



On the Characteristics of Housing Spatial Structure and Location Selection of Residential Communities: A Case Study of Wuhan City

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Abstract

With the deepening of the housing system reform in China, the residential spatial structure has gradually assumed a complex shape along with its tremendous changes in Wuhan city. It is very crucial and necessary to show the city's housing spatial structure in order to guide the city's housing development and administration. Based on current statistic data and field survey, this paper tries to open up the spatial law of residential communities of Wuhan city, by means of GIS, from the quantitative and empirical points of view.

As far as housing spatial structure is concerned, the three characteristics on the spatial development of residential communities are identified: (1) the housing is stretching towards surroundings with ring and wedged structure; (2) residential communities distribution in urban district is concentrating; (3) on the other hand, the amount distribution of residential communities in the suburbs are examined, mainly along main traffic lines.

Meanwhile, based on the above analysis of the housing spatial structure, the characteristics on residential

location selection of residential communities are also put forward: (1) residential communities development and distribution are mainly concentrated along main traffic lines to obtain more convenient location; (2) moreover, a great many of residential communities have distributed around some lakes and along Yangtze or Hanjiang River. So, it is thought much of gradually for the whole city's residents to obtain the better accessibility and surroundings.

Keywords: Residential communities, Housing spatial structure, Residential location selection, GIS, Wuhan city

1. Introduction

With the rapid development of urban economy and the alarming increase of urban population since 1990s, housing reform has been deeper and deeper and the contradiction between housing demand and real estate supply has become fiercer and fiercer. At the same time, the spatial structure of urban internal housing market has also experienced tremendous changes, which draw researchers' and relevant authorities' attentions to some relevant issues such as the development and management of real estate industry, especially for housing space and investment location decision. Foreign researchers had systematically investigated housing space from various aspects such as economy, geography, social science and political science and so on, and formed a multi-aspect, multi-hierarchy, multi-dimension (spatial-temporal) and multi-scale (microscopic and microcosmic) research system where both quantitative and qualitative approaches, theoretical and practical methodologies are used. In general, their researches are respectively concentrated on the spatial structure of residential landscape (from the view of ecology) (Caster, 1981), tenements' housing selection and decision behavior (from of the view of behavior science) (Alonso, 1964; Forrest, 1991), the characteristics and social spatial structure of residential community (from the view of social science) (Johnston, 1966). While domestic researchers investigate the spatial structure of residential market from the aspect of urban internal spatial structure, thus their studies focused on various aspects including the spatial distribution of real estate (or residence) and its influence on regional structure (Zhang, 1997; Yan, et al., 2001), the spatial structure evolution of residential space(Wu and Cui, 1999; Zhang and Liu, 2002), housing price and land price(Du, 1997), housing type and its social spatial structure(Xu, et al., 1989; Wang, 1995; Gu, 1997), residential suburbanization and population distribution(Zhou, 1996; Cai and Zhou, 2000), the location of residential community and traffic expansion(Xu, 2002; Zhou and Xu, 2002) and so on. However, there is a lack or weakness in the quantitative and practical study on the spatial distribution of residential community.

In Wuhan city, its residential market is rapidly commercial and humanization environment has gotten more and more attention. Furthermore, in order to uncover the rule of residence spatial extension, guide community commercial service planning and realize sustainable development of humanization environment of residential community, we need to deep investigate the development and complexity of real estate. Based on existing statistical data and on-the-spot investigation and with the aid of GIS, this paper investigates the location selection characteristics of residential community development through the spatial distribution analysis of residential community development. This study can give out some suggestions to residential community management and commerce network planning.

2. Research area and methods

2.1 Research area

Considering the internal deep-mining centralization and edge expansion suburbanization, we set the 9 city zones as the main research area and part analysis are only pointed to 4 outskirts due to data accessibility.

2.2 Framework of study

Based on statistical data and on-the-spot investigation, we build a GIS spatial data set which includes tenement number, average housing price, construction scale, housing type and floor location etc. With the help of some spatial analysis functionalities of GIS (e.g. buffer and overlay), we then investigate the spatial distribution characteristics of tenement number, price, combination type and construction scale of residential community. Finally we can uncover the properties of spatial structure and location selection for residential community. The frame of this study is listed as shown in Figure 1 below.

