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STUDY ON THE RELATIONSHIP BETWEEN HOUSING PRICE AND TRANSPORTATION ACCESSIBILITY IN URBAN DISTRICT OF TIANJIN, CHINA

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Abstract
This paper examines the relationship between transportation accessibility and housing price in Tianjin,China. The transportation accessibility was measured by some indexes, such as Betweenness, Closeness and Straightness

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on the road network. The indexes and sample plots were transformed into the same dimension by means of Kernel Density Estimation. Based on the dimension, the correlationship between housing price and transportation accessibility was analyzed under the conditions of including or excluding some other important factors, such as construction year, distance from subway and education resources. Finally, an optimum proposal for the road network is given and the change feature of housing price is analyzed. Results indicate that housing price are highly correlated with transportation accessibility, which is more significant when excluding the other factors, and the optimization of road network will make different influences on transportation accessibility and the housing price increasing in terms of different indexes. If to plan residential quarters or adjust the housing price, the government should focus on Closeness and Straightness of the road network.
Keywords: transpotation accessibility, housing price, betweenness, straightness, closeness

1. INTRODUCTION

The interrelatedness of transportation and settlement has been a constant theme of theoretical and empirical inquiries. Especially, with the rapid development of city economy, people have changed their way of travelling, and transportation network has made an important influence on city development and resident travel, so the impact of housing prices is becoming more and more important. In addition, the government usually makes macro-control on real estate market to achieve price stability by increasing the effective supply of real estate by means of road construction. It has become a research consensus that housing price is influenced by location. While for the description of location, research perspective is not exactly the same. Alonso analyzed city residential land selection behavior in the assumption of a monocentric city. Results show that where it is closer to CBD (Central Business District), people are more willing to pay higher housing price (Alonso, 1964). Subsequently, Muth (1969) and Mills (1972) pointed out that under the hypothesis of single center, people farther away from CBD should spend more on commuting, and the compensation is that the housing price will be lower. But the hypothesis of single city center is facing more and more empirical challenge. The coexistence model of multiple main centers and sub-centers is increasingly being recognized (Fahui, 2011),that is, urban morphology is gradually transforming from monocentric to multi-center (.Fahui, 2011; Ladd et al., 1991) To explore the relationship between location and housing price, we can not merely consider the distance to CBD. For instance, Eddie C.M et al (2007) pointed out although traditional theories emphasizes that transportation accessibility has an influence on housing price of CBD, which ignore location-specific attributes of housing(Berry et al.1993), so it is unreasonable to consider only the distance.

Present studies on location generally use accessibility as a measure, which shows how easily it is to travel from one point to another (Eddie et al. 2007). Some researchers expand the location theory. Wang (1998) explored the pattern of urban population distribution by means of Garin-Loery model, and showed that various structures of road networks had an influence on urban location and the urban population distribution (Johnston, R. J,2004). In order to maximize general coverage of the population and their total accessibility to service area, a dual-objective model was developed to identify optimal locations for these services (Gu et al.,2010). Taede et al (2012) found that accessibility plays an important role in the location theory of microeconomics, and much attention should be paid on regional accessibility characteristics in the residential satisfaction research(Wang,F,1998).While most researches mainly include the relationships between accessibility and economics(LIU Hailong et al., 2008), the accessibility of public transportation (CAO Xiaoshu et al., 2013), or urban land use pattern(Karst Geurs et al., 2010), etc. And studies focusing on accessibility and housing price with empirical research are generally about rail transit and housing price (LIU Guiwen, HU Guoqiao, 2007), or the influence of public service facilities accessibility on housing price (WANG Songtao et al., 2007).

