Residential Differentiation Based on Reachability and Spatial Clustering: A Case Study of the Main Urban Area of Wuhan City

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Abstract The differentiation of urban residential space is a key and hot topic in urban research, which has very important theoretical significance for urban development and residential choice. In this paper, web crawler technology is used to collect urban big data. Using spatial analysis and clustering, the differentiation law of residential space in the main urban area of Wuhan is revealed. The residential differentiation is divided into five types: "Garden" community, "Guozi" community, "Wangjiangshan" community, "Yashe" community, and "Shuxin" community. The "Garden" community is aimed at the elderly, with good medical accessibility and open space around the community. The "Guozi Community" is aimed at young people, and the community has accessibility to good educational and commercial facilities. The "Wangjiangshan" community is oriented towards the social elite group, with beautiful natural living environment, close to the city core, and convenient transportation. The "Yashe" community is aimed at the general income group, and its location is characterized by being adjacent to commercial districts and convenient transportation. The "Shuxin" community is aimed at the middle and lower income groups, far from the city center, and the living environment quality is not high.

Key words Big data; Residential space; Spatial differentiation; Spatial clustering; Functional zoning

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With the rapid expansion of urban residential land, a series of problems have emerged in cities, such as increasing traffic congestion, deteriorating living environments, and ecological damage[1]. With the acceleration of urbanization, the "single center ring" expansion model of cities has caused various urban problems to deteriorate day by day, and the central area of cities is becoming less attractive. Based on the theoretical understanding of organic decentralization and spatial agglomeration, major cities around the world have begun to develop from a single center structure to a multi-center and multi-level structure, and many forms of clustered residential spaces have been produced. At the same time, residents with higher incomes in cities have a pursuit of higher quality of life, which promotes suburbanization[2]. Following this, more and more affluent groups are relocating to the outskirts of cities, and the city center is gradually weakening. Western cities have experienced a phenomenon of differentiation in residential space, shifting from a tree level residential space to a multi-center, multi-level network structure[3-4]. Domestic scholars not only focus on the research of the development process of urban residential space in different time periods, but also the study of residential space structure and its differentiation mechanism[5]. Urban planners conduct research on the layout and planning of residential areas, mainly in terms of technical means of planning. Other research scholars mainly focus on the formation factors and mechanisms of urban residential locations[6-7].

Based on urban big data mining and analysis, the social, economic, location, cultural, and ecological characteristics of urban residential space are captured, and the residential needs of residents with different social characteristics are perceived. Based on residential needs and multidimensional features, spatial clustering is conducted, and functional zones of residential space are divided, and optimization strategies for corresponding functional zones are proposed.

1 Analysis methods and data source

In this paper, web crawler technology is used to collect POI data of infrastructure in the main urban area of Wuhan City from the Internet, and location information and infrastructure classification information are extracted, to construct an urban infrastructure database. Infrastructure accessibility is evaluated using near neighbor analysis. Then, the K-means clustering algorithm is used for spatial partitioning.

Wuhan is the provincial capital city of Hubei Province and also the national central city. The urban population of Wuhan in 2017 was 10.914 million. Among them, the main urban areas include 33.43 km^2 of Jianghan District, 64.24 km^2 of Jiang'an District, 46.39 km^2 of Qiaokou District, 108.34 km^2 of Hanyang, 87.42 km^2 of Wuchang, 480.20 km^2 of Hongshan, and 85.50 km^2 of Qingshan. The research focuses on the differentiation of residential conditions in these 7 main urban areas.

2 Functional zoning of residential space based on residential needs

2.1 Impact factor analysis Seen from Fig. 1a, high accessibility areas are concentrated in several major commercial districts and expand outward in a circle like manner, presenting a multi-point concentration pattern. Seen from Fig. 1b, the distribution

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pattern of the accessibility assessment map for large electrical appliances is almost the same as that of large supermarkets, showing a multi-point concentration pattern and expanding outward in a circular pattern, but it is not as dense as large supermarkets. Fig. 1c shows that the accessibility distribution of the market is relatively average.