2.3 Research Methodology (see Figure 1 below)

Step 1: data collection. Using some maps of Wuhan city such as traffic map, land use planning map (from 1996 to 2020), on-selling building distribution map (<http://www.zdxx.net/houses/index.htm>), (the ChuTian Metropolis Daily, Chutian Golden newspaper and some other newspapers, the almanac of Wuhan real estate (year 2005), Wuhan Soufang website(<http://wuhan.soufun.com>) and Yifang website(<http://www.fdc.com.cn>), we can get some basic attributes of residence sample including the name, address(house number), house type, floor location, area and average price, tenement number etc.

Step 2: Extraction of the spatial feature of the data. Firstly, we build a housing sample spatial data based on the selected on-selling house distribution map and housing number geographical code, then we carry out overlay analysis, i.e., combine these maps with Wuhan traffic map, land-use map. Finally, we build the spatial and attribute dataset of these housing samples.

Step 3: Data processing and data analysis. (1) Cell classification. We carry out 1 kilometer buffer analysis of the inner-ring, the main lakes, rivers and traffic arteries of Wuhan city. Use the inner-ring as a border we can divide the whole research area into 40 annular belts, and use the four radicalized traffic arteries as the axes, we can carve up the whole research area into four sector extension belts(see Figure 2 below). (2) Spatial clustering analysis. Respectively use type of residence, housing scale (area of structure, land area), the total floor number, housing price and land load (rate of green, capacity rate) as standards to classify the annular or sector structure of research area. Finally, we can find out the residential group according to the density of housing sample data.

3. Characteristics of spatial distribution

3.1 Ring-shape distribution difference of buffering-belts

After comparing the number and density of sample data, tenement size and land scale of each residential community of the whole research area, we find out that it demonstrate a significant hierarchical diversity and forms a circle region distribution. We set the sample density, sample ratio, average price, tenement size (means average number of tenement), land scale (means the ratio of construction area), land load (means capacity rate) of 266 randomly chosen new-built buildings in the year of 2005 in Wuhan city as the vertical ordinate while the distance from each annular belt to the area center as the horizontal ordinate. Obviously, the 40 annular belts can be divided into 4 big circle regions: i.e. inner-circle, mid-circle, outer-circle and out-edge circle region respectively comprises of the area between annular belt 1 to annular belt 12, annular belt 13 to annular belt 24, annular belt 25 to annular 33 and outside annular belt 34 (see Figure 3 below). More importantly, the inner-circle buildings are characterized by high density, big construction area, small land area, high capacity and price and fewer tenements, the main housing style are mainly residential/commercial houses and economy houses. Differentiated from it, the mid-circle building are of mezzo density, big land scale and less higher price and more tenements, the main housing style of this region are common houses and economy houses. House located in the outer-circle region can be identified by their big land scale, less developing density, lower price but a large number of tenements, together with a form of housing suburbanization. The main house types in this region are villas and common houses. Houses located in the outer-edge circle region are with a quite low

density, higher price and less tenements. Most of the houses there are villas. See Table 1 below.

3.2 Sector extension

Recently, the development of residential communities in Wuhan city tends to be extended along the line of several main traffic arteries, such as Jinyin Lake residential community sector region(RCSR), '318' national highway residential community sector region(RCSR), Miao Mountain residential community sector region(RCSR) and Wuhuang Road residential community sector region(RCSR) (see Figure 4 below). This sector extension is consistent with former studies (Zhang et al. 2004). To illustrate it clearer, we describe the 4 sectors as follows: (1) Jinyin Lake RCSR refers to the northwest extension region located between Jinsan Avenue and Hanfei Avenue, most of them are around-lake low-rise villas and along-river low-rise common house, and they always have convenient traffic, wonderful living environment, low tenement density, low capacity rate, high quality and price. A large number of tenements here are wage earners of Wuhan East Lake high-tech development zone (EDZ). This region is at the stage of rapid development and house price here is more than 3000 RMB per square meters and its capacity rate is lower than 1.5. (2) '318' national highway RCSR, it covers Wuhan East Lake high-tech development zone (EDZ), regions around Houguan Lake, south Taizi Lake and Sanjiao Lake etc. it extends southeast along the '318' national highway. Similar to Jinyin Lake RCSR, this area also have convenient traffic and good living environment, and most of the houses here are low-rise villas and multi-level common houses. House price here is relatively low (2500-3000 RMB per square meters). (3) Miaoshan RCSR. It mainly includes the east part of around-Tangxun Lake area and extends south along Lianghu Avenue. This region is quite closed to Wuhan East Lake high-tech development zone (EDZ); also have good traffic and very wonderful living environment. Many houses here are multi-level common houses, some low-level villas and economy house are located around Tangxun Lake. As this residential community is developed for teachers in university, it formed a university town. Some of the around-lake apartment has become the first choice of peoples who works in Wuhan East Lake high-tech development zone (EDZ). Moreover, house price here is relatively low (2000-2500 RMB per square meters). (4) Wuhuang Road RCSR. It locates between Wuhuang Highway and Wuhuang Road and extends east. Houses here are mainly high-level economy house and common houses, which serves for mid and low-income families. The capacity rate of this region is relatively high (2.1). Besides, both traffic and natural environment here is preferably. House price here is around 1500-200 RMB per square meters.

