Regional Land Use Correlation Analysis for Rail Station Impacts

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ABSTRACT

In order to study the interaction between rail transit and neighboring land use as well as the differences in the development of rail transit lines in Xi'an. Based on the POI data from 2016 to 2020 and with the help of spatial autocorrelation analysis, Xi'an Railway Transit Line 1 to Line 4 are selected as the research objects. The spatial distribution of POI data was used to reflect the impact of rail transit on land use around the stations. Using six types of POI data, namely, scientific, educational, and cultural, administrative office, business and residential, road traffic, living and entertainment, and commercial services, to represent the corresponding land use. Using the Tyson polygon created by the rail station as the rail station impact area. Local spatial autocorrelation analysis was conducted for each land use type on the impact areas of lines 1 to 4. The results show that: (1) The high value gathering area of science, education, and culture, living and entertainment, and administrative office land is obviously transformed to the surrounding low value area. (2) The land around Line 2 is relatively well developed, with little overall change, while Lines 3 and 4 are still under rapid development. The study of the impact of rail transit opening and operation on land use around stations is important for rail transit planning and land use along the line.

Keywords: urban rail stations, rail stations, poi, land use, local spatial autocorrelation

1. INTRODUCTION

At present, China has become the country with the largest total mileage of rail transit built and under construction, and Xi'an city has opened 8 lines of rail transit and has 6 lines under construction. The connection between rail transit and surrounding land use has become more and more close [1, 2], and the current research on the impact of rail transit and land use mainly includes: economic impact[3], scope of influence[4], built environment[5], spatial characteristics[6], development intensity[7], development mode[8], simulation prediction [9], etc. However, many studies only focus on a single station as the research object, and lack of inter-site development. However, many current studies only take a single site as the research object, lacking the correlation analysis between each site, so the land use is analysed based on the spatial autocorrelation method.

Spatial autocorrelation analysis, as a typical geospatial analysis method, is to study and analyse the degree of spatial correlation of things, Moran in 1950 to study the distribution of random phenomena in two-dimensional or multi-dimensional space, thus defining the Moran index[10].In 1995, Anselin developed a local analysis of spatial autocorrelation method LISA[11], and since then the LISA local spatial autocorrelation is widely used in other related fields, local spatial autocorrelation has been further developed; with the rapid development of computer science, spatial autocorrelation is now widely used in the geographic distribution of spatial elements[12, 13], spatial change law[14] and other aspects. The POI data used can characterize the location and attribute information of various types of infrastructure and physical space in the region, present the spatial agglomeration of various types of production and construction factors in the city, and reflect the distribution pattern of the density of production and living of residents [15].

In view of this, using the spatial statistical analysis method for correlation analysis of the land around the rail transit stations in Xi'an, through the changes in the local Moran index of the various types of POI data around the stations, reflecting the changes in the land use of various types of land around the rail transit stations, as well as the differences in the development of the situation between the various routes, in order to provide reference for the development of the land use around the rail transit stations and the development of reference.

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2. RESEARCH METHODOLOGY

The spatial statistical analysis method is chosen to study and analyse the changes of various land use properties around the rail transit stations in Xi'an, classify, and connect the POI data, select global and local Moran's I index to analyse the spatial autocorrelation of each type of land use, and analyse the changes of each type of land use as well as the differences in the development of each line.

2.1 Global spatial autocorrelation

Global Moran's I is to reflect the spatial autocorrelation characteristics of the study area, to observe the spatial correlation and difference of the study object, and to test whether the overall data have spontaneous spatial correlation. The score of global Moran's I is generally between -1 and 1, less than 0 means negative correlation, spatial distribution has obvious dispersion characteristics; equal to 0 means irrelevant, spatial distribution does not have obvious pattern; greater than 0 means spatial positive correlation, spatial distribution has obvious aggregation characteristics. The formula is shown in formula (1):

$$I = \frac{n}{S_0} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}(x_i - \overline{x})} \tag{1}$$

Where: x_i and x_j denote the observations at the ith and jth spatial locations; w_{ij} is an element of the spatial weight matrix W (n × n), which represents the topological relationship between spatial units; n denotes the number of observation units; and S0 is the sum of all the elements of the spatial weight matrix W, which reflects the degree of similarity of the attribute values of spatial neighborhoods or spatial neighbors of the regional units.

