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Research Article

The Impact of Subway Lines on Residential Property Values in Tianjin: An Empirical Study Based on Hedonic Pricing Model

Hui Sun,[1] Yuning Wang,[2] and Qingbo Li[1]

[1]*School of Management and Economics, Tianjin University, Tianjin, China*
[2]*College of Urban and Environmental Science, Tianjin Normal University, Tianjin, China*

Correspondence should be addressed to Yuning Wang; wangyn8158@126.com

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The construction of subways has an external impact on the urban environment. Among them, the most important acceleration function lies in the property values of housing near subway stations. Tianjin, the largest open coastal city in Northern China, is selected as the subject of the research in this paper by virtue of its unique background. The Hedonic Pricing Model is used in analysing the change in the value of the properties located within 1,000 metres of completed subway line 3 stations. Using the theories of land rent and land location, and a model of the impact of urban traffic on the surrounding real estate prices, we analyse the sphere of influence of Tianjin Metro Line 3 on real estate prices. Finally, the paper stresses the importance of urban construction and subway building and finds that different development strategies should be used according to the characteristics of the subway in various regions of the city.

1. Introduction

In recent years, we have seen rapid increases in the population, the urbanisation process, and the number of vehicles in China's central cities. According to the statistics, currently, the total number of compact cars in China is more than 250 million. Accordingly, such facts have resulted in a series of problems, such as traffic congestion, environmental pollution, and an energy crisis. As one of the four municipalities in China, Tianjin is facing traffic problems that are increasingly severe and increasingly common. The Tianjin Public Security Traffic Management Bureau released figures showing that, at the end of January 2016, the number of motor vehicles in Tianjin had reached 2,850,000. At the same time, the Tianjin Environmental Protection Bureau pointed out that the total amount of automobile exhaust emissions from such motor vehicles was up to 500 thousand tons per year, which constitutes its main source of urban air pollution.

Most cities worldwide regard the construction of urban rail transit systems as an effective means of easing traffic pressures and improving traffic pollution, due to their high speeds, accurate times, low pollution, and large passenger capacity. Therefore, in order to alleviate the severe traffic pressure that it currently faces, Tianjin is also actively promoting the construction of a subway system. The subway system is playing an important role in improving travel conditions for residents. Meanwhile, the construction of a subway changes both a city's original location advantages and the disadvantages in its layout, and it contributes greatly to the appreciation of surrounding residential houses and alters the spatial structure of the prices of the surrounding houses.

At the same time, the expense associated with the construction and operation of track transportation has been creating a bottleneck that has impeded its rapid development. The key ideas that have arisen regarding a solution for the lack of capital in the construction of the subway system involve using the appreciation in the value of the land along subway lines to foster track construction and combining capital demand and the promotion of track construction. By means of these facts, using the Tianjin subway as an example, this paper studies the impact of the various locations (urban centre areas and nonurban centre areas) on nearby property values. Further, subject to the impact of subways on property appreciation, this paper proposes the integration of planning and development strategies based on the coordination of the development of land and transportation, in order to provide

theoretical support for subway construction in Tianjin and the integrated development of the subway and nearby land.

2. Literature Review

Since the 1970s, a large number of international research studies have given close attention to the mutual influences of track transit and property values. Damm et al. examined the preservice impacts of the Washington metro [1]. Gatzlaff and Smith studied the relation between transit costs and housing expenses to point out the trade-offs of urban housing [2]. Stegman established a computational model for residential values and locations and traffic costs [3].

Since then, a large number of scholars have performed empirical research to prove that the construction of rail transit facilities significantly improves the added value of properties along subway lines. The research conducted by Dewees et al. reached the conclusion that the cost reductions resulting from urban transportation will lead to increases in the prices of residential properties [4–7]. Tang et al. found that the establishment of urban rail transportation may result in a 1/3 value-added effect of the total investment of the track for nearby properties [8–10] and so conducted research on the residential housing near the DART light rail transit (LRT) system. They concluded that the prices of residential housing near subway stations had experienced a 32.1% increase after the construction of the light rail system [11]. In another research study on the values of various residential properties, the value of nearby condominiums increased 46% and the value of single family housing increased by 17% [12].