3.3 Synchronous concentrations and distribution

As mentioned above, from the relevant data of the almanac of Wuhan real estate (in 2005), we can obviously see that influenced by the housing policies and system (e.g. urban function, land construction planning, housing reform) and interaction between urban land price, location, population density and purchasing scale, the spatial distribution of the development intensity and construction density of residential community in Wuhan city is complex and uneven.

3.3.1 Centralization of internal deep-mining

In recent years, the urban land use planning of Wuhan city paid a lot of attention to the intensive development of urban function. Due to the remove of unfinished buildings and low-level short old buildings in urban field and growing immigration of companies, there are a large number of left lands. Moreover, infrastructure of traffic, medical treatment and education is relatively perfect in Wuhan city. All of these made the real estate development "making use of every bit of time and space" and concentrated in the internal city. Or more detailed, the real estate development of Wuhan city is: (1) intensive, dense and with a large scale. The number of developed buildings in the central city has accounted for 80% of the whole city, while total construction area, total tenement number, average density, sum of high-rise and semi high-rise houses and the sum of

multi-level houses in central city has respectively account for 90%, 60%, 80%, 90% and 65%. In this regions, land load are always high, the capacity rate had been up to 3.6. (2) circle region distribution of the combination pattern of residential community, in general these communities are resident, official and commercial buildings. Conventional central district is characterized as frequent commercial activities and population migration and large-scale development of official & residential buildings. These buildings are mainly super high-rise with large construction area and are always concentrated in beneficial location such as along the traffic artery. While economy house, multi-level common house are served for low and middle income family, they are always rebuilt from old communities and concentrated in sub-central district. Medium size villas with a low density are also popular in common strict where suitable traffic and living environment is equipped, such as around a lake or river. (3) High price. Comparing with outskirts, urban district residential communities have a higher price. For instance, in year 2005, the rock-bottom price of major building in all urban districts of Wuhan city is 2350 RMB per square meters which is 1.5 times as high as housing price of urban outskirts. Additionally, the average house price of central district of Wuhan is 3000 RMB per square meters.

3.3.2 Suburbanization of edge expansion

With the extension of urban suburbanization, many companies migrate from city center to urban outskirts. Economic development zone also concentrated in these outskirts. Such “company-residence separation” and “company-residence closely adjacent” have become two main trends of residential community development, which greatly promotes the development of housing community in urban outskirts. And with the tide of population suburbanization, the residential community also became suburbanization (Cai and Zhou 2000). Comparing with residences in urban area, residence in urban outskirts is always with a moderate even low price, and its development intensity and scale are small. The spatial distribution of residences in outskirts has demonstrated some specific characteristics: (1) on the support of external traffic arteries, the extension of low density multi-level residential communities is radicalized and formed four sector regions. (2) Most of the around-lake houses are low-level, low-density but high-price villas. Such as villas group of Houguan Lake, villas group of Tangxun Lake, South Lake and Hou Lake etc. (3) with the support of economic development zone, many mediate density multi-level common houses had been built which mainly serves for wage earners. This type of houses can been found in Wujiashan development zone, Zhuan kou and East Lake economic development zone.

