou has developed rapidly and the transaction cases are rich. It has strong representation in small and medium-sized cities in North China.

2.2. Research data sources and pretreatments
According to the distribution of the survey data, the research area of this paper selects the built-up area of the main city: Yingbin Avenue in the west, Changlu Avenue in the east, Haihe Road in the south, and Bohai Road in the north, with an area of about 55 km². The research data collected in this paper spans from 2007 to 2013, mainly from the survey data of benchmark land price update of 2014. A total of 147 valid data samples were collected in this study. Due to the limited number of plots sold in the built-up area within the study time range, the research area data mainly comes from the second-hand housing market transaction data and commercial housing sales data. According to the "Urban Land Valuation Regulations" (gb/t 18508-2014), the second-hand housing transaction data and commercial housing sales data can be measured by the income method. Since the land price level in the land market changes from time to time, in order to ensure the consistency of the transaction time of the sample data, the transaction time of all residential land price samples was revised to December 2013 in this study. The land price of all sample sites is revised to the land price corresponding to 70 years' land use right. All land price samples will be uniformly revised to the seven access and site leveling. Correct the plot ratio of all land price samples to 2.5.

3. Spatial Distribution of influence factors of Residential Land Price in Cangzhou City Based on GWR Model

3.1. GWR model
The Geographically Weighted Regression (GWR) model is based on the general linear regression model. The spatial position of the data is embedded in the regression parameters of the multiple linear regression model, that is, the geographically weighted regression model is obtained:

\[ y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i)x_{ik} + \epsilon_i \quad i = 1, 2, \cdots, n \]  

(1)

In the equation: \((u_i, v_i)\) is the spatial coordinate of the i-th data sample. \(\beta_k(u_i, v_i)\) is a continuous function describing the spatial position of the sample, representing the k-th regression coefficient of the i-th data sample. If \(\beta_k(u_i, v_i)\) remain unchanged, the geographically weighted regression model is transformed into a general global regression model, that is, the general global regression model is a special form of the geographically weighted regression model. Therefore, the applicatio of the GWR model is to describe the spatial instability of the object, that is, the position function \(\beta_k(u_i, v_i)\) varies with the position of the data sample. The spatial weight matrix is the core of the geographically weighted regression model, and the spatial weight function of the matrix is used to represent the
spatial relationship of the data. In this paper, Gaussian function is applied to determine the weight function.

3.2. Construction of the GWR model

In this paper, when selecting the influence factors of residential land price, for one thing, it refers to the research results of many scholars; for another thing, according to the provisions of the “Rational Rules for Urban Land Grading” (gb/t 18057-2014), the impact on residential land price in the benchmark land price. Factors are selected according to priority, and the following five factors are selected: urban center impact, urban traffic (main road), public facilities (primary and secondary schools, hospitals), landscape environment (parks, Beijing-Hangzhou Grand Canal). In this paper, the influence factors are quantified by measuring the spatial distance. For the point, line and surface elements in the location factor, calculate the linear distance from the land sample to the nearest element, as the quantitative standard of each influencing factor.

Table 1 Factors quantization table.

| Influence factors | Quantitative standard | Expected effect |
|-------------------|-----------------------|-----------------|
| Urban center      | Minimum distance to urban center (m) | positive |
| Main road         | Minimum distance to main road (m) | positive |
| School            | Minimum distance to school (m) | positive |
| Hospital          | Minimum distance to hospital (m) | positive |
| Park              | Minimum distance to park (m) | positive |
| Grand Canal       | Minimum distance to Grand Canal (m) | positive |

Let the land price of the i-th sample be \( y_i \), and \( x_{ik} \) represents the closest distance from the land sample to a certain influencing factor. \( \beta \) representing the regression coefficient of the factor, the GWR model can be constructed as equation (2):

\[
y_i = \beta_0(u_i, v_i) + \beta_{CBD}(u_i, v_i)x_{i1} + \beta_{ROAD}(u_i, v_i)x_{i2} + \beta_{SCH}(u_i, v_i)x_{i3} + \beta_{HOS}(u_i, v_i)x_{i4} + \beta_{PAR}(u_i, v_i)x_{i5} + \beta_{CAN}(u_i, v_i)x_{i6} + \beta_{PR}(u_i, v_i)x_{i7} + \epsilon_i
\]

\[
= \beta_0(u_i, v_i) + \sum_{k=1}^{7} \beta_k (u_i, v_i)x_{ik} + \epsilon_i
\]  