2.2 Local spatial autocorrelation

Moran's I is an evaluation of an overall autocorrelation of the whole study area, and needs to analyse and evaluate the individual study sub-areas of the study area, so local spatial autocorrelation is introduced.

The spatial aggregation of the study area to its neighboring areas can be reflected by the value of local spatial autocorrelation LISA, the local spatial autocorrelation of each study sub-area is combined to get the global spatial autocorrelation. The LISA formula is shown in formula (2) and (3):

$$L_i = \frac{(x_i - \overline{x})}{S^2} \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_j - \overline{x}) \tag{2}$$

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2 \tag{3}$$

Where: $i \neq j$, n is the number of spatial units involved in the analysis; x_i and x_j denote the observed values of a phenomenon x on spatial units i and j, respectively; and w_{ij} is the spatial weight matrix, which denotes the proximity or distance relationship between regions i and j. Based on the calculated test statistics, the spatial autocorrelation can be tested for significance.

2.3 Moran Scatterplot:

In the Moran scatterplot, the Moran scatterplot can be divided into 4 quadrants corresponding to 4 different spatial patterns. Where H indicates that the variable is above average and L indicates that the variable is below average. Upper right quadrant (HH): regions with high values are surrounded by regions with high values; upper left quadrant (LH): regions with low values are surrounded by regions with high values; lower left quadrant (LL): regions with low values are surrounded by low-value neighbors; and lower right quadrant (HL): regions with high values are surrounded by low-value neighbors. the HH and LL denote regions that have a small difference between the region and its surroundings, i.e., the higher or lower values are concentrated in a concentrated distribution of regions, whereas the LH and HL indicate regions with some degree of difference in the values of the variable from their neighbors. The Moran scatterplot is shown in Fig. 1.

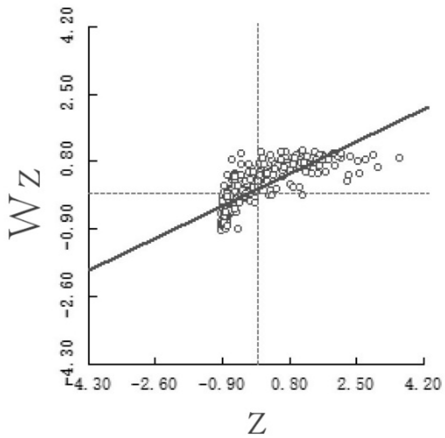


Fig. 1 Moran scatter plot

3. DATA PROCESSING

3.1 Data Acquisition

With the rapid development of the Internet as well as electronic map services in recent years, POI data (POI is an abbreviation of Point of Information, which can be translated as Point of Information in Chinese. POI data can be translated as Points of Information (POI), which are any non-geographic meaningful points on the map, such as shops, stations, entrances and exits of a district, bicycle return places, etc. POI data are widely used in many fields such as architecture, planning, landscape, business analysis, geographic information, etc., for example, identification of functional zones in the city center, accessibility analysis, analysis of the industry agglomeration state, community evaluation, nuclear density analysis and visualization, etc.

Firstly, we obtain geographic data such as road network and administrative boundaries of Xi'an city through Open Street map website, and secondly, we obtain POI data of Xi'an city through the open platform of Gaode map, and the data selected in this paper are POI data of Xi'an city in the five years of 2016, 2017, 2018, 2019 and 2020, and the data mainly include Name, Type, Tel, Longitude, Latitude, City, District, Address, and there are three levels of classification totaling 869 subclasses in the classification Type. The content of POI data is schematically shown in Tab. 1.

Tab. 1 Diagram of POI data content

Name	Type	City	District	Longitude	Latitude
PetroChina Qujiang Petrol Station	Automotive Services; Petrol Stations; PetroChina	Xi'an	Yanta District	108.9990842	34.20281976
Daniel Rehabilitation Hostel	Accommodation Services; Accommodation Services Related; Accommodation Services Related	Xi'an	Xincheng District	108.9876648	34.27044536
Peace of Mind Hosting	Science, Education and Culture Services; Science, Education and Culture Venues; Science, Education and Culture Venues	Xi'an	Chang'an District	108.7282303	34.20819521
Shanbei Fine Souvenirs	Shopping Services; Shopping Related Places; Shopping Related Places	Xi'an	Gaoling District	108.9973811	34.44474456
Jinyu Construction Machinery	Company Enterprise; Company; Company	Xi'an	Chang'an District	108.7825516	34.29426661
No.8 Intersection (Bus Stop)	Traffic Facilities Services; Bus Station; Bus Station Related	Xi'an	Shuangyi District	108.6843424	34.10918294

3.2 Data Classification

Due to the many POI data and miscellaneous classifications, we refer to the Urban Land Use Classification and Planning and Construction Land Use Standards (GB50137-2011) and combine the POI classification standards given by the operator, and select several types of POI data that have a greater impact on the urban land use: science, education and culture, administrative offices, business and residential buildings, administrative facilities, living and recreation, and commercial services [16]. The specific classification is shown in Tab.2.