Great difference existed in different areas for the quantification and measurement of accessibility. Liv Osland and Gwilym Pryce(2007) studied the relationship between housing price and the accessibility of workplace in Glasgow (Scotland)with the help of gravity-based model, indicating that accessibility has a nonmonotonic effect in housing price (Liv Osland,Gwilym Pryce,2012). Using logistic regression models, Zhong et al (2011) concluded that the good accessibility could speed up the conversion of agricultural land to other uses(Zhong Tai-Yang et al., 2011). Zheng et al (2014) explored the land supply and the capitalization rates of pubic goods by means of the Hedonic Regression Technique, and showed that the capitalization of school quality and subway accessibility is larger in supply-constrained locations Zheng Siqi et al.,2014) .Wang and Tang(2013)took the method of quadratic programming QP (quadratic programming) with the help of GIS platform, explored the issue of service of equal accessibility and made an advanced contribution in the field(Wang et al., 2013). HAO used “the distance to CBD”, “accessibility of rail transit”, “public transport accessibility” to express location accessibility(HAO Qianjin, CHEN Jie,2007). YAN measured location factors by “accessibility of city center” and “public transport” (YAN Siqi et al.,2011). Accessibility was also defined as the convenience from one location to a designated activity location by specific transportation system(ZHU Tianming et all,2010), the time needed to the destination (CAO Fangdong et al., 2012), or the fastest paths and shortest paths (LU Qian, LIN Tao, 2010) as accessibility indicators. To sum up, the definition of accessibility is roughly divided into two types: one is the distance to city center, the other is traffic convenient degree which can be divided into the shortest distance and the shortest time.

In current study, the description of location is mainly based on the distance of two points and the number of road. While less attention was paid on the relationship between accessibility of network structure and the housing price. According to the characteristics of road network structure, present studies have put forward indicators like “node degree”, “average path length of network”, “nodes”, “node compactness”, “closeness”, “betweenness”, “straightness”, “aggregation index” ,etc (Jin, 2008; Zhao ,2014; Wang, 2011; Chen et al.,2013). Considering the characteristics of the real estate market,

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this paper chose “Closeness”, “Betweenness” and “Straightness” to measure accessibility, and studied the effects and differences of the three indicators on housing price.

Major contributions made by this research may be summarized in four aspects:

1) This study finds a method that can transform the road network and the distribution of residential area into the same analytical scale.
2) Transportation accessibility is well captured by three indexes, some of which correlate with housing price better than others.
3) The correlationship between housing price and transportation accessibility is different under the conditions of including or excluding some other important factors, such as construction year, distance from subway and education resources, and the later is higher.
4) The housing price could be regulated by adjusting the road network.

2. RESEARCH METHODS AND TECHNOLOGY PLATFORM

This study was based on Arcgis10.0 software, and Urban Network Analysis Tool which was developed by UTD (Singapore University of Technology and Design) and MIT (Massachusetts Institute of Technology).Road network traffic Accessibility index was measured by Closeness, Betweenness and Straightness.

Since network and the distribution of residential area are in two different scales, we should transform them into the same scale in order to explore the relationship between them. We used Kernel Density Estimation (KDE) to convert road network and sample plot to the same dimensions, then we extracted the Kernel Density Estimation of network accessibility and housing price of the corresponding sample plot by the software ArcGIS10.0, and analyzed correlationship between Housing price and traffic Accessibility.

(1)The definition of Accessibility index

Closeness C^C measures how close a node to all the other nodes along the shortest paths of the network in the city. C^C for node *i* is defined as:

$$C_i^C = \frac{N-1}{\sum_{j=1;j\neq i}^{N} d_{ij}} \quad (1)$$

Where N is the total number of nodes in the network, and d_{ij} is the shortest distance between nodes *i* and *j*. There exists an inverse proportion between C_i^C and the average distance from this node to all other nodes.

Betweenness C^B measures how often a node is traversed by the shortest paths between all pairs of nodes in the network. C^B for node *i* is defined as:

$$C_i^B = \frac{1}{(N-1)(N-2)} \sum_{j=1;k=1;j\neq k\neq i}^{N} \frac{n_{jk}(i)}{n_{jk}} \qquad (2)$$

Where n_{jk} is the number of shortest paths between nodes *j* and *k*, and $n_{jk}(i)$ is the number of these shortest paths that contain node *i*. C^B captures a special property for a place, which does not act as an origin or a destination for trips, but as a pass-through point.

Straightness C^S measures how much the shortest paths from a node to all others deviate from the virtual straight lines (Euclidean distances) connecting them. C^S for node *i* is defined as:

$$C_i^S = \frac{1}{N-1} \sum_{j=1;j\neq i}^{N} \frac{d_{ij}^{Eucl}}{d_{ij}} \qquad (3)$$

Where d_{ij}^{Eucl} is the Euclidean distance between nodes *i* and *j*. C^S measures the degree a place can be reached directly.