Meanwhile, some scholars have performed comparative studies on the influences on surrounding properties caused by rail transportation, based on different time and space conditions [13]. Bae et al. came to the conclusion, after researching Seoul's subway line 5, that, before the opening of rail transport lines, the distance to transit had a significant impact on property prices; three years after the opening, the attenuation of the effect may have been nearly complete [14]. Kim et al. pointed out that residential property values near urban rail transit decrease with increasing distances from subway stations [15]. Cervero and Kang, after studying Seoul's BRT system, arrived at the conclusion that a BRT station plays a visible role in the appreciation of the value of residential housing located within 300 metres of it, and a more moderate role for housing beyond 300 metres [16]. Cervero developed a research study that examined properties in a business centre and in a noncommercial centre. Land prices within a 400 m radius of a station near the business centre increased by 120%, and they increased by 23% nearby other light rail stations that were close to the noncommercial centre [17]. Armstrong and Rodríguez estimated local and regional accessibility benefits of commuter rail services in Massachusetts and found that the effect of proximity to commuter rail right-of-way indicated a negative effect on property values [18]. Bowes and Ihlanfeldt analysed its impact on Atlanta housing prices, and found that the railway stations could raise the value of nearby properties [19]. In a study of the Izmir region in Turkey, Celik and Yankaya claim that railway and transit investments will provide additional economic value beyond direct ticket revenues [20]. Debrezion et al. used a Hedonic Pricing Model to analyse the impact of the railway network on house prices in the Netherlands; they found that there is a relationship between the houses price and the railway investment [21]. Kahn investigated the impact of 14 rail systems built in the US; the research found that the radius of the price-distance gradient increased as a result of improved rail accessibility [22]. Duncan studied the capitalization benefits of LRT in San Diego on houses, and he found that rail stations have a positive impact on nearby property values [23].

In the 1990s, we witnessed the prosperity that was generated by the construction of rail transit in China. A large number of research studies on the manner in which property values were influenced by transportation emerged. It was believed that the convenience of transit has a positive effect on the increase of land prices [24, 25]. So, Glascock et al. analysed its impact on Hong Kong housing prices. They confirmed that the prices of housing located near subways, buses, and ferries were significantly influenced [26]. Feng et al. asserted the idea that a subway's degree of influence on the prices of nearby housing, before and after the opening of subway lines, was inversely proportional to its distance from the subway site [27, 28]. After targeting Beijing Line 1 as a subject of research, Zhang et al. concluded that the influence of subway stations on residential housing prices is the result of specific accessibility variables and the combined effects of other conditions [29]. Wang et al. found that the pattern of distribution of the values of property along the lines will be altered, forming a gradual decrease in the spatial pattern of distribution of housing prices along the two sides of the tracks [30–32]. The impact of rail transit on property prices has a chronology. The time-based impact of rail transit on the surrounding housing is mainly centred around the period from the announcement of construction to the opening of the line, as well as before and after the commencement of construction [33].

A review of the domestic and international research reveals that scholars have primarily been studying the degree of influence on the appreciation of the value of nearby properties which has been caused by the construction of rail transit in various cities from an empirical point of view. They have asserted that traffic improvement is an important factor affecting land appreciation [34–36]. However, due to different degrees of maturity in cities' economies, their urban planning, and their urban infrastructure, the extent to which the development of rail transportation has an influence on property appreciation differs. Compared to other major cities, the foundation of subway construction in Tianjin is weak, but it has great potential for development. In recent years, the rapid expansion of the city has created a greater need for subway construction. Combined with the specific characteristics of Tianjin, it is important to thoroughly study the influence of subway construction on the property prices surrounding the site in order to facilitate relevant planning for the city in the future. With reference to the methods used in previous studies, this dissertation studies the degree of influence on the value of residential property near subway lines that is caused by completed lines, as well as lines that are under construction in different areas of Tianjin; in addition,

Table 1: Description of variables for modelling residential property values.

Variable categories	Variables	Description
Accessibility variables	Distance to CBD	Straight-line distance to the crossing of Tianjin Binjiang Avenue and Nanjing Road (km)
	Distance to nearest urban artery	Straight-line distance to urban artery (km)
	Distance to nearest subway station	Straight-line distance to subway station (km)
Neighbourhood variables	Distance to nearest park	Straight-line distance to park (km)
	Distance to nearest first-class hospital	Straight-line distance to first-class hospital (km)
	Distance to nearest key school	Straight-line distance to key primary school or middle school (km)
Structure variables	Green area rate	Ratio of green area to floor area
	Floor area ratio	Ratio of total building area to floor area

it discusses the comprehensive impact on property prices in areas in the urban centre, for the purpose of providing specific guidance for the development of the Tianjin subway system.