3.3.3 Relatively concentrated big group

It is well known that influenced by some factors such as urban planning, population distribution, location and regional infrastructures (traffic, water and power supply, hospital, school etc.), and natural environment, urban residence tend to favor certain places and form a big group structure. It is because such big group structure can provide a better location advantage and can better meet the complex housing demand of urban citizens (e.g. convenient traffic, perfect environment, good auxiliary facilities). There are some big residential community groups in Wuhan city: (1) Xudong residential community group (RCG). Xudong has obvious location advantage. For instance, it is the intersection of Youyi Avenue and Heping Avenue, near Sha Lake and have the support of Xudong Avenue, besides, convenient traffic and developed commerce makes it more attractive. Many super-level commercial residence concentrated here such as Xudong europe garden, Kaixuanmen plaza, Hengqin garden etc. such residences are with a high density and high price (3000 RMB per square meters), also large scale. (2) Sha Lake RCG. This group locates in the inner ring of Wuhan and is adjacent to the central-south-central-north commercial belt, besides, it has very beautiful scenes around the lake. Residences here are mainly high-rise or semi high-rise common houses whose price are relatively high (average price is 2500 RMB per square meters). Huiyu garden, Xin'an garden and Jiahe sunshine cost all belongs to this group. (3) South Lake RCG. This group extends along South Lake and South Lake Airport. Also have good traffic

and environment. Most of the residences here are multi-level semi high-rise commercial and residential houses. It is with high density and price (2000 RMB per square meters). It is needed to mention that South Lake new town is developed along the South Lake, in this new town, not only multi-level common houses can be found for university teachers including teachers who work in south-central university, Huazhong normal university, Huazhong agriculture university and Zhangnan university of economics & law, but also super high-rise common and commercial residences designed for abroad market (e.g. ‘Shi long ming ju’, ‘li shang ren jia’ etc.). Besides that, low-rise and low density villas are also built here. The house prices here are nearly 2500 RMB per square meters. (4) Guan shan RCG. This group is near Guanggu and Huazhong university of science and technology, has good traffic. Most residences here are low density multi-level commercial and common houses. House price here is between 1800-2800 RMB per square meters. This group is mainly built for wedge earners who work in university and high technological industries. (5) Tangxun RCG. This group is around Tangxun Lake and closely adjacent to university town. Most houses are mainly low-rise and low density villas. Some are multilevel and high-rise common houses. This region has cheaper land price and better environment, which endows it with a great potential of development. (6) Changqing RCG. It is located in the intersection of Hanfei Avenue, Jinsan Avenue and Changqing Road and adjacent to Jiangnan economic development zone and industry industrial parks of mainland and Taiwan. Residential real estate developed very fast. Most of the houses here are large-scale and high density common houses (see Figure 4 below). (7) Qing shan RCG. This group extends along Yejing Avenue and Heping Avenue. Since year 1954, Party central community has located Wuhan iron & steel group in Qingshan district, those areas along the Yangtze River from Jiangjiadun to Renjia Road is used mainly for worker’s residences of Wuhan iron & steel group. In recent years, many low-rise but high density common houses are built for mid-income workers of both Wuhan iron & steel group and Cailin group.

4. Characteristics of location selection

From the above spatial analysis of residential communities of Wuhan city, it can be easily found out that the development of residential community was greatly influenced by the location condition, the level of regional infrastructure (e.g. traffic, water and power supply, hospital, school etc.), environment condition (natural, social and humanistic environment) and so on. Among all of these influence factors, convenient traffic and perfect environment play the most import role in peoples’ house purchasing decision. Thus, the spatial location selection illustrates an obvious characteristic of “contiguity to the street or water”.

4.1 Traffic orientation

In this section, we take the inner ring of Wuhan city, Fazhan Avenue, Yanjiang Avenue, Hanyang Avenue, Wuluo-Luoyu-Wuhuan Road as an example to investigate the traffic orientation of the location of residential community. We draw 1 kilometer buffering for each object with the aid of ArcGIS 8.3(see Figure 5 below), and respectively calculate the sum of residence sample located in each buffer. See Table 2 below.

Obviously, there are 147 residential communities in the 1 km buffers of inner-ring road and five major traffic arteries, which account for 55.26 of the total number of sample data (266). Moreover, the average density of residence sample is 2.85/km², which is 5.5 times as many as the density value of research area (middle-ring). Thus there is a significant traffic orientation in the development of residential community. Or in other words, most of the real estate projects are concentrated along the side of traffic arteries.

Most of the buildings are dense (more than 3/km²) and located in inner-ring of Wuhan city or along Heping Avenue. Such buildings are always super high-rise common houses or commercial buildings with a large scale and high capacity ratio. The proportion and density of those buildings located along the middle-ring road such as Jianshe Avenue, Hanyang Avenue and Fazhan Avenue are lower than the inner-ring buildings. Houses in

this region are mainly large scale multi-level common houses and economy houses with a high capacity ratio. Although the buildings along the Wuluo-Luoyu-Wuhuang Road have a low average density and proportion, comparing with the average residence density of outskirts, the residence development intensity of outskirts is greatly higher than city skirts. For instance, the density of residence sample along Wuhuang Road is 2.17/km², which is 24 times higher than the density of residence sample of outskirts (0.09/km²). Furthermore, the concentration degree of outskirt residence along traffic artery is quite higher than city residence sample. So we can speculate that in the city, residential communities concentrated along traffic artery and usually have a large scale while the development of residential communities along the radical arteries of outskirt are always not so intensified and always have a not so large scale. However, in general, the development of residential communities of outskirts depend more on traffic artery than city residential community.