(2)

In the equation: \( \beta_{CBD}, \beta_{ROAD}, \beta_{SCH}, \beta_{HOS}, \beta_{PAR}, \beta_{CAN}, \beta_{PR} \) represent the regression coefficient of the city center influence degree, main road influence degree, school influence degree, hospital influence degree, park influence degree and canal influence degree at point i, for simplifying the equation, the coefficient is unified \( \beta_k \).

3.3. Analysis of model calculation results

The calculation results of the GWR model are shown in Table 2:

Table 2 Regression coefficients of bi-square weight function with AIC.

|          | Mean | Min | Q1 | Median | Q3 | Max | S   |
|----------|------|-----|----|--------|----|-----|-----|
| CBD      | -0.476 | -0.677 | -0.539 | -0.483 | -0.403 | -0.350 | 0.165 |
| ROAD     | -0.114 | -0.421 | -0.234 | -0.032 | -0.133 | 0.268 | 0.151 |
| SCH      | -0.202 | -0.640 | -0.233 | -0.184 | -0.130 | 0.026 | 0.076 |
| PARK     | -0.028 | -0.303 | -0.189 | -0.001 | 0.082 | 0.345 | 0.201 |
| HOS      | 0.015 | -0.152 | 0.066 | 0.001 | 0.084 | 0.265 | 0.111 |
| CAN      | 0.204 | -0.043 | 0.042 | 0.134 | 0.390 | 0.505 | 0.258 |

In the ArcGIS 9.3 environment, the regional difference maps of the impacts of various influence factors on residential land prices are generated and analyzed.
3.3.1. Impact of the urban center. The regression coefficient of urban center to land price is negative, indicating that the closer the distance is to the commercial service center, the higher the land price is, that is, the urban center has a positive impact on the land price, and all the land price samples are in line with this law (Figure 1). Figure 1 shows that the impact of urban center on the residential land price is centered on the business center of the old urban area in the east, and decreases toward the surrounding area. The decreasing mode is similar to the spatial distribution trend of land price. According to the regression coefficient, the unit land price drops by 350-572 yuan for every 1 km increase from the commercial center. The closer to the business service center, and the impact is more obvious. In the area east of the canal, an annular region with a radius of about 1.5 km is formed, and then spreads to the surrounding area. In the area east of the railway, the degree of influence is at the same level, which is about [-0.523, -0.473]. The degree of influence of the service center has played a certain role in blocking. In the area west of the canal (canal area), the trend of the influence factors of the commercial service center is obviously different from that in the east. The degree of influence is bounded along the canal, forming a decreasing trend of the belt until Yong’an Avenue. In the area from Yong’an Avenue to Yingbin Avenue, the influence degree of the commercial service center has declined to a certain extent, and the influence of the commercial service center in the north is slightly higher than that in the south. The main reason is the difference in the surrounding environment and supporting facilities. At present, the north of Yongji Road, the west of Fuyang Avenue and the south of Bohai Road is being developed. The surrounding supporting facilities are slightly different from the vicinity of the southern Yihe Manor Community, so under the same distance from the business center, the northern land price is lower than that of the south, that is, the business center is more influential.

3.3.2. Impact of major roads: The regression coefficient of the main road to land price is negative, that is, the closer to the road, the higher the residential land price, the positive impact of the road on the land price, and the negative impact in some areas (Figure 2). The regression coefficient of the main road to land price is negative, that is, the closer to the road, the higher the residential land price. The roads have positive impact on the land price, and have negative impact in some areas. Figure 2 shows that the main roads have a much greater impact on the Xinhua District to the east of the canal than the western canal area, and have the opposite trend in the two administrative districts. In Xinhua District, the land price is positively related to the main road, that is, the farther away from the main road, the lower the land price. However, in the canal area, the opposite trend has appeared. The closer to the main road, the lower the land price, and the northwest corner of the city is the most serious. After analysis, the reason for this phenomenon may be that although the main road resources in the western part of the Canal District are rich, most of them are newly built, and their bus lines are not yet perfect, and the accessibility is not as good as the original ordinary roads. In general, the rapid road system has not yet been formed in Cangzhou City. The main roads in the built-up area are five-horizontal and four-vertical. However, due to the small size of the built-up area, except for the nine main roads, other
road systems are more developed. In other words, the accessibility is high, so the degree of influence of roads on residential land prices has a large regional difference.