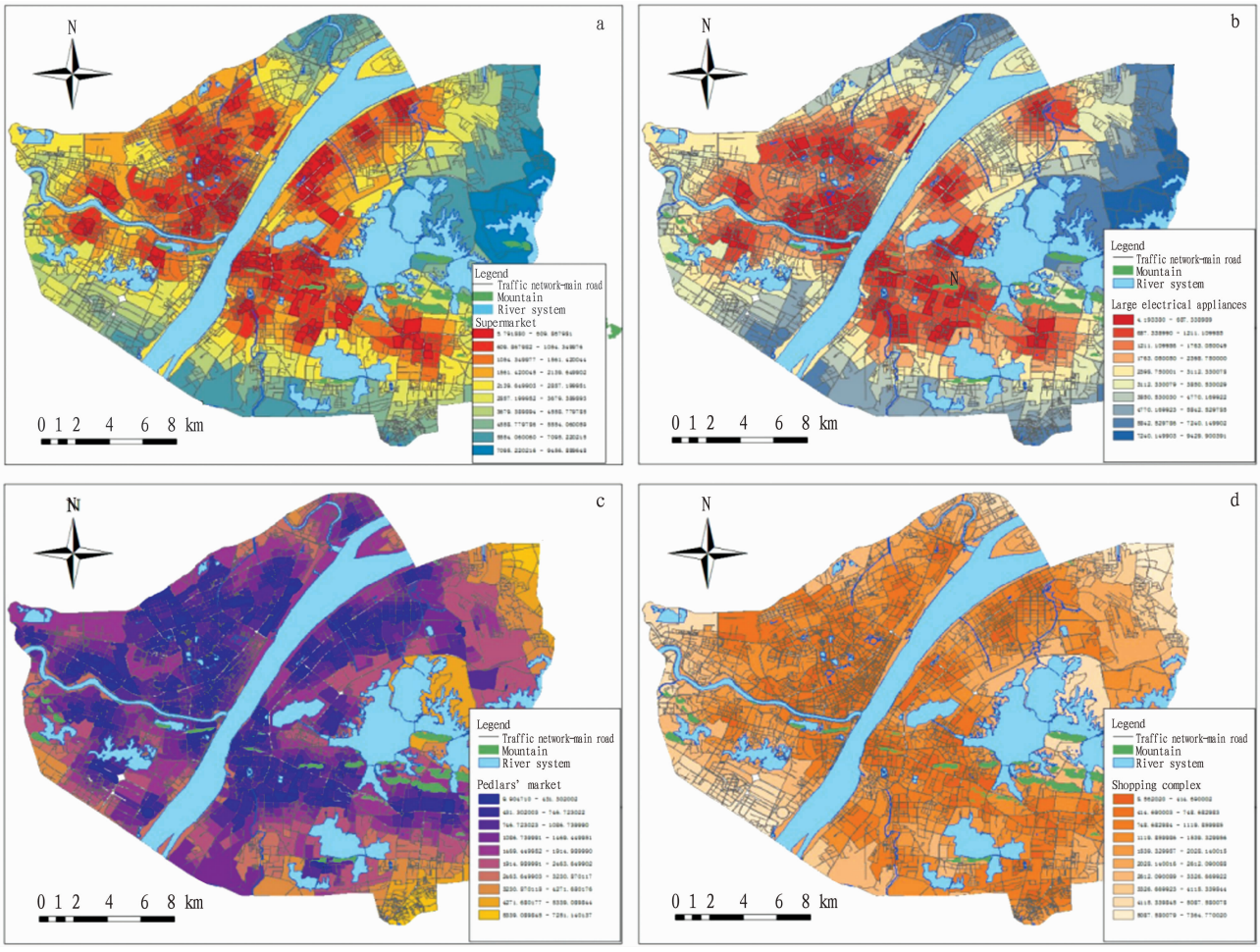

Fig. 1 Accessibility of commercial facilities

From Fig. 2a, it can be seen that the most ideal location for the accessibility of universities in the main urban area of Wuhan is around Zhuodaoquan and Wuluo Road in Hongshan District, the west of the Yangtze River, around Jiefang Avenue. Their accessibility is almost all below 648 m. Fig. 2b shows the accessibility assessment of primary schools in the main urban area of Wuhan. The service radius of urban planning for primary schools is less than 500 m, which almost meets the indicators near Jiefang Avenue, Wuluo Road, and Heping Avenue in the main urban area of Wuhan. However, the accessibility is significantly lower near Hanyang District, Hujiadun, and Tuanjie Avenue. From Fig. 2c, it can be seen that the accessibility of kindergartens in the main urban area of Wuhan is generally evenly distributed, with Hanyang District in the lower left and Qingshan District in the upper right slightly lower. Fig. 2d shows the accessibility assessment of vocational and technical schools. The most ideal places for the accessibility of vocational schools are almost all located around several main roads in the main urban area of Wuhan, making it convenient for nearby students to attend vocational and technical schools, and cultivating more technical talents for Wuhan.