3. Research Methodology

For the purpose of studying the influence on the values of properties near the lines, research methods that have been utilised both at home and abroad are used as references in this paper. The Hedonic Pricing Model (HPM) is the main method used in this article. The HPM believes that property prices are determined by the functions delivered to people by different combinations of characteristics (factors influencing the pricing of property). A change in the quantity of these characteristics or the combination modes of the property may alter the property value. Accordingly, when transit conditions affecting properties appear to have undergone any changes, the values of properties will be changed. Therefore, the distance between subway stations and the selected properties could be used as the main variable in HPM to explore this impact. A quantitative study of each influential factor may be performed utilising a Multivariate Regression Analysis combined with the HPM, due to the continuously changing property prices.

3.1. Selection of Variables for the Model. The indicators affecting the values of property can be divided into three categories: accessibility variables, neighbourhood variables, and structure variables [37–39]. Based on the features of the property market in Tianjin, we excluded the impact of the multicollinearity of various factors; the factors listed in Table 1 were selected as the factors that had the most influence on changes in property pricing.

The most important and basic factor affecting the value of property is location. The distance to the CBD represents the degree of influence on properties in the city centre. To a certain extent, this determines the main economic and sociocultural location of the property. At the same time, traffic is one of the important connotations of location. Convenient traffic conditions can effectively change the relative location of the property and impact the economic and sociocultural location. Regarding various modes of urban transit, the construction of subway lines has a substantial impact on the travelling mode of nearby residents; the closer a property is to a city's arteries, the more the alternative travelling modes are selected. Accordingly, the surrounding residents may enjoy more convenience, which produces an appreciation function for the properties in those areas. Therefore, the influential accessibility variables for the property values of housing located near tracks are the distance to the CBD, the distance to the nearest subway station, and the distance to the nearest artery.

At the same time, studies have found that 15%–50% of property pricing is caused by neighbourhood variables [40]. Neighbourhood variables include government-provided service facilities, schools, hospitals, parks, and large commercial facilities. China has adopted the policy that children and teenagers should attend the nearest primary and junior secondary schools. Also, the current distribution of educational resources in China is severely imbalanced. Therefore, there is a large gap between normal and key schools. It is not unusual for a property owner with children to lease out a unit he owns in a less desirable school district and lease a chonsei unit in a better school district. Therefore, the distance to the nearest key schools is becoming an important factor that impacts residential property prices. Meanwhile, China has an extreme imbalance in the distribution of medical resources. A large number of medical resources are concentrated in key hospitals in cities. Within a certain range, the distance to first-class hospitals has a definite influence on property prices. Chinese urban residential buildings are multiunit buildings. The area around a typical building is narrow, with no independent green space. The establishment of parks near the property may greatly improve the living environment and air quality, and they may provide residents with a place for recreation and physical exercise. Accordingly, this also is one of the factors that affects property prices.

The floor area ratio and the greening rate form the structure variables. As we all know, the floor area ratio is an important factor in the property price per unit area.

For different properties, different floor area ratios may result in various average prices per unit area. At the same time, modern residents are placing increased emphasis on the residential environment. A beautiful residential environment is an important factor in increasing housing prices. Therefore, a property's green area is one of the factors that affects housing prices.

3.2. Data Source. For data collection, in order to reduce the impact of the property market that is caused by the property policies and changes in the market economy, all of the property price data collected were selected from the actual transaction data listed on the Tianjin "Housing Search" website in March 2016; the collected housing prices do not represent individual residential housing at a single price but the average transaction price of the same property. The variables, which include the distance to the nearest subway station, the distance to the CBD, the distance to the nearest artery, the distance to the nearest parks, the distance to the nearest first-class hospital, and the distance to the nearest key school, are mainly calculated using Google maps. Floor area ratio and the greening rate of the researched object are also collected from relevant real estate information which has been released on the "Housing Search" website.

Generally speaking, the primary sphere in which urban rail transit has an influence on surrounding property values is within 10–15-minute walking distance [41]. An optimal walking system and a comfortable environment may enlarge this radius to 800 m. Accordingly, a 1200 m to 1500 m distance to the urban rail transit may have a minimal impact on the value of property. Therefore, we selected 125 properties which are located within 1,000 metres of subway line 3 stations as the subject of this research. In the sample we chose, 60% are located within 600 metres of the subway stations.

4. Model of Residential Property Value

The standard Hedonic Pricing Method is used in this paper. All selected housing prices and accessibility variables, neighbourhood variables, and structure variables are divided into dependent variables and independent variables.