4.2 Water orientation

For explaining the water orientation of residential communities, we take Yangtze River, Hanjiang River, Sha Lake, Jinyin Lake, South Lake and Tangxun Lake as an example. We use the same approaches as part 4.1 to calculate the proportion and density of every sample residential community located in the buffer of each lake (see Table 3 and Figure 5 below).

From Table 3, we find out that: (1) On the whole, the distribution of residential community around water is disperser than those residential communities along streets. The proportion and density of residential community around the water are both low. Besides, the development intensity, capacity ratio and green rate of such communities are relatively low. Residences around water are always multi-level common house or low-rise villas which have good environment but high prices. (2) Most of the around water residences located in the central city with a high density, and such residences are always multi-level, super high-rise common houses. For instance, Sha Lake sample residential community (located in central city) is lowly proportioned but concentrated with a large development scale, while the residential communities in the sub central city have relatively small development scale and very low density; as most of the land use in such residential communities are Greenland, large scale development of real estate are restricted to the regions located on the west of east and south of the bustling urban built-up area. Two residential community groups have been developed rapidly, namely South-Lake RCG and Along-River RCG. The former are dense buildings of multi-level common houses and villas, while the latter are crowded with more than 17% newly built-up residences of Wuhan city and houses there have low dense and small scale, the main house type are multi-level common houses and villas. (3) The suburb residential communities around lake are developed with a low density and small scale, and most of them are low-rise villas. The Jinyin Lake residential community and Tangxun Lake residential community only proportioned 4.5% of the whole residential communities around rivers, which is relatively lower than urban residential communities. This is because residential communities around Tangxun Lake are on its early development stage, most of residential buildings there are low-rise large-scale villas and multi-level common houses; while Jinyin Lake developed more rapidly than Tangxun Lake, the density of its residential community are relatively high and houses there are always low-rise large scale expensive villas.

5. Conclusion

Using the type of building and house, tenement number, selling price, construction scale and other statistical data of sample residential communities in Wuhan city, with the help of spatial analysis in GIS, we find out that:

(1) On the whole, the spatial distribution of residential community in Wuhan city is circle region-sector extension, it demonstrate a structural complexity of the co-existing circle differentiation and sector

differentiation (Wang 1995, Wang et al. 2001). The development intensity and construction scale of residential communities tends to decrease from central city to city outskirts. Moreover, the residential communities form several circle regions from center to edge, i.e. central city, sub central city, common urban areas. In the common urban areas, the residential communities extended radicalizedly along traffic arteries and large lake and finally formed several sector areas. The developing density rapidly decreases along the sector.

(2) Synchronous concentration and diffusion of building development in local which is greatly influenced by traffic, population and environment. The spatial distribution of residential communities is uneven. Locally, the circle region-sector extension has been changed by “perturbation deformation” to concentration-diffusion structure. On one hand, through remodeling the old houses, residences for workers of immigration companies have “make use of every bit of time and space” and their distribution is diffused, on the other hand, with the development of artery and the group structure of economic development zones, population suburbanization has also developed rapidly, which promotes the emerging of “company-residence separation” and “company-residence closely adjacent” residential pattern or residential suburbanization. As this residential pattern is easily influenced by traffic and environmental condition, they are always concentrated along traffic arteries or around lakes. Regional differences can be found for their spatial combination ways. Besides, the uneven spatial distribution of residential communities is very significant from the aspect of several concentrated residential group.

(3) In recent years, with the deepening of the housing system reform in China, the residential communities of Wuhan have grown rapidly and influencing factors of them has become more and more complex. In general, among all the factors influencing the location selection of residential community, such as urban planning policy, population distribution and purchasing capacity, infrastructure level (traffic, medical, education etc.), location condition, land use structure and planning, land price, natural environment, social environment and so on, traffic and environmental plays the most important role. This point of view can also be found through our practical study in Wuhan city.