Fig. 3a is the accessibility assessment map of the main roads in Wuhan City. It is known that the accessibility of the main roads within the second ring road of the city is relatively high, while the accessibility of the suburbs is relatively low. Fig. 3b shows the accessibility assessment map of Wuhan subway stations. It can be seen that the ideal locations for the accessibility of these subway lines are Jianghan District, Jiang'an District, Qiaokou District, and Wuchang District, while the lowest points are Hongshan District and Qingshan District. The subway line runs through the economic core of Wuhan City.

Seen from Fig. 4a and Fig. 4b, residential areas within 666 m of accessibility are located on both sides of the Yangtze River or near lakes and mountains such as the East Lake, and spread outward in a circular pattern. The lowest points of accessibility are still in Qingshan District and Hanyang District, with reachable distances exceeding 6 011 m. Seen from Fig. 4c, the ideal areas with a accessibility of less than 634 m from residential areas to general parks are relatively concentrated along the Yangtze River

and Jianghan District, and the accessibility of Dongxihu District is also relatively ideal. The accessibility of parks in Hongshan District, Qingshan District, and Hanyang District is not ideal, and the accessibility of parks along the East Lake is almost 1 447 m or less. Fig. 4d is accessibility assessment map of comprehensive park. Seen from Fig. 4d, the ideal locations of accessibility for comprehensive parks in the main urban area of Wuhan are mainly concentrated in Ma'anshan Forest Park, Yellow Crane Tower Park, Guishan Park, Yinhu Imperial Park, and Heping Park. The lowest points are still in Hanyang District and Qingshan District.