The basic functions of the Hedonic Pricing Model have the following three forms: where P represents housing prices, α_0 means constant, β_K is the coefficient of variables ($K = 1, 2, 3, \ldots, n$, n = number of variables), X_{aiK} refers to the ith characteristic variable of accessibility variables, X_{njK} is jth characteristic variable of neighbourhood variables, X_{stK} means the tth factor of structure variables, and ε is the residual error term.

HPM in Linear Form. In formula (1), the relationship between housing prices and characteristic variables is in linear form. Each regression coefficient represents the average appreciation of residential housing prices caused by the change in characteristic variables:

$$P = \alpha_0 + \beta_K X_{aiK} + \beta_K X_{njK} + \beta_K X_{stK} + \varepsilon. \quad (1)$$

HPM in Logarithm—Linear Form. In formula (2), the housing prices and each characteristic variable are taken in logarithmic form. Each regression coefficient corresponds to the price elasticity of the characteristic variables. Namely, the percentage change in the characteristic variables causes the change in the housing price percentage;

$$\ln P = \alpha_0 + \beta_K \ln X_{aiK} + \beta_K \ln X_{njK} + \beta_K \ln X_{stK} + \varepsilon. \quad (2)$$

HPM in Semilogarithmic Form. In formula (3), each characteristic variable is in linear form. The housing price uses a logarithm. The regression coefficient corresponds to the ratio of the characteristic price and the total price; namely, the unit change in the characteristic price will change the percentage of the housing price.

$$\ln P = \alpha_0 + \beta_K X_{aiK} + \beta_K X_{njK} + \beta_K X_{stK} + \varepsilon. \quad (3)$$

The collected residential data near subway lines 3 and 4 are used in the regression trial of the above three functional forms. It is found that the equation for the residential value regression analysis using the semilogarithmic form obtains the conclusion that R^2 is the nearest to 1 with the best statistical effect. Therefore, HPM in semilogarithmic form is adopted for the statistical analysis of the residential values near the subway lines.

5. Model Results

Table 2 is the results of a regression analysis of the residential housing along subway line 3 in Tianjin. To further examine the degree of influence of the subway stations on residential property prices in different urban areas, based on an all-region regression of the surrounding residential housing, in accordance with the Tianjin urban centres and nonurban centres condition, a regional regression is implemented for subway line 3 housing. The average value of R^2 of each regression model is between 0.95–0.99. The degree of fit is good.

5.1. Regression Analysis of Residential Property Values along Subway Line 3. We calculated the Hedonic Pricing Model of the housing prices and each influential factor mentioned above in the entire region, in the nonurban centre areas and in the urban centre areas of subway line 3, respectively. The final influential factors in the model and the coefficients are shown in Table 2.

We can conclude from Table 2 that the housing located at the closest distance to the station has experienced a significant impact. The regression results for the entire region show that the coefficient of the distance to the nearest subway station is −0.099011. Namely, if the property is located 1 km from the station, its property prices increase by 9.9011%. For nonurban centres, subway line 3 stations have a very strong impact on housing prices. The coefficient reaches −0.247471, of which the absolute value is higher than the absolute value of the coefficient of the distance to the nearest subway station in the regression of the entire subway line 3 which is −0.099011. In the centre area, the influence coefficient of the distance to the nearest subway line 3 station is −0.079166. This means

Table 2: Regression results of residential property values near subway line 3.

Region	R^2	Variables	Coefficient	P	F
Regression of characteristic variables of property prices near the entire subway line 3	0.999739	Constant	10.14595	0.00	0.00
		Distance to CBD	−0.076619	0.00	0.00
		Distance to nearest subway line 3 station	−0.099011	0.00	0.00
		Distance to nearest key schools	−0.042276	0.00	0.00
		Floor area ratio	−0.024547	0.00	0.00
Regression of characteristic variables of property prices near nonurban centre areas of subway line 3	0.984989	Constant	10.00903	0.00	0.00
		Distance to CBD	−0.059938	0.00	0.00
		Distance to nearest subway line 3 station	−0.247471	0.00	0.00
		Distance to nearest first-class hospital	−0.036604	0.0005	0.00
		Floor area ratio	−0.009824	0.0590	0.00
Regression of characteristic variables of property prices near urban centre areas of subway line 3	0.956991	Constant	10.08503	0.00	0.00
		Distance to nearest subway line 3 station	−0.079166	0.2710	0.00
		Distance to nearest park	−0.089342	0.0001	0.00
		Distance to nearest key schools	−0.097831	0.00	0.00