Tab.2 POI classification table

POI Types	POI category
Executive Offices	government agencies, companies and enterprises
Road Traffic	airports, railway stations, piers, metro stations, bus stations, car parks, car parks
Science, Education and Culture	schools, museums, libraries, art galleries, media organizations
Business & Residential	residential areas, buildings, industrial parks
Entertainment	sports & leisure, healthcare, scenic Spots, public facilities
Commercial Service	catering services, shopping services, accommodation services

3.3 Data connection

POI data can reflect the spatial distribution of production and living facilities, such as the location information of rail transit entrances and exits, bus stops, restaurants, hotels, etc. Through the spatial distribution of POI data in terms of proximity and how much, the spatial distribution of various types of POIs can be reflected, which can then reflect the distribution of the residents' main production and living places.

Using the WGS-84 geographic coordinates in the POI data, the poi data are imported through ArcGIS, and the ArcGIS data visualization function is used to transform the POI table data into map data[17]. Various POI data visualization maps are shown in Fig. 2.

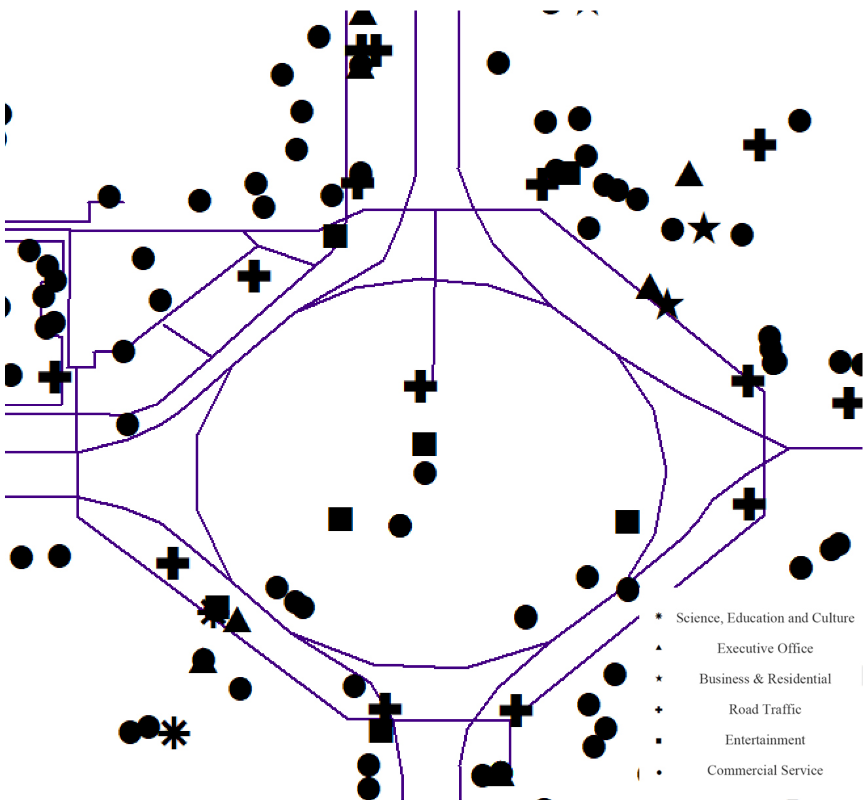


Fig. 2 Diagram of various types of POI spac

4. SPATIAL RELATIONSHIP BUILDING

Using methods such as spatial autocorrelation, the POI data of Xi'an from 2016 to 2020 were processed and analysed, and by analysing the spatial autocorrelation changes of POI data, to a certain extent, it can react to the changes of the relevant land data and the differences in the development of metro lines.