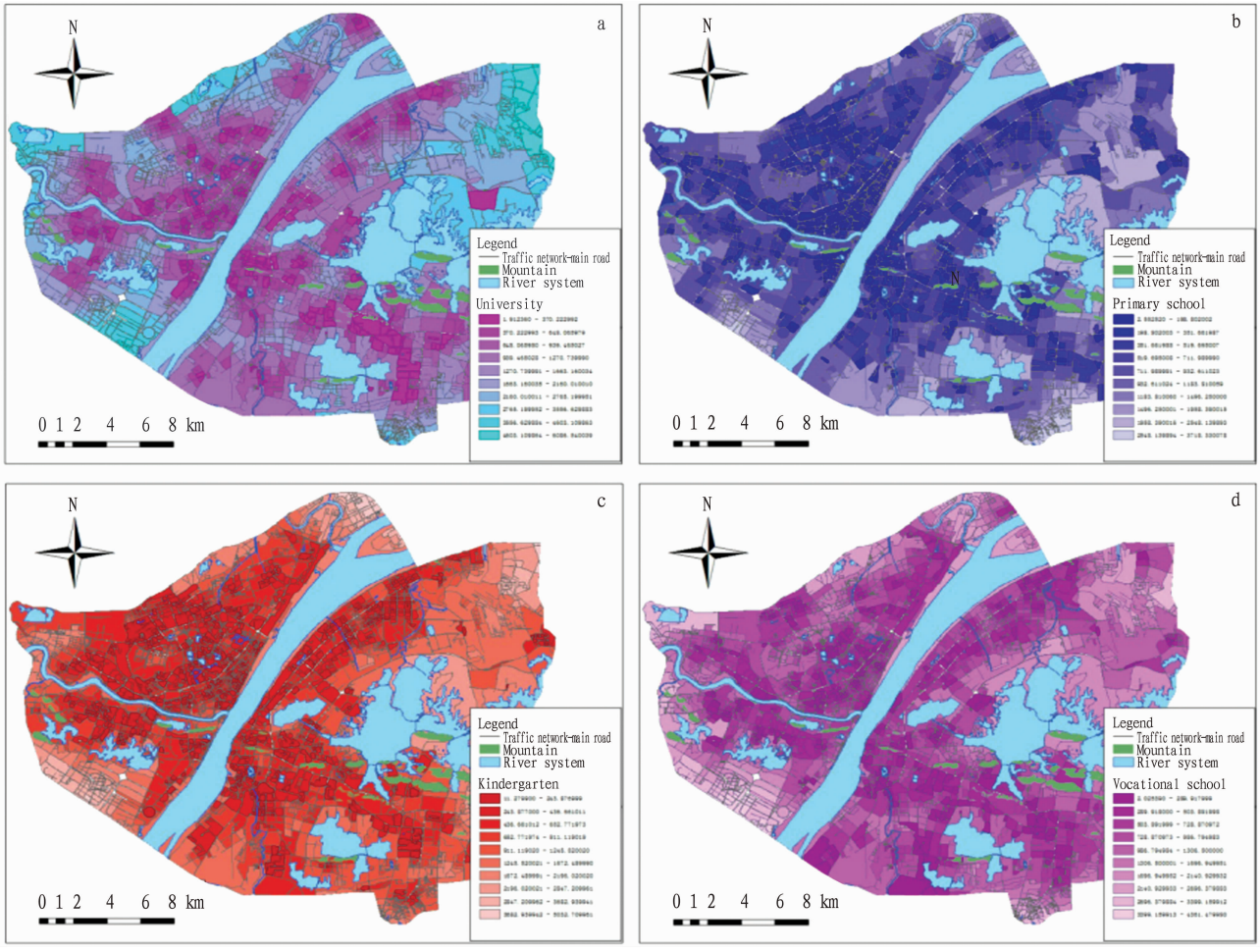

Fig. 2 Accessibility of educational facilities

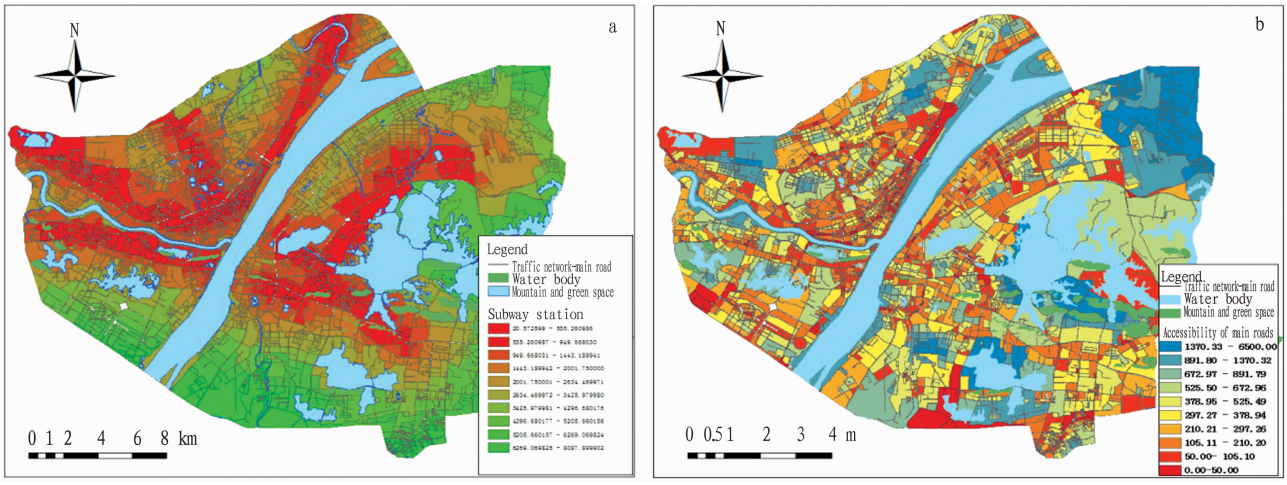

Fig. 3 Accessibility of transportation facilities

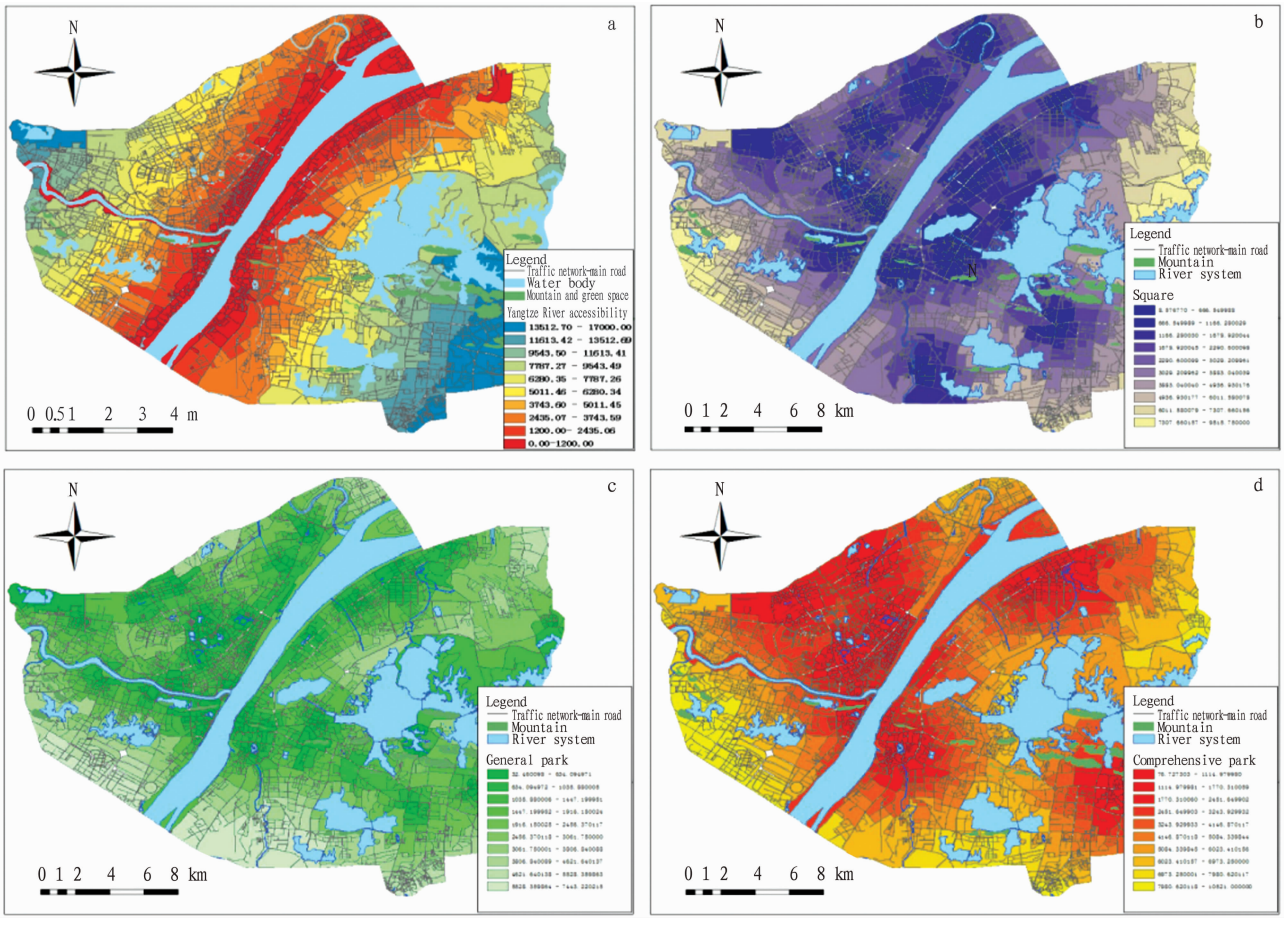

Fig. 4 Accessibility of open spaces

Fig. 5a shows the accessibility assessment map of the central location in the main urban area of Wuhan, showing a trend of spreading