(2) Kernel Density Estimation

Accessibility index and Housing price were in different dimensions. Accessibility index reflects the feature of traffic nodes, not the samples for Housing price, therefore, how to eliminate the difference and define the Accessibility index for these samples was a key problem. KDE (Kernel Density Estimation) was applied in the paper.

KDE is a method which mainly calculates the density of discrete points in the surrounding area. Points fall into the search area were calculated with different weight, and the closer to the search center, the greater weight will be given, and with the increase of the distance to the center, the weight will reduce(MOU Naixia et al., 2012). In addition, the Accessibility index and Housing price of these discrete points will be put into the model as crucial calculation parameters. With this method, the indices with different dimensions can be standardized, and Accessibility index can be assigned to all the samples by its interpolation function.

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A kernel function looks like a bump centered at each point x_i and tapering off to 0 over a bandwidth or window. The kernel density at point x at the center of a grid cell is estimated to be the sum of bumps within the bandwidth.

So, Housing price kernel density of the sample point x :

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} P(1\text{-}\frac{x_i - x}{h}) \quad (4)$$

Where P is the Housing price for point x, h is the bandwidth, n is the number of points within the bandwidth.

Accessibility kernel density of the sample point x :

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} T(1\text{-}\frac{x_i - x}{h}) \quad (5)$$

Where T is the value of Accessibility (substituted by Closeness, Betweenness and Straightness separately) for point x, h is the bandwidth, n is the number of points within the bandwidth.

3. RESEARCH OBJECT AND DATA SOURCES

This paper selects the built-up area of the center city as the research area, including six districts of Tianjin, Heping district, Hedong district, Hexi district, Nankai district, Hongqiao district and Hebei district, with a total area of about 173 km^2. We utilized the main highway network as the basis road data, without considering the waterway and subway. The extraction of road network mainly based on Landsat—7 Satellite Image of Tianjin in 2012 Samples of residential land were selected to meet distribution equilibrium as much as possible. The average housing price data from March to August in 2014 mainly comes from internet (http://tj.fang.com/). Besides, some data come from spot investigation.

4. RELATIONSHIP BETWEEN HOUSING PRICE AND TRAFFIC ACCESSIBILITY

4.1. Present situation of traffic accessibility in the six districts

The current situation of Betweenness, Straightness and Closeness in urban district of Tianjin was shown in Figure 1, Figure 2 and Figure 3.