that if the housing is 1 km from each track site, the prices will increase 7.9%. However, the coefficient fails to pass the t-test, indicating that the distance to the subway stations has an obscure relation to the prices of the surrounding property. Therefore, the regional housing prices are not sensitive to the establishment of subway line 3. The comparison of the degree of influence of subway line 3 station sites on different urban area housing indicates that the promotion function generated from subway line 3 in urban centre areas is lower than in nonurban centre areas. This may be due to the dense transport network in urban centres. There are 269 bus lines in the urban centre area. Meanwhile, subway line 1 and subway line 2 meet in this region, with five stations. So, the completion of subway line 3 provides greater convenience for nondowntown area residents in day-to-day travel than for those in the urban area. Accordingly, subway line 3 has a small function for the central region, compared to the nonurban centre areas.

As can be seen in the regression results listed in Table 2, the residential housing along subway line 3 is significantly influenced by its distance to the CBD. The farther away from the city centre, the lower the price. The results for the urban centre area show that the distance to the CBD does not generate a significant impact on property prices. In the CBD region, there is a concentration of financial, commercial, information-based, and service agencies. Employment is relatively concentrated in this area. The service facilities are sound with higher levels. A large number of key schools and hospitals are concentrated there. So, taking into consideration the balance of work and residence, as well as the convenience of living, people are more willing to live closer to the CBD to reduce their cost of living. Therefore, the distance to the CBD has a significant influence on nonurban centre areas. Residential housing in the urban centre area that is close to Binjiang Avenue, Xiaobailou, and other commercial centres has natural advantages. Many of the region's residents work in the financial agencies or in the government of this region. They do not need to give much consideration to the distance to their workplaces when they select housing in the central region. Accordingly, the CBD has an obscure impact on such residential properties. The residents in this region give consideration to neighbourhood variables such as the surrounding residential landscape.

The factors that have a significant impact on the prices of housing surrounding subway line 3 also include the distance to the nearest first-class hospital, the nearest key school, and the nearest park, as well as the floor area ratio. The closer the distance to the key school, the higher the housing price. Families with children tend to purchase a house to gain an opportunity for them to enter a key school. Therefore, key schools have a significant impact on housing prices. In urban centre areas, in addition to the impact of the distance to key schools, the prices of housing surrounding subway line 3 are influenced by the quality of the landscape surrounding the property and by the proximity of parks. The properties located near parks enjoy higher prices. In nonurban centre areas, the prices of housing have a negative relationship to the distance to a first-class hospital. This is because a decrease in the distance from residents' housing in nonurban centre areas to such hospitals greatly improves the convenience of medical treatment for the residents.

6. Studies about the Sphere of Impact of Tianjin Metro Line 3 Sites on Real Estate Prices

6.1. Setting Up a Model of the Subway Lines' Impact on Real Estate Prices. Theories of land rent and land location show

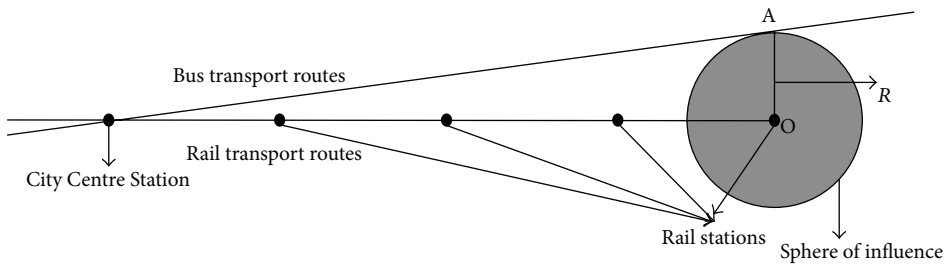

Figure 1: Metro effects on real estate prices range schematic model.

that there is a shifting trend between urban residents' housing rents and travel costs. The emergence of urban rail transit has changed the location of regional land transit, thus changing the cost of residents' transportation, as well as their land rents. It can be inferred that, where there have been changes in land leases, there have been changes in transit costs. Based on the above analysis, regarding the boundary points of the impact of rail traffic, the accessibility to the urban centre would be the same for residents in this area, even if they choose different forms of transportation. Therefore, urban rail transit did not change the areas of traffic, and changes in real estate prices never occurred. Thus, the area is the critical point for real estate price changes.