### 3.3.3. Impact of educational resources

There is a positive correlation between school and residential land prices, that is, the closer to the school, the higher the land price is (Figure 3). Figure 3 shows that the regression coefficient to the distance of the school is [-0.601, 0.057], the most influential place is located on the east side of the canal, in the area of the old city business center. The school is more densely distributed, including the first middle school of Cangzhou City and the eighth middle school, which are two key middle schools in Cangzhou. There are also several primary schools such as Xinhua Road Primary School, Canal Primary School and Experimental Primary School. The schools in this area have a greater impact on land prices, which reflects the concentration influence of these schools to a certain extent. The impact of the school on residential land prices is centered around the old city business center, with a decreasing gradient to the surrounding areas; the area east of the Xinhua District Railway and the south of the Jiefang Road in the Canal Zone, the school has a small impact on land prices, and even has a negative correlation. That is, the closer to the school, the lower the land price. The main reason is that, on the one hand, the land price level in the east of the railway is generally lower due to the barrier effect of the railway. On the other hand, the education quality of only three schools in the region is general, and the promotion of land price is not obvious.

![Figure 3](image1.png)

Figure 3: Different spatial influence of schools for residential land price.

![Figure 4](image2.png)

Figure 4: Different spatial influence of parks to the residential land price.

### 3.3.4. Impact of landscape factors

The landscape factors selected in this study mainly include parks and canals. The following are the effects of the two factors on residential land prices.

1. **Impact of park.** The park has a positive impact on residential land prices, and there is a large spatial difference in the degree of impact (Figure 4). Figure 4 shows that the park with the highest impact on land price is located in the area of Nanhu Park and is decreasing around the Nanhu Park. In this area, the park is positively correlated with land price, that is, the closer to the park, the higher the land price is. There are relatively few parks or green spaces in the east of the canal. In addition to the Nanhu Park, there are also the Lotus Pond Park and the Qiantong Park, all of which have a positive impact on residential land prices. Along the area of Yingbin Avenue, the impact of the park on residential land prices is negative, that is, the closer to the park, the lower the land price. The main reason is that Yingbin Avenue is located on the west boundary of the study area. The park along the line mainly includes Lion City Park, Shengli Park and Celebrity Botanical Garden. It is an auxiliary facility for the city to develop westward. Due to it is newly constructed, the degree of influence has not yet been reflected. According to the “Cangzhou City Master Plan (2008-2020)”, as the city expands further westward, it is expected that the park along Yingbin Avenue will have a positive impact on land prices.

2. **The influence of the canal factor.** The Beijing-Hangzhou Grand Canal runs through the city from north to south and is the dividing line between Xinhua District and the Canal District. It is also
an important landscape belt in Cangzhou. The extent of the impact of the canal on residential land prices is positive except for a small number of areas, which is generally negative, that is, the closer to the canal, the lower the land price, contrary to expectations. The extent to which the canal affects land prices varies across the study area (Figure 5). According to Figure 5, the impact of the canal on Xinhua District and the Canal District is very different. The areas with positive impact on land price are all distributed in Xinhua District. In other areas of Xinhua District, the impact of the canal is [-0.058, 0.068], close to 0. The overall impact of the canal on Xinhua District is small. The influence of the canal on the residential land price in the canal area is all negative, and its distribution law is that along the canal to the west, its negative influence gradually increases. The main reason for the negative impact of the canal on land prices is twofold. First, the negative impact of the canal on the land price in the far west of the canal is mainly due to the formation of the regional sub-center of the Tongtian shopping mall in the west, which has caused radiation impact to the surrounding land price. The canal is located between the sub-center of the new city and the old city center, and its degree of influence on the land price is dispersed by the influence of the commercial service center. Second, the canal has a negative impact on the residential land price along the coast, mainly due to some land along the canal are not developed. For example, in the south of Jiefang Road in the north of Huanghe Road, and on the west side of the canal, there are still villages in the city, such as Qianxinzhuang, Nanguankou and Zhangjiafen. It is a problem left over from the transformation of the old city and needs to be solved urgently. It can be expected that with the completion of the transformation of the village in the city and the expansion of the canal landscape zone, the land price around the canal will rise sharply, that is, the canal will have a more obvious positive impact on its coastal land price.