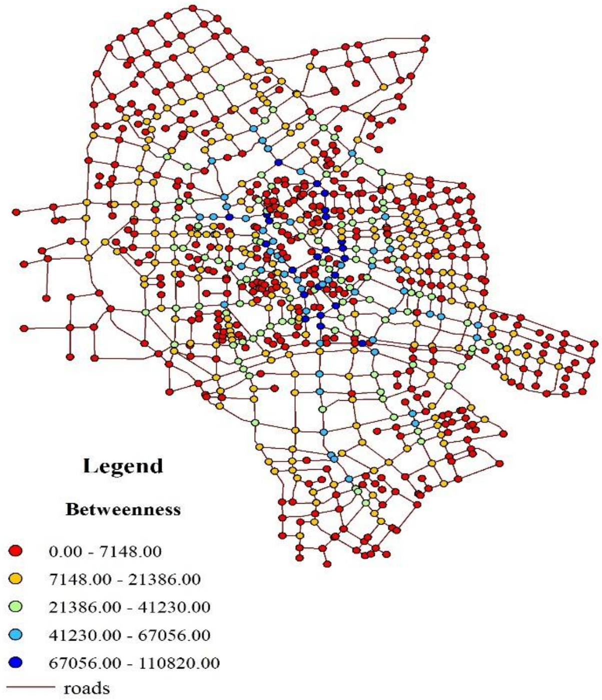

FIGURE 1 - SYMBOLS OF ROAD NETWORK BETWEENNESS

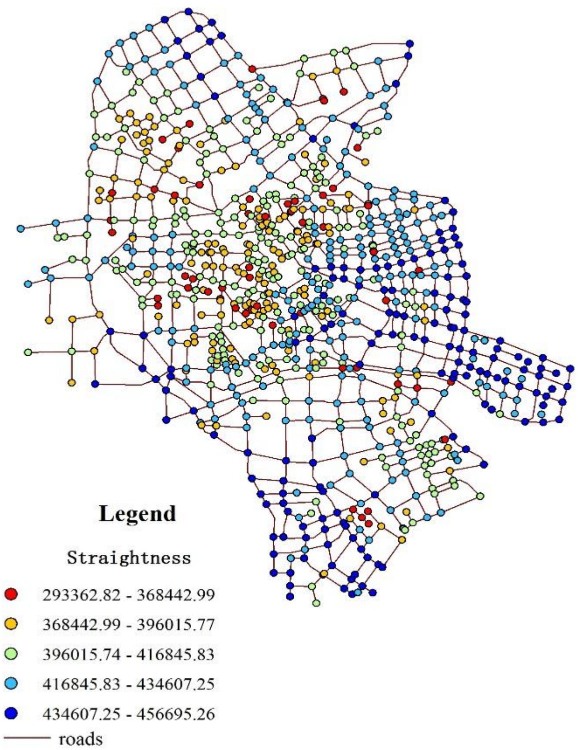

FIGURE 2 - SYMBOLS OF ROAD NETWORK STRAIGHTNESS

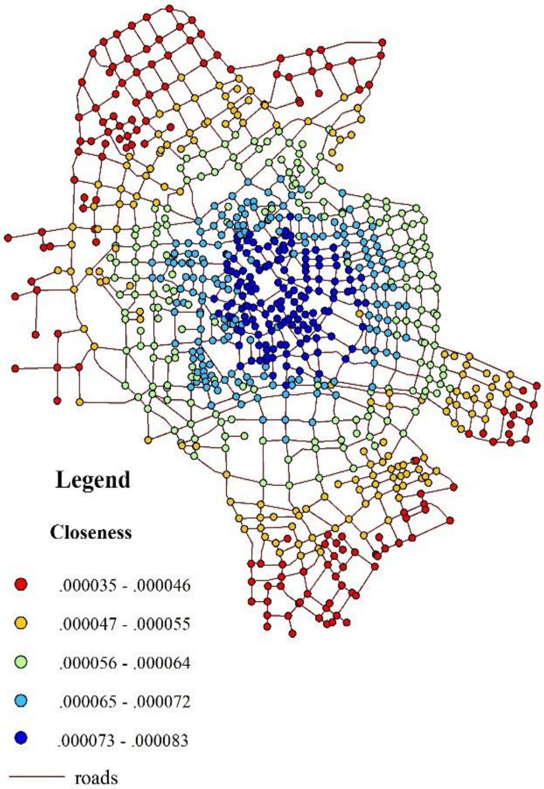

FIGURE 3 - SYMBOLS OF ROAD NETWORK CLOSENESS

Through the analysis of network nodes we knew that "Closeness" showed the concentric peak around CBD and decreased gradually outwards, while "Betweenness" and "Straightness" did not show the trend. These three indicators measured the accessibility, which can be used to explore the relationship between housing prices and transportation accessibility from different angles.

4.2. Study on the relationship between Housing price of samples and accessibility

258 residential quarters were selected as samples. According to the above methods we measured the road network traffic, made road network traffic and samples into the same study scale, and analyzed the correlation between Housing price and traffic Accessibility. The KDE of Housing price is Y, and the KDE of traffic Accessibility index is X. The results are shown in Table 1 and Table 2.

TABLE 1 - THE CORRELATION COEFFICIENTS BETWEEN HOUSING PRICE AND ACCESSIBILITY INDICES

	Correlation coefficient
Housing price and Betweenness	0.59
Housing price and Straightness	0.71
Housing price and Closeness	0.71
Average value	0.67

TABLE 2 - TREND LINE EQUATION AND THE FITTING DEGREE (R2) BETWEEN HOUSE PRICES AND THE THREE INDICATORS

	The trend line equation	t-test	R^2
Housing price and Betweenness	$Y = 0.01 + 0.34{*}X_1$	11.57	0.34
Housing price and Straightness	$Y = -0.003 + 0.032{*}X_2$	16.02	0.50
Housing price and Closeness	$Y = 0.003 + (1.49E+08){*} X_3$	16.00	0.50

From table1, it can be inferred that there is a strong correlation between Housing price and Closeness and Straightness. While the Housing price and Betweenness are in moderate correlationship. Table 2 showed that the significance test of Housing price and Accessibility indexes are remarkable. The fitting degree between House price and Straightness is the same with that between Housing price and Closeness, and much higher than that between Housing price and Betweenness.