outward from the main urban center. Fig. 5b shows the accessibility assessment of comprehensive hospitals in residential space in the main urban area of Wuhan, with a relatively uniform distribution of comprehensive hospitals.

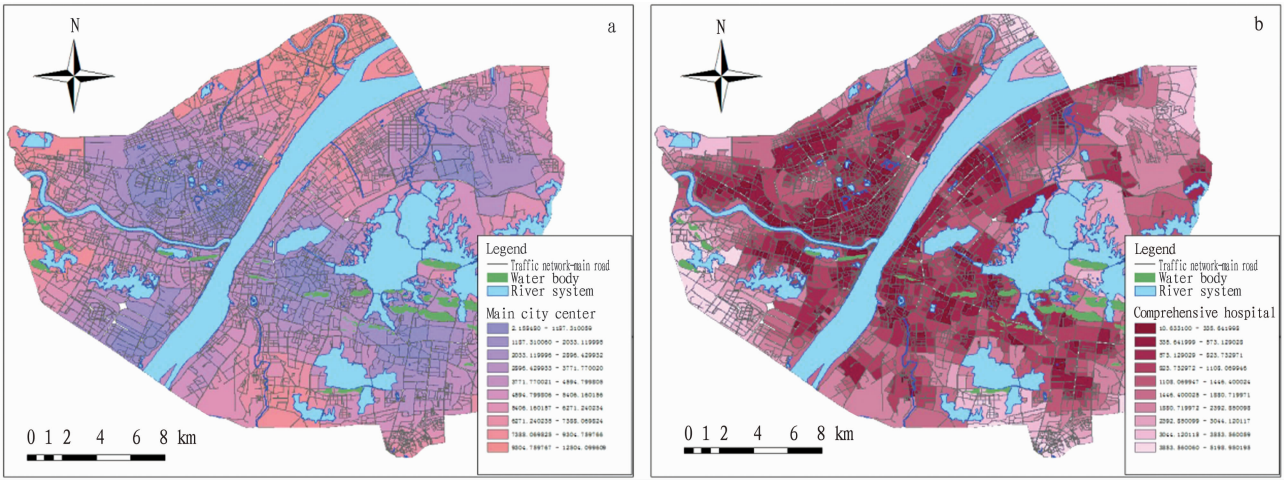

Fig. 5 Accessibility of urban structure and medical facilities

2.2 Differentiation characteristics of residential space in Wuhan City

2.2.1 Residential space clustering zoning based on spatial clustering. Based on the number and distribution of various influencing factors built in the main urban area of Wuhan before May 2017, cluster analysis is conducted, thereby dividing into five types of residential spaces and groups. The "Garden" community targets the elderly, and this type of community has high accessibility to