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Table 1. The ring-shape structure of residential communities with hierarchy in Wuhan city

| Circle region | Construction area rate (%) | Rate of tenement (%) | Rate of house type (%) | Ratio of sample gross (%) | Ratio of sample density (%) | Ratio of average price (%) | Ratio of type of building (%) | Main characteristics | Regional type |
|---------------------|----------------------------|----------------------|------------------------------------|---------------------------|-----------------------------|----------------------------|--|---|---|
| Inner-circle region | 59.83 | 13.83 | A-37; B-61; C- 29; D- 15 | 33.67 | 52.50 | 1.29 | High rise: 47 Semi high-rise: 60 Multi-level: 31 Low-rise: 10 | High density & capacity rate, most of them are high rise buildings, residential & commercial high price | High density, large scale, high-rise residential & commercial Common houses |
| Mid-circle region | 29.34 | 40.14 | A-25; B- 23; C- 38; D- 22 | 45.12 | 24.24 | 1.19 | High rise: 30 Semi high-rise: 26 Multi-level: 34 Low-rise: 17 | Medium density Multi-level Common house Large development scale Large tenements number | Medium density & scale Multi-level Common house Economy residential house |
| Outer-circle region | 7.63 | 36.52 | A-28; B- 9; C-11; D-35 | 14.81 | 14.50 | 1.33 | High rise: 14 Semi high-rise: 9 Multi-level: 23 Low-rise: 39 | Low density Most of them are low-rise/villas Development of high-intensity large tenements number High price villas | Low density Medium scale High price Low-rise villas |
| Out-edge region | 3.20 | 9.51 | A-10; B- 5; C- 12; D- 28 | 6.40 | 8.76 | 0.77 | High rise: 9 Semi high-rise: 5 Multi-level: 12 Low-rise: 35 | Low density, most of them are low-rise & villas Lower price Fewer tenements | Low density Large scale Low-rise villas |

(Noted: A: common house, B: residential/commercial house, C: economy house, D: villas)

Table 2. Distribution of residential communities along main roads

| Sample residence distribution | Inner Ring | Fazhan Avenue | Jianshe Avenue | Heping Avenue | Hanyang Avenue | Wuluo-Luoyu -Wuhuang Road | Sum | Average |
|----------------------------------|------------|---------------|----------------|---------------|----------------|---------------------------|-------|---------|
| Proportion (%) | 16.54 | 7.89 | 6.02 | 11.65 | 6.77 | 6.39 | 55.26 | 100 |
| Density(number/km ²) | 3.12 | 2.56 | 2.76 | 3.16 | 2.81 | 2.36 | 2.85 | 0.52 |

Table 3. Distribution of residential communities around rivers and lakes

| Sample residence distribution | Centre city | | | | Urban fringes | | Sum | Average |
|----------------------------------|--------------------------------------|----------|-----------|------------|---------------|--------------|-------|---------|
| | Along Yangtze River & Hanjiang River | Sha Lake | East Lake | South Lake | Jinyin Lake | Tangxun Lake | | |
| Proportion (%) | 17.29 | 3.76 | 5.26 | 7.89 | 2.26 | 2.26 | 38.72 | 100 |
| Density(number/km ²) | 1.95 | 3.25 | 0.71 | 2.56 | 1.38 | 0.52 | 1.46 | 0.52 |