Besides traffic accessibility, residential construction year, distance from subway and education resources may also have influence on Housing price. In order to eliminate the effects of these factors on the relationship between Housing price and Accessibility, we compared the KDE results before and after eliminating each mentioned factor to make a judgment whether it is a remarkable factor. And in the final calculation, those remarkable factors would be eliminated.

4.2.1. The factor of residential construction year

The time span of the construction year of sample buildings years is nearly 40 years. Taking 10 years as building year, analysis results of trend line equation between Housing price and Accessibility index were showed in Table 3.

TABLE 3 - TREND LINE EQUATION AND IT'S GOODNESS OF FIT OF CORRELATION ANALYSIS

	Trend line equation	t-test	R^2
Housing price and Betweenness	$Y = 0.01 + 0.33{*}X_1$	9.65	0.40
Housing price and Straightness	$Y = -0.0002 + 0.028{*} X_2$	11.76	0.50
Housing price and Closeness	$Y = 0.005 + (1.32E+08){*} X_3$	11.71	0.50

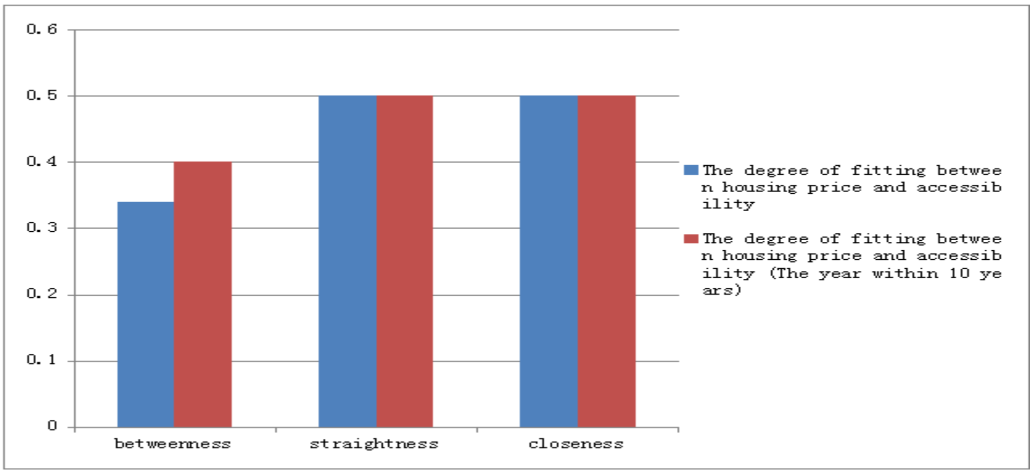

FIGURE 4 - THE COMPARISON BETWEEN HOUSING PRICE AND ACCESSIBILITY WITH CONSTRUCTION YEAR FACTORS

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By comparison in figure 4, we can know that building year has no obvious effect on the correlation analysis.

4.2.2. The factor of distance from subway

Many scholars at home and abroad had done empirical researches on the relationship between rail transportation and housing price. HE et al studied the influences of Beijing metro line 13 on the price of surrounding housing. Results showed that in the range of the impact of its 500m, housing prices have 1000 yuan /m2 premium (HE and Zheng, 2004). Zheng et al (2014) studied the influence of the subway site to housing prices in Shenzhen. Results indicated that the average of the housing price increases by 23% and 16% in the range of the subway surrounding 400~600m (Zheng and Liu,2005).So, the influence of the subway on the housing price should not be ignored.

Considering the influence of Metro on housing price in the previous literature, we selected the area 500 meters around the subway station as the impact of the region on housing price. And we introduced dummy variables, setting 1 to the house which is within 500 meters far away from subway station, and setting 0 to the others. The analysis between Housing price and the three Accessibility indicators was as follows:

(1) Housing price and Betweenness

Y=0.01+0.33X1+0.008D1

（7.90） （11.52） （5.72）

(2) Housing price and Straightness

Y=-0.003+0.03X2+0.007D1

（-1.38） （15.68） （5.25）

(3) Housing price and Closeness

Y=0.003+ (1.41E+08) X3+0.007D1

（1.69） （15.66） （5.26）

TABLE 4 - SERIAL CORRELATION COEFFICIENT TEST AND ITS FITTING DEGREE

	Variable sequence	p	R^2
Housing price and Betweenness	X1、D1	0.000	0.42
Housing price and Straightness	X2、D1	0.000	0.55
Housing price and Closeness	X3、D1	0.000	0.55

From Table 4 we knew the virtual variable is significant, which showed that the subway has a certain effect on the housing price. So there were some effects of subway factor for the study on Housing price and Accessibility.