4.1 Determination of station influence range

The influence range of conventional rail transit stations is generally from the center of the rail transit station to the outside with a radius of 400m[18], 500m, 600m, 800m[19], 1000m, etc. as a circular area as the influence range, but this will lead to the influence area of each station is not continuous or mutual coverage, so the Xi'an City Railway Station as a discrete point to generate the corresponding Tyson polygons (Tyson). Polygon: each Tyson polygon has only one discrete point inside, and each point inside the Tyson polygon has the closest distance to the discrete point in the region) as the influence area of the rail transit stations[20], and use this to carry out spatial autocorrelation analyses, and the scope of the study is shown in Fig. 3.

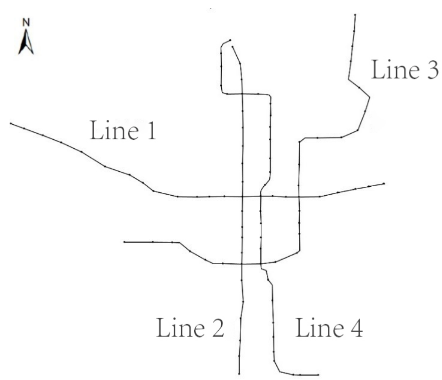


Fig. 3 Scope of study

4.2 Spatial POI data connection

The pre-classified and processed POI data are visualized by ArcGIS and then connected with the influence range of the rail transit stations, and through the calculation of geometry, the area of the influence range of each station, the number of POIs, the density and other spatial data are calculated and counted.

4.3 Create spatial weight matrix

Based on the spatial distance to create the spatial weight matrix, in the distance algorithm there are two algorithms of Manhattan distance (the distance between two points in the north-south direction plus the distance in the east-west direction) and Euclidean distance (i.e., for the straight line distance between two points), because this experiment is for the city of Xi'an, and most of the roads in Xi'an present a grid type, i.e., east-west or north-south direction of the road is dominated, so the Manhattan distance is used[21]. The inverse distance squared algorithm is used, which is like the inverse distance algorithm, but it is more sensitive to distance, and as the distance increases, the degree of influence of the elements on the target decreases at a rate that becomes faster, so that only the elements that are closer to the target are counted.

The Tyson polygon shape area varies from site to site, so spatial relationships are created using adaptive bandwidths [22], which, by correcting the parameters, allow each area to have a bandwidth of its own.

5. SPATIAL AUTOCORRELATION ANALYSIS

5.1 Global spatial autocorrelation

Spatial autocorrelation analyses were performed and the degree of spatial autocorrelation (Moran's I index) was calculated for the six types of POI data in the study area. The Moran's I indices of the six POIs were all greater than 0.2 and increased to different degrees with each year, and the z-scores were all greater than 2.58, with a confidence level of >99%, indicating that the spatial positive correlation of the six POIs was significant, and that the aggregation of the spatial distributions was significant, and the specific Moran's I indices are shown in Tab.3.

Tab.3 Site Moran Index by year

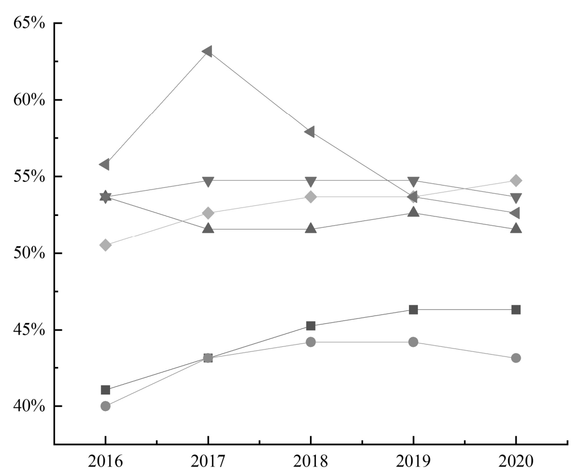
POI Types	2016	2017	2018	2019	2020
Science, Education and Culture	0.343	0.365	0.376	0.391	0.420
Executive Office	0.294	0.316	0.323	0.318	0.326
Business & Residential	0.495	0.503	0.504	0.506	0.496
Road Traffic	0.457	0.478	0.483	0.485	0.490
Entertainment	0.453	0.354	0.417	0.427	0.439
Commercial Service	0.377	0.405	0.337	0.310	0.318