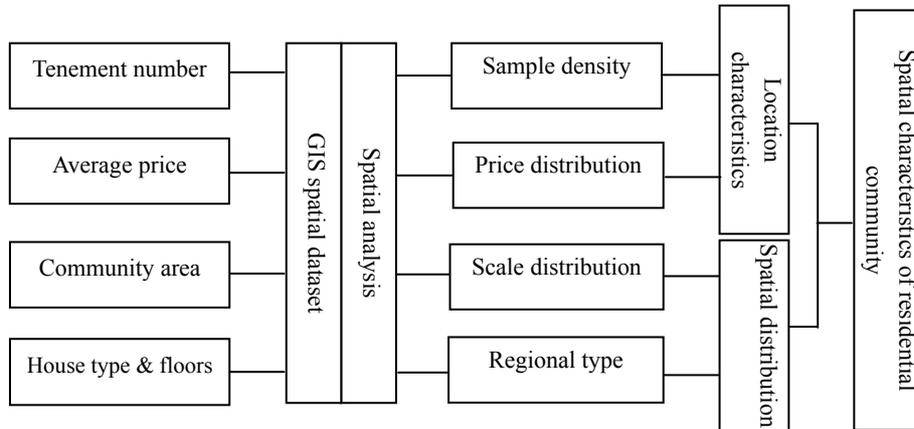


Figure 1. Framework of study

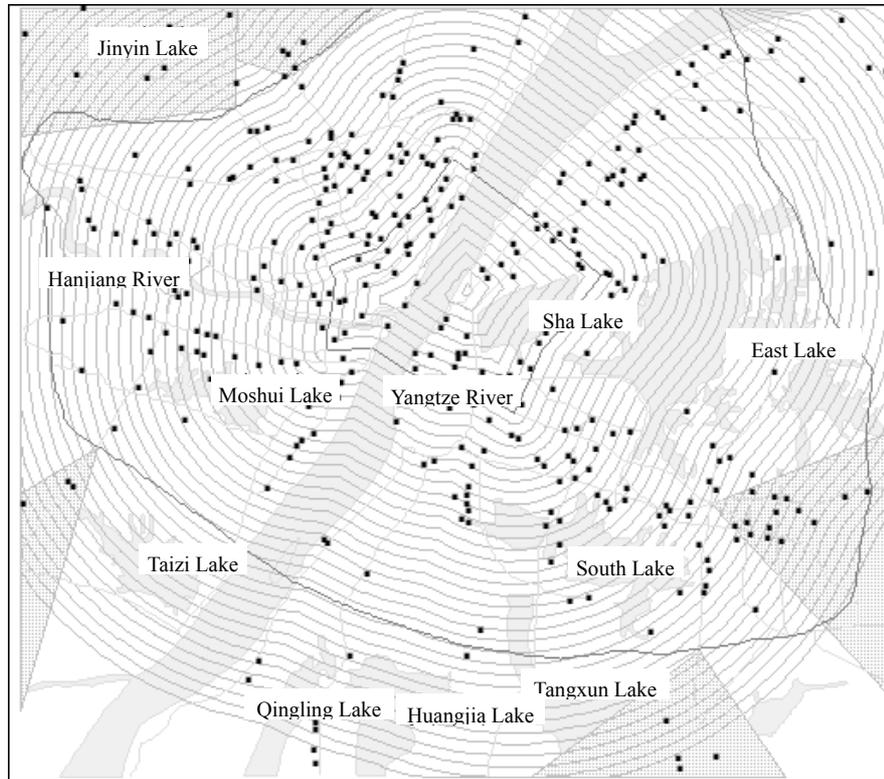


Figure 2. The spatial distribution difference of residential communities by buffering in Wuhan city

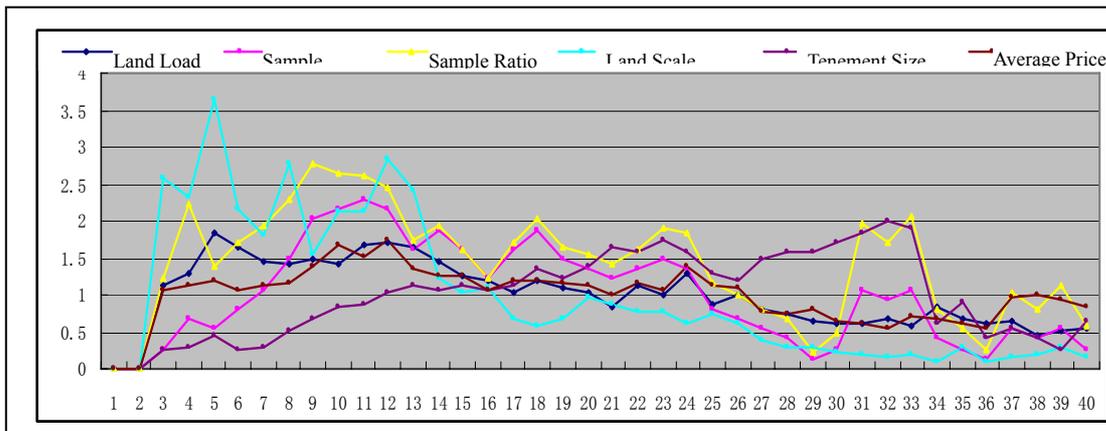


Figure 3. Distribution difference of residential communities by buffering in Wuhan city