4.2.3. The factor of education resources

The key primary schools in Tianjin are mainly located in Heping district, Nankai district and Hexi district. It would have a greater impact on housing price and on the relationship between Housing price and Accessibility. Therefore, to exclude the factor of education resources, we analyzed the samples in the left districts, including Hebei district, Hongqiao district and Hedong district. Results demonstrated in Table 5, and it was compared with the original relationship R2 before the elimination. Result was shown in Figure 5. It shows that the impact of education resources on housing prices should not be ignored.

TABLE 5 - TREND LINE EQUATION AND IT'S GOODNESS OF FIT OF CORRELATION ANALYSIS AFTER ELIMINATING SCHOOL DISTRICT HOUSING

	Trend line equation	t-test	R^2
Housing price and Betweenness	$Y = 0.005 + 0.36*X_1$	15.28	0.65
Housing price and Straightness	$Y = -0.004 + 0.026*X_2$	14.98	0.64
Housing price and Closeness	$Y = 0.0006 + (1.25E+08)*X_3$	15.93	0.67

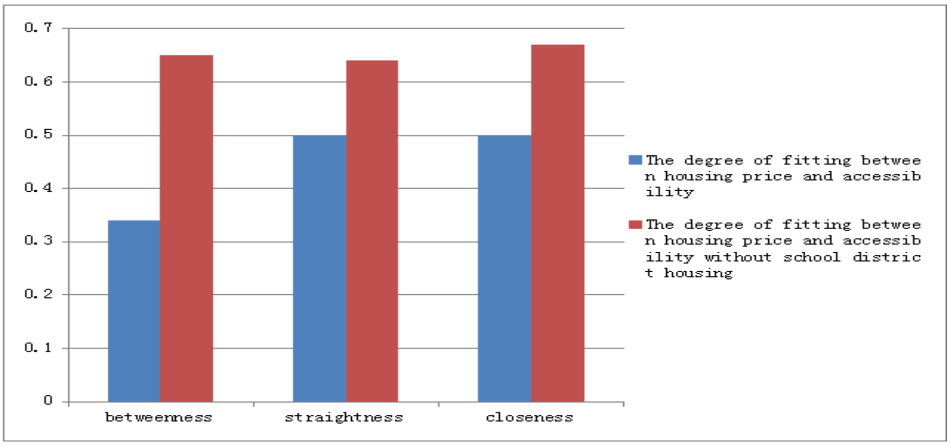

FIGURE 5 - THE COMPARISON BETWEEN HOUSING PRICE AND ACCESSIBILITY WITH SCHOOL DISTRICT HOUSING FACTORS

To sum up, Residential construction year, distance from subway and education resources had different influences on Housing price. And after individual factors were eliminated, the fitting degree of the Housing price and Closeness, Betweenness and Straightness presented different trends. The change for Betweenness was the greatest. And for the above three factors, the influence of education resources is the first, and that of distance from subway lists the second.

In order to exclude the three factors, we chose the samples which are located in Hebei district, Hongqiao district and Hedong district, keeping construction year within 10 years, and no subway station

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distributed within 500 meters around. Then we analyzed the correlation degree between Housing price and Accessibility index again. Results were shown in table 6 and table 7.

TABLE 6 - THE CORRELATION COEFFICIENTS BETWEEN HOUSING PRICE AND ACCESSIBILITY INDICES AFTER ELIMINATING OTHER INFLUENCE FACTORS

	Correlation coefficients
Housing price and Betweenness	0.85
Housing price and Straightness	0.87
Housing price and Closeness	0.89
Average value	0.87

TABLE 7 - TREND LINE EQUATION AND IT'S FITTING DEGREE OF CORRELATION ANALYSIS AFTER ELIMINATING OTHER INFLUENCE FACTORS

	Trend line equation	t-test	R^2
Housing price and Betweenness	$Y = 0.003 + 0.37^*X_1$	13.34	0.73
Housing price and Straightness	$Y = -0.008 + 0.03^* X_2$	14.68	0.77
Housing price and Closeness	$Y = -0.003 + (1.42\ E+08)^* X_3$	16.13	0.80

From table 6 we knew that the correlation between Housing price and Accessibility could reach a strong correlation after removing the other factors. The correlation coefficients were 0.85, 0.87 and 0.89 respectively. At the same time from table 7 we can see the fitting degree also increased, among them the fitting degree of Housing price and Closeness was the highest.