In a study regarding how "land value changes affect accessibility," Wegener proposed methods for measuring transportation accessibility in terms of distance and time [42]. Currently, most scholars choose the measure by distance as the main method to conduct this type of study. Although this choice makes it easier to collect data, it fails to fully reflect the costs of transportation. In comparison, the changes in cost over time more accurately reflect changes in transportation costs; those results more closely reflect the reality of the mutual relationship between changes in real estate prices and transportation systems.

Zhang et al. developed the "impact of the construction of urban traffic on the surrounding real estate prices model." Their model assumes that, regardless of the transit mode choice, the amount of time spent would be the same from the point of impact range to the urban centre [43]. Figure 1 shows the effects of rail traffic on the range schematic model for real estate prices.

As shown in Figure 1, where there are different types of transportation, the impact of the border on accessibility to the urban centre is the same. That is to say, when residents move from edge point A to rail station O to take rail transportation to the CBD, the time spent would be the same as taking public transportation directly from point A to the urban centre.

$$T_g = T_d, \tag{4}$$

where "T_g" is the time spent in travelling from the track transit boundary to the urban centre by rail and "T_d" stands for the time spent in travelling from the track transit boundary to the urban centre by public transportation.

Meanwhile, we believe that the amount of travel time depends on the choice of transportation and that transportation is affected by many factors, such as fares, the travel preferences of residents, regional economic development, and urban traffic conditions. Residents ultimately select their preferred mode of transit through an analysis of all of these factors. Therefore, taking data availability into consideration, the transit fares and travel time by public transport are the main factors in the description of reachability.

$$T_g = \frac{C_g}{d} + \frac{R}{V}, \tag{5}$$

$$T_d = \frac{C_d}{d}. \tag{6}$$

Then, we can get

$$\frac{C_g}{d} + \frac{R}{V} = \frac{C_d}{d}. \tag{7}$$

"C_g" refers to the cost of track transportation from the border point to the urban centre; d is the value of time (per unit) of the residents; "R" is the distance from the border point of urban rail traffic stations, known as the radius of influence from an urban rail transit site to that site's traffic; "V" is the average moving speed from the track transport boundary point to the rail transit station. Generally speaking, there are two kinds of transportation from the track transport boundary point to the nearest rail transit station: travel on foot or by bike. The V value can represent the speed on foot or by bicycle. C_d is the cost of public transportation from the track transport boundary point to the urban centre.

$$\begin{aligned} C_g &= p_g + d \times t_g, \\ C_d &= p_d + d \times t_d. \end{aligned} \tag{8}$$

"p_g" is the cost of a car from the track transport boundary point to the urban centre; "t_g" is the travel time from the track transport boundary point to the urban centre; "p_d" represents the cost of a bus from the track transport boundary point to the urban centre; "t_d" is the travel time from the track transport boundary point to the urban centre by bus; "t_g" and "t_d" can be calculated separately on the basis of the distance and average speed of rail transport from the track transport boundary point to the urban centre or on the basis of the distance and average speed by bus.

There are many factors affecting residents' choices regarding transportation. However, the main two factors are travel time and travel cost. Therefore, taking the aforementioned

formulas on the impact on real estate into account, we can conclude that the main two modes of transit for outside residents are track transportation and buses. Here, we will study Tianjin Metro Line 3 further to determine the radius of its influence on surrounding real estate prices.

6.2. The Area of Influence of the Tianjin Metro Line 3 Transit Station. It is found that the Yingkoudao transit station is located in the Heping District of Tianjin: the commercial and financial centre. As a result, it is the key hub station, as well as a destination in the city. Therefore, this paper will focus on the Yingkoudao station, which can be seen as the destination for outside residents.

6.2.1. Transit Fares. Public transit in the city of Tianjin is guided by the same ticket system; the tickets are, respectively, 2 CNY and 1.5 CNY. Some urban lines are charged according to section fares. The actual charges can be obtained from Baidu Maps and from Tianjin IC bus lines, where they are kept updated.

The Tianjin subway fares are based on the number of stations through which a train runs. When travelling through subway station sites within the interval 0–5, the fare is 2 CNY; for 6–10, it is 3 CNY; for 11–15, it is 4 CNY; and for more than 15, it is 5 CNY.