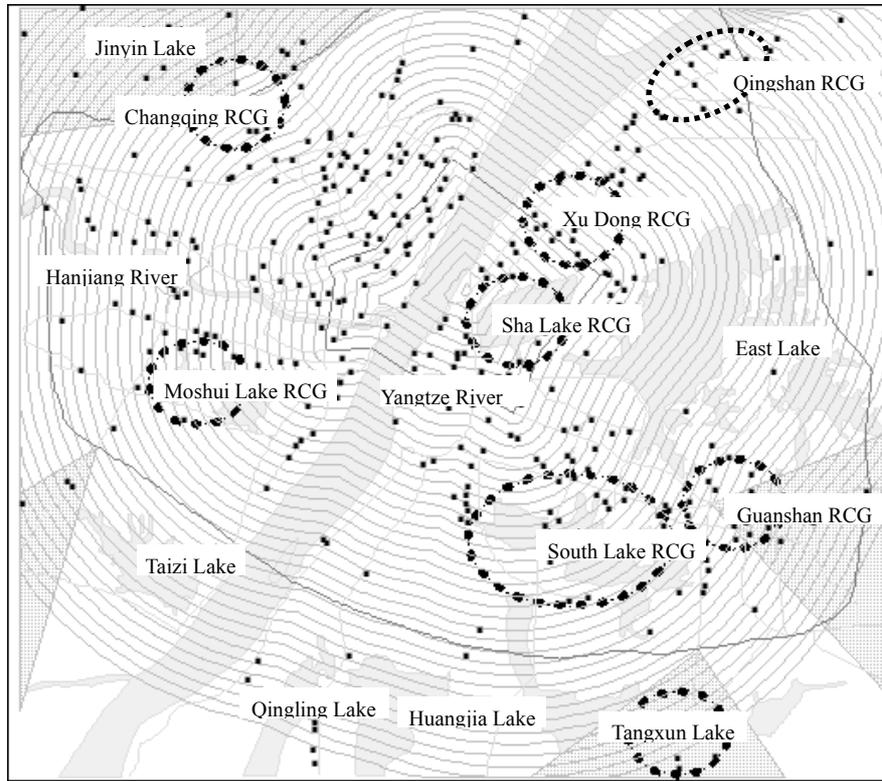


Figure 4. Aggregation distributions of residential communities in Wuhan city

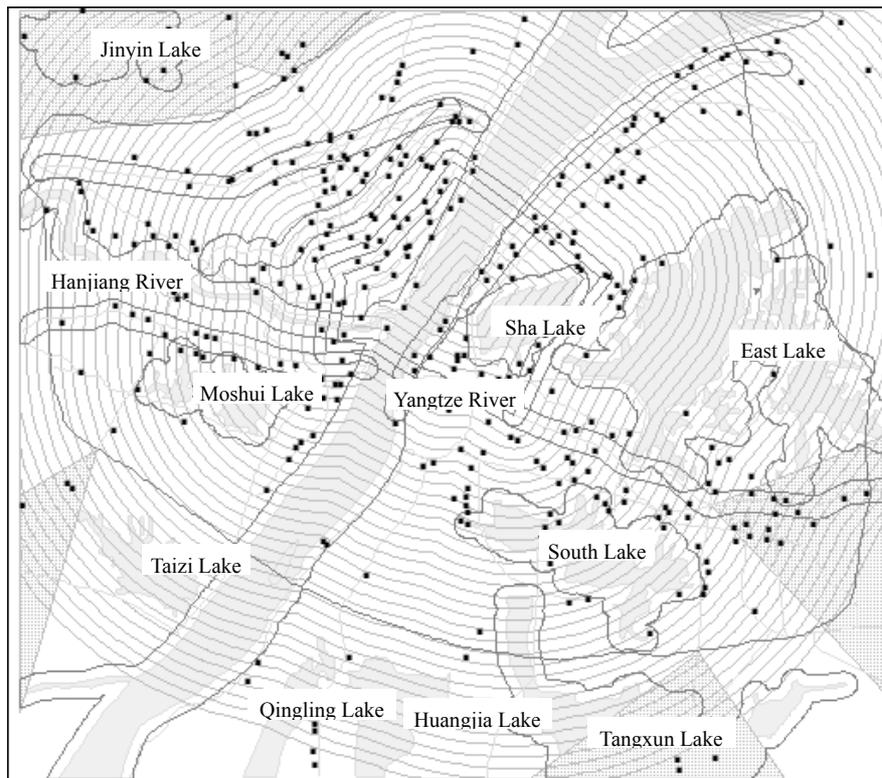


Figure 5. Spatial distribution of residential communities by buffering main roads, rivers and lakes