5 CONCLUSIONS

There is a positive correlation between the Housing price and transportation accessibility, and the average correlation coefficient is 0.67. The reason why the fitting degrees of the three Accessibility index do not exceed 0.5 is that there are other factors affecting prices. After excluding the factors such as construction year, distance from subway and education resources, the average correlation coefficient of housing price and transportation Accessibility is 0.87 and the fitting degrees are all above 0.73. As the input-output intensity of the land increasing, housing price is affected a lot by the location transportation accessibility. From the perspective of our research, accessibility takes a supporting role in the regional development and better accessibility can make a relatively rapid development. This paper just discusses the relationship between Housing price and Accessibility from the perspective of highway accessibility, and we also can't ignore the impact of the rail transportation on Housing price. In the future research, road in planning would also be added in the road network to forecast the future road network accessibility and the impact on Housing price.

In Chen's research on the relationship between commercial networks and the network accessibility, he pointed out that the effect of Betweenness to large supermarkets and distribution of furniture building materials is strong and straightness is an important factor in affecting consumer goods market (Chen et al.,2013). From the empirical research, we can see that the highest correlation with the urban residential community is Closeness, and the lowest is Betweenness. The correlation degree between different study objects and Accessibility is different. And in the layout of urban planning, residential quarters should be planned in the area that has better Closeness and Straightness to promote the concentration of population and residential demand. Meanwhile, when planning and building roads, the government should also pay attention to the improving of Closeness and Straightness of residential land near the road line to promote the stability of Housing price.

EXTENSION RESEARCH

We can see that some roads break off from road network (Figure 6). Index values of Betweenness for the interrupted node are zero and Closeness and Straightness are both relatively low. Under the ideal state, the nodes of the network should be opened up (Figure 7).

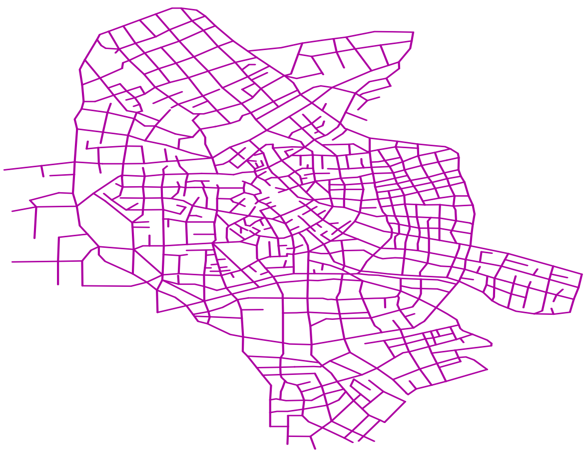

FIGURE 6 - TIANJIN CITY ROAD NETWORK

FIGURE 7 - IMPRESSION OF PART OF THE ROAD CONNECTION

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Under the ideal state, we optimized the road network ideally, and then measured the index value of the road network accessibility again. We analyzed the average value of the KDE of Accessibility of 258 samples. Results show that the three indexes were improved by different degrees. The average value of KDE of Betweenness is increased by 8.09%, the Straightness is increased by 5.45% and the Closeness is increased by 5.95%.Through making comparisions of the change of Housing price KDE we can see that the three factors would enhance by 8%, 7%, 20% respectively.

TABLE 8 - THE CHANGE OF KDE OF HOUSING PRICE

Index	Betweenness(Y_1)		Straightness(Y_2)		Closeness(Y_3)	
	Before optimization	After optimization	Before optimization	After optimization	Before optimization	After optimization
The KDE of Housing price	0.025	0.027	0.028	0.030	0.005	0.006

Therefore, it can be seen that the change of the road network structure will change the location accessibility obviously and then affecting housing price. So in the future, the government should make scientific planning about the road network according to the regulation target when they make regulations of the real estate market.

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