medical facilities and open spaces. The "Guozi" community targets teenagers and children, and this type of community has excellent educational and commercial facilities. The "Wangjiangshan" community targets high-income individuals, and this type of community has high open space and high-end residential areas with high development quality or suburban villas far from noise and with elegant environment. The "Yashe" community targets middle income groups, almost all of whom are located in multi story commercial housing in the city center or small high-rise buildings in the suburbs. The "Shuxin" community targets the middle and lower income groups, and this type of community mainly refers to low-end commercial housing, affordable housing, *etc.* in suburban or urban areas.

2.2.2 Differences in residential space distribution. The differentiation status of the five types of residential spaces defined in this article in the main urban area of Wuhan is shown in Fig. 6.

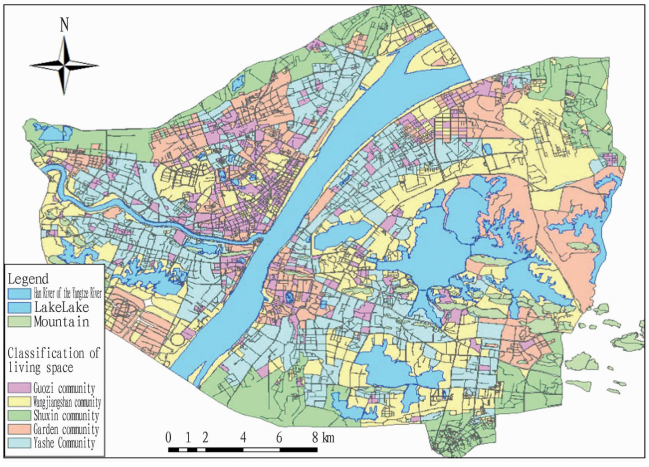

Fig. 6 Differentiation of residential space in the main urban area of Wuhan City

(1) The "Garden" community is mainly located in residential areas with a relatively concentrated elderly population in Wuhan. This type of residential area is relatively scattered and concentrated in the outskirts of the city or in the dangerous old houses in the city center. From Fig. 6, it can be seen that this type of residential area is mainly concentrated in Lujia Village and Gujia Village of Donghu Scenic Area, as well as near the intersection of Yuyuan Avenue and Guanggu Avenue, around Yellow Crane Tower Park, Houhu, Changqing, and around Zhonghe Times Square. It can be seen from this that such residential areas are either located in elegant natural environments such as Donghu Scenic Area, or near medical facilities such as Zhonghe Times Square, with good open space. Due to being far from the urban area, the housing prices are not very high, and they belong to Class II – III housing.

(2) The "Wangjiangshan" community is mainly located in the high-end residential areas of city center, with convenient transportation, convenient commuting, and high-quality development or elegant suburban villas far from the hustle and bustle, such as the Houhu and Jinyin Lake areas of Hankou, the South Lake and Tangxun Lake areas of Guanggu, the Triangle Lake and Houguan Lake areas of Zhuankou. These types of residential areas are located in places with beautiful natural environments, close to the city core, and convenient transportation. The landscape functional conditions are very good, with a high degree of landscape enjoyment of open space. The landscape engineering is outstanding, and the housing prices are high, and they are Class I high-end residential area.