3.3.5. Spatial differences in hospital impact on residential land prices. The mean regression coefficient of hospital impact on residential land price is positive, but the spatial distribution of its impact is not obvious (Figure 6). From the distribution of the regression coefficient, the hospital has a negative impact on the land price, that is, the farther away from the hospital, the higher the land price is, and it is different from common sense. There are two reasons for explanation: First, hospitals are good at specialties, and the levels are uneven. In terms of choosing medical treatment, there are differences based on specific conditions. Second, the closer to the hospital, the lower the land price, it maybe because when residents choose their homes, they think that the living environment around the hospital is more complicated and the livability is poor.

4. Conclusions and discussion
Based on the GWR model, the analysis of the influence factors of residential land price shows that the urban center has a significant positive impact on land prices, that is, the closer to the city center, the higher the land price is. The main roads, schools, and parks have different positive impacts on
residential land prices, and there are large spatial differences in the degree of influence of various factors. The canal has a negative impact on residential land prices, that is, the closer to the canal, the lower the land price, mainly due to the existence of villages in city on both sides of the canal, which has a certain inhibitory effect on land prices. The impact of hospitals on residential land prices is not regular in spatial distribution. Compared with the conventional linear regression and the characteristic price model, the GWR model based on the spatial instability assumption can not only extract the factors that significantly affect the residential land price performance, but also describe the spatial differentiation of the influence of various factors on the residential land price, which is more suitable. It provides a basis for residential space planning and land price update from the perspective of micro location, and is more in line with the city’s smart growth planning concept.

The research in this paper inevitably has some shortcomings that need to be further explored. First of all, in terms of data acquisition, due to the limited transaction data of land market in Cangzhou City, the number of land parcels is small, mostly mixed with commercial and residential distribution, and the distribution is not balanced. Considering the availability of research data, this paper chooses second-hand housing transaction data and housing sales data for the basis of the research. The land price of residential transaction samples is mainly calculated by the residual method. Compared with the directly obtained land transfer data, there is a certain measurement error. Secondly, in terms of the quantification of the influence factors, in view of the complexity of the calculation, the quantification criteria of each factor uniformly select the distance from the sample to the factor, the next step of discussion and improvement is needed.

References

[1] Brunsdon C, Fortheringham A S, Charlton M. (1996) Geographically weighted regression: a method for exploring spatial nonstationarity. Geographical Analysis, 4(28): 281-298.
[2] Platt R V. (2004) Global and local analysis of fragmentation in a mountain region of Colorado. Agriculture, Ecosystems & Environment, 101(2–3): 207-218.
[3] Gao X, Asami Y. (2007) Effect of urban landscapes on land prices in two Japanese cities. Landscape and urban planning, 81(1): 155-166.
[4] Luo G, Wu C, Zheng J. (2007) Effect of area of ancestral land to residential land price. China Land Science, 205: 66-69+78.
[5] Li Z, Zhou S, Zhang H, et al. (2009) Influence factors of residential land and marginal price action in Nanjing City, China Land Science, 10: 20-25.
[6] Haider M, Miller E. (2000) Effects of transportation infrastructure and location on residential real estate values: application of spatial autoregressive techniques. Transportation Research Record, 1722(1): 1-8.
[7] Qin B, Jiao Y. (2010) Spatial distribution of residence price and urban spatial structure evolution in Beijing. Economic Geography, (11): 1815-1820.
[8] Liu H, Wang Q. (2011) Influence factors of urban residential land transfer price based on hedonic model. Economic Geography, (06): 1008-1013.
[9] Zhong H, Zhang A, Cai Y. (2009) Effect of Nanhu landscape in Wuhan to neighborhood residence price—empirical study based on hedonic model. China Land Sciences, (12): 63-68.