6.2.2. Travel Time. Baidu Maps were used to determine all of the bus lines which can take residents from the track transport boundary point of Tianjin Metro Line 3 to the urban centre. Then, we chose the most economic route and worked out the travel distance and fees. Also, we determined the distance from the boundary point to the centre by track transport via the Baidu Search Maps. According to the travelling speed of national conventional buses, as well as research regarding the travelling speed of Tianjin buses, the average speed is 15 km/h. According to the timetable and distance list for Tianjin Metro Line 3 issued by the subway corporation, its average speed is 35.5 km/h. The average walking speed is 4.5 km/h, while riding a bike is twice as fast as walking, at 9 km/h ("Urban traffic planning and design specifications").

6.2.3. The Value of Travelers' Time. The value of the residents' time can be treated as the shadow price of residents' travel. That is, if they used the travel time to work, they would receive a different amount of pay. Accordingly, the value of the residents' time can be calculated on the basis of the average salary and the total working time. The formula is as follows:

$$d = \frac{I}{T}, \tag{9}$$

where "d" is the time value of money. "I" is the average individual annual income; "T" is the average annual time spent working.

As stated in the report, "Average wage of workers' per capita income in 2012," issued by the Tianjin Human Resources and Social Security Bureau, it is 46,464 CNY. If there are five working days per week and 8 working hours per day, the wage per hour is 22.27 CNY.

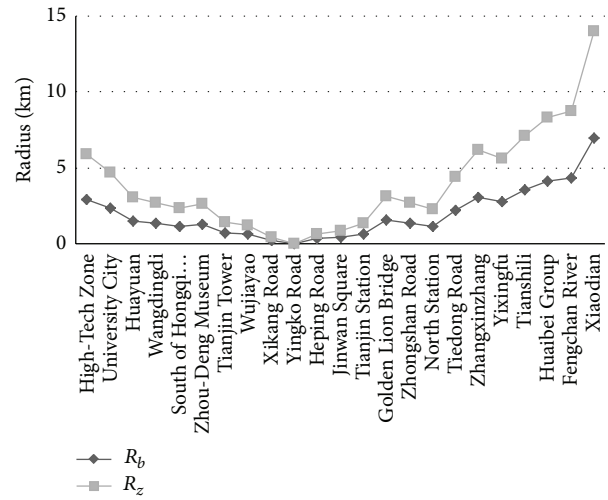

Figure 2: Radius of Tianjin Metro Line 3's influence on real estate prices.

According to the variables identified in the model above, we can determine the theoretical value of the Tianjin Metro Line 3's area of influence. As shown in Table 3 and Figure 2, we can determine its area of influence when walking and when riding a bicycle, respectively.

From Table 3 and Figure 2, regardless of whether the V value is the average velocity of walking or of riding a bike, the influence area enlarges as it is farther from the centre, showing changes in the shape of the "V" trend. Throughout the radius of influence of each metro line 3 site, when the V value is the average walking speed, the radius of influence in the region between the Sky Tower Metro station and the Tianjin Railway Station is within 1 km; from the Zhou-Deng Museum station to the Huayuan Tang Museum station, and from the Lion Bridge Station to the North Station, it is 1 km-2 km; however, from the high-tech zone station to the University City station, and from the Zhongshan Station to the Fengchan River station, it is over 2 km. When the V value is the average bicycle speed, they are, respectively, within 1 km, 2-3 km, and over 4 km.

As is shown in Figure 2, the whole curve did not have a smooth continuous "V" shape. It can be easily determined that its influence did not increase, but rather, fell, as the Hongqi Road Station, the Zhongshan Station, the North Station, and the Yixingbu station are far from the city. Thus, it shows a short-term downward trend. This is because these stations are at the inflection point for the price of 2 CNY-3 CNY and 3 CNY-4 CNY. Accordingly, the increasing prices resulted in abnormal changes in the influence, which suggests that the area of influence of track transit has a certain relationship with the price. This is due to the lower cost of travelling by bus at the Golden Lion station and the Zhangxingzhuang station. In conclusion, the cost of other transportation will also affect the area of influence of track transit.

As shown in Figure 2, when V is different, that is, there are different walking and riding speeds, the area of influence of

Table 3: The calculation of the influence of Tianjin Metro Line 3 on real estate prices.