5.2 Local spatial autocorrelation

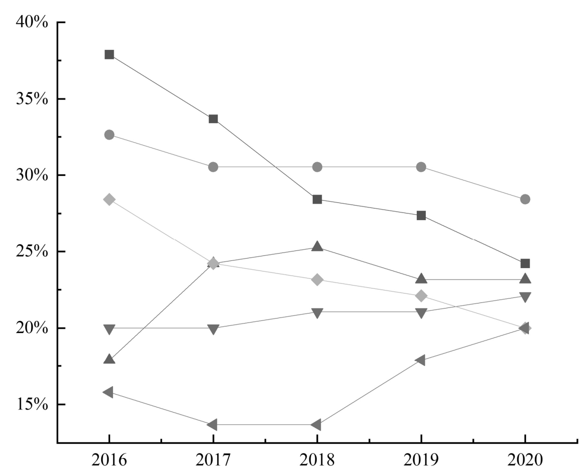
Xi'an Metro Line 2 (Phase 1 North) opened in 2011, Xi'an Metro Line 1 (Phase 1) opened in 2013, Xi'an Metro Line 2 (Phase 1 South) opened in 2014, Xi'an Metro Line 3 opened in 2016 and Xi'an Metro Line 4 opened in 2018 were selected. A total of 95 stations of 4 lines are analysed for local spatial autocorrelation in their rail station generation study plots.

5.2.1 Changes in local autocorrelation of different types of land

The results of the local spatial autocorrelation of the six types of land in the 95 study areas were analysed, and the results of the changes in the regional share of each type of land are shown in Fig. 4.



a Change in the proportion of high value areas by land type



b Change in the proportion of low value areas by land type

c Figure Legend

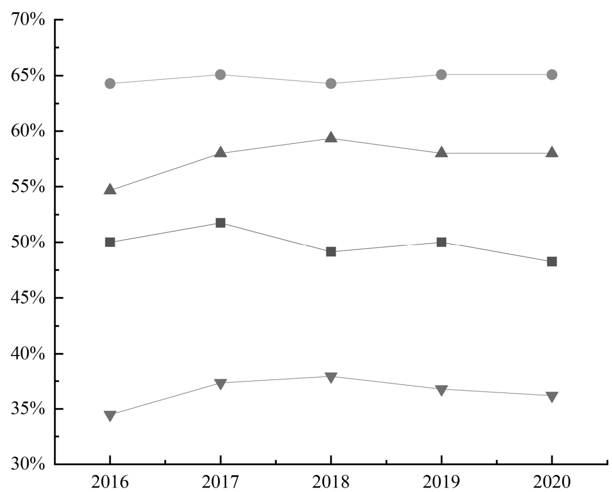
Fig. 4 Changes in the proportion of land of each type

From the proportion of high value areas of each type of land, it can be seen that the proportion of high value areas of land of science, education, culture and administrative office types is low, but there is a clear upward trend, the proportion of high value areas of land of life and recreation, road traffic and business and residential land is high, and there is not much change in the high value areas, and the proportion of high value areas of land of the commercial service type is the highest but there is a downward trend.

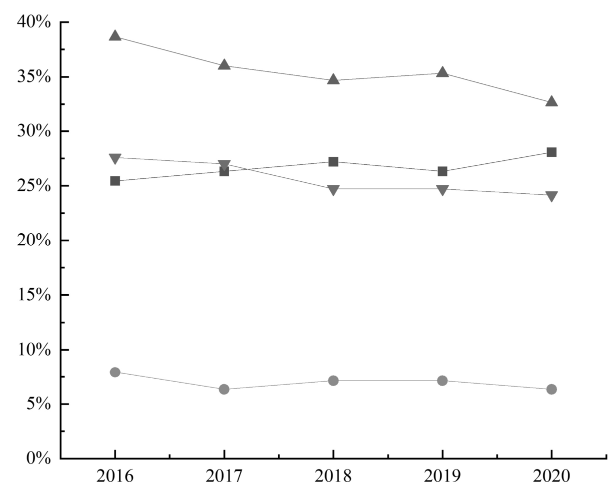
From the ratio of low-value areas of each type of land, it can be seen that the ratio of low-value areas of land in the commercial services category is the lowest, but there is an upward trend, the ratio of low-value areas of land in the road transport and business residential categories is low, and tends to stabilise after an increase, and the ratio of low-value areas of land in the science, education and culture, administration and entertainment categories is high but there is a clear downward trend.