(3) The "Yashe" community mainly refers to multi story commercial housing in the city center or suburban small high-rise buildings, such as near the core areas of Wuhan (Qiaokou District and Wuchang District), or near emerging areas (Optics Valley and Zhuankou). This type of residential area is mostly composed of professional and technical personnel, administrative personnel, individual merchants, and commercial service personnel. These people choose to live in such urban spaces due to various factors. They are not willing to relocate due to their satisfaction with the work location, transportation facilities, and some infrastructure of their existing address. From Fig. 6, it can be seen that the distribution of such residential areas is almost scattered in various parts of the main urban area of Wuhan, and these people are also the largest group of residents. The main feature of such residential areas is that they are located in the core or emerging commercial districts of Wuhan, with convenient shopping, entertainment, and transportation. From Fig. 6, it can also be seen that this type of residential area belongs to Class II housing, with a higher grade.

(4) The "Shuxin" community mainly refers to low-end commercial housing and affordable housing located in the suburbs or urban areas. Most of them are located at the junction of urban and suburban areas, outside the Third Ring Road or on the Third Ring Road. The target audience is also some low-income, elderly and other vulnerable groups. The main characteristics of such residential communities are being far away from the city center, inconvenient transportation, or in some places with poor living environments such as urban villages. This type of person is slightly better than the disadvantaged group, but they also belong to the grassroots level of society. They live in the bottom communities or middle and lower residential areas of society, and may also rent affordable housing. This type of residential area is relatively scattered and concentrated in the outskirts of the city or in the dangerous old houses in the city center. From Fig. 6, it can be seen that these types of residential areas are located on the outskirts of the city, around the Third Ring Road, such as the Workers' Village Urban Industrial Zone in Qingshan District, Liufang in Jiangxia District, near Chenjiadun, and around Yuanbo Avenue, all of which are far from the city center. Moreover, the living environment is generally not very good, and they belong to Class III low-end housing.

(5) From Fig. 6, it can be seen that the most concentrated locations of the "Guozi" community are in Jianghan District and Jiang'an District. The characteristics of these two districts are that educational and commercial facilities are very developed, and accessibility is very ideal, indicating that such communities are very suitable for young people and children to live in. The accessibility of primary, secondary, and kindergarten in this type of residential area is within 500 m, which is very suitable for parents to pick up and drop off. In areas with almost perfect educational and commercial facilities, it belongs to Class II – III middle and high-end residential areas.

3 Conclusions and recommendations

(1) The target population of the "Garden" community has a high demand for living environment, and they need open space and complete medical facilities to facilitate their daily activities. It should mainly improve the accessibility of medical facilities, open spaces, and educational facilities in such communities.

(2) The target population of the "Wangjiangshan" community is extremely picky about their quality of life. They need beautiful natural environments, convenient transportation facilities, and perfect living places. Therefore, the suggestion for the "Wangjiangshan" community is to increase parks to improve the environmental quality. Residential locations should be built near the river or lake and closer to the city center, and within the service radius of commercial implementation such as comprehensive shopping malls. It should mainly improve the accessibility of urban centers and open spaces in such communities.

(3) The "Yashe" community does not require too many open spaces such as parks, but they place great importance on the convenience of transportation and have a higher demand for educational facilities than the "Wangjiangshan" community. This type of community does not need to live in prime locations in the city center, but transportation must be convenient.

(4) The target population of the "Shuxin" community is in the stage of basic needs, and they are unable to independently choose their place of residence and houses. Instead, they try to choose better places of residence in some poorer areas as much as possible. Medical and educational facilities can be appropriately added, and the open space does not need to be too large or beautiful, but it is also an indispensable part. Some commercial facilities such as commercial markets and small supermarkets can be added to meet their basic living needs.

(5) The "Guozi" community is mostly inhabited by people with children, so the demand for educational facilities in the "Guozi" community is relatively high. From this perspective, the layout of educational facilities in the main urban area of Wuhan can almost meet the needs of such communities. Some shortcomings are that this type of community has a slightly higher demand for medical facilities than other types of communities except for the "Garden" community. It is recommended to appropriately increase some medical facilities and open spaces, increase the accessibility of medical facilities and open spaces appropriately, and improve the life satisfaction of urban residents living in the "Guozi" community.

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