Stations	$V = V_b$ (km/h)	R_b (km)	$V = V_z$ (km/h)	R_z (km)
High-Tech Zone	4.50	2.96	9.00	5.92
University City	4.50	2.35	9.00	4.70
Huayuan	4.50	1.54	9.00	3.09
Wangdingdi	4.50	1.37	9.00	2.74
South Road of Hongqi	4.50	1.18	9.00	2.37
Zhou-Deng Museum	4.50	1.33	9.00	2.66
Tianjin Tower	4.50	0.72	9.00	1.43
Wujiayao	4.50	0.63	9.00	1.25
Xikang Road	4.50	0.23	9.00	0.47
Yingkou Road	4.50	0.00	9.00	0.00
Heping Road	4.50	0.35	9.00	0.69
Jinwan Square	4.50	0.44	9.00	0.89
Tianjin Station	4.50	0.67	9.00	1.34
Golden Lion Bridge	4.50	1.56	9.00	3.13
Zhongshan Road	4.50	1.37	9.00	2.74
North Station	4.50	1.13	9.00	2.27
Tiedong Road	4.50	2.22	9.00	4.44
ZhangXing Country	4.50	3.08	9.00	6.16
Yixingfu	4.50	2.79	9.00	5.59
Tianshili	4.50	3.57	9.00	7.14
Huabei Group	4.50	4.16	9.00	8.31
Fengchan River	4.50	4.38	9.00	8.77
Xiaodian	4.50	7.00	9.00	14.00

track transit also differs greatly, and these differences become sharper and sharper as the distance from the centre increases. From the Sky Tower station to the Tianjin Railway Station, the affected area between riding a bicycle and walking is the same; from Zhou-Deng Museum, it is twice; from the high-tech zone station to the University City station and from the Zhongshan station to the Fengchan River station, it is more than twice. Based on the above analysis, if the rail station has a good bus transfer, it will effectively expand the radius of rail transit and promote regional development along the urban rail transit system, and it will be particularly effective in expanding the scope of development in nonurban centres.

With regard to the destinations of the Tianjin Metro Line 3 stations, the Xiaodian station is not covered by the bus system, which means that there are no convenient bus lines to reach that region, and thus, residents generally rely on private cars and taxis to get there. Therefore, we need to consider the path of taxis or cars, instead of buses, to determine the area of influence of track transit. From Table 3 and Figure 2, we can clearly determine that the scope of influence of the Xiaodian station is 7 km, which reflects a sharp increase in the radius of influence, compared to other sites. It shows that the area of influence depends not only on the quality of the track transit itself, but on the station's location, especially for those at which public transportation is not very good. In those places, the influence of the track transit can extend over a larger area, and it plays an important role in regional development. Still, at Xiaodian station, the area of influence of track transit when V is for riding a bicycle is twice what it is when V is for walking. It is the same for other stations. This means that if other modes of transportation can be developed and can be connected, its area of influence would be even larger than it is now.

7. Conclusion

The HPM is used to comparatively analyse the degree of influence and the characteristics of the influencing factors caused by subway line 3 for housing prices in urban centre areas and nonurban centre areas of Tianjin. The results of our analysis showed the following.

(1) The construction of a subway plays a significant role in promoting increases in the surrounding land prices. By comparison, subway lines which already have been built have a greater influence on surrounding residential housing than lines that are being planned.

(2) The construction of subway lines has a greater impact on marginal zones of the city than on the city's downtown area. In nonurban centre areas, the prices of properties near stations show the decreasing spatial distribution of the two sides; however, in urban centre areas, the stations' impact on the pattern of distribution of property prices is not obvious, as it is in nonurban centre areas. This may be because the influence of subway lines on housing prices is masked by the impact of other factors.

(3) In addition to the distance to the nearest subway station, the residents living in urban centre areas may focus on factors such as the distance to the nearest artery and key schools, as well as the condition of the neighbouring landscape, when choosing housing. This indicates that local residents pay more attention to comprehensive convenient transportation, the residential landscape, and the degree of comfort.

(4) Generally, the sphere of influence of rail transportation is positively associated with the distance from the city centre, but it does not unvaryingly increase with it. Moreover, rail transportation fares and the price of other transportation can also affect the sphere of influence of rail transportation.

(5) If the city has convenient connecting forms of transit, they can effectively expand the sphere and availability of rail transportation. Because urban centres are often faced with a daily flow of large numbers of people, convenient connecting transit can effectively expand the radius of transportation, relieve traffic pressure in the downtown area, and significantly improve the availability of public transportation in the city centre. On the other hand, nonurban centres do not experience a large flow in population like urban centres, but improving connecting transit can redouble the sphere of influence of rail transportation, and it can effectively increase the area of land which can be developed around rail transportation.

Competing Interests

The authors declare that they have no competing interests.

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