5.2.2 Changes in local autocorrelation of land on different lines

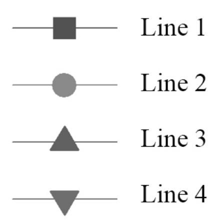
The local spatial autocorrelation results of the four lines are analysed, and the results of the changes in the proportion of each line are shown in Fig. 5.



a Change in the proportion of high value areas by line



b Change in the proportion of low value areas by line



c Figure Legend

Fig. 5 The proportion of each line changes

From the changes in the proportion of high value area of each line, the proportion of high value area of line 2 is the highest, the proportion of high value area of line 4 is the lowest, the proportion of high value area of line 3 is higher than that of line 1, and there is a slight increase in the proportion of high value area of line 3 and line 4, and a slight decrease in the proportion of high value area of line 1.

From the changes in the proportion of low-value areas of each line, the proportion of low-value areas of line 2 is the lowest, the proportion of low-value areas of line 4 is the highest, the proportion of low-value areas of line 3 and line 4 is comparable and has slightly decreased, and the proportion of low-value areas of line 1 has slightly increased.

6. CONCLUSION

To obtain POI data for data classification and data connection to create Tyson polygons for Xi'an rail transit stations as a study plot, firstly using global Moran's I index to verify the global spatial autocorrelation as a positive correlation, and next selecting Xi'an metro lines 1, 2, 3, and 4 for the analysis, and draw the following conclusions:

(1) Among the six types of land use within the study area of the four rail transit stations, the land use for science, education and culture develops the fastest, followed by the land use for living and entertainment and administrative office, which develops at a slightly lower rate than that of the land use for science, education and culture, and the land use for science, education and culture, living and entertainment, and administrative office show a tendency of the high-value agglomeration area expanding to the surrounding low-value agglomeration area. The development of road and traffic land use has not changed much, and the transition between high-value and low-value areas is rare. The business and residential land use and commercial service land use show a decrease in the high value area, and the space shows a trend of contraction of the high value area and expansion of the surrounding low value area.

(2) Xi'an is a typical ring-shaped development city, with urban development from the inside to the outside. In the inner part of the city, where the metro lines are densely packed, such as Beidajie Station, Zhonglou Station, Xiaozhai Station, Wuloukou Station, Tonghuamen Station, etc., the development of urban land is perfect, and the proportion of high-value areas is very high; on the contrary, in the outer part of the city, where the metro lines are gradually thinned out, the proportion of low-value areas is beginning to rise. However, the differences between the lines are also more obvious due to the differences in line selection as well as the specific conditions of each line.

Among the four metro lines studied, Line 2 has the highest proportion of high-value agglomeration, the lowest proportion of low-value agglomeration, and the smallest change in the agglomeration area, which indicates that the surrounding land use of Line 2 is the most mature and the functional structure is the most complete, and its development has already tended to be stable.The degree of development of the surrounding land of Line 1 is a little lower than that of Line 2, and its proportion of high-value agglomeration is the third, while that of low-value agglomeration is approximately the same as that of Line 3, with the proportion of low-value agglomeration being about the same. The proportion of line 3 is roughly the same, overall, there is still a certain gap between the land development around line 1 and line 2, in the future, the high value area may continue to increase, and the low value area may continue to decrease, but the speed may be slower. line 3 is ranked second in terms of the proportion of high-value aggregation area, and the proportion of low-value aggregation area is ranked first, and the change of the aggregation area of line 3 is the biggest, which indicates that the development speed around line 3 is the fastest in recent years, but the high and low aggregation are both at a high level now. High and low aggregation are in a high ratio, compared with the more perfect development of line 2, line 3 high value aggregation area ratio is fast reaching the level of line 2, but there is still a certain gap in the low value aggregation area, in the future the low value aggregation around line 3 may have a larger development, and its high value area may exceed that of line 2. line 4 ranked fourth in the high value aggregation area ratio, the low value aggregation ratio is roughly the same as line 1, and the change of line 4 aggregation area in recent years is the largest. In recent years, the speed of change of the gathering area of Line 4 is higher than that of Line 1 but lower than that of Line 3. The development speed of Line 4 is faster, but whether it is the high-value gathering area or the low-value gathering area, there is a big gap between Line 4 and Line 2, and Line 4 will still have a big potential for development in the future.

The development of urban land is closely related to a series of factors such as policy, population, economy, traffic, etc. Since other influencing factors are also influencing the land use during the whole research process, how much the opening and operation of the metro affects the development of urban land needs further in-depth discussion.

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