Analysis and Research of Urban Street Functions Based on GIS

: A Case Study of Xuhui District, Shanghai, China

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Abstract: In the context of the shortage of public space resources in large cities, the concept of "Street Space Renaissance" has been reintroduced, and the social attribute of urban streets as public space have been reemphasized. Street vitality is one of the main indicators to evaluate the social attribute of urban streets, and it is also the main target of urban street design and control in recent years. In this paper, GIS technology is used to evaluate the vitality of streets of different functional types, which makes up for the deficiency of ignoring the functional properties of streets when evaluating the vitality of streets by spatial syntax. This paper takes the Xuhui District of Shanghai, China as an example and comprehensively analyze urban facilities' POI data of different functions (commercial, office, residential and public service facilities, etc.) to identify the density, mixing degree and the dominant nature of the street functions, and using the three indicators to identify the characteristics of urban streets. The research found that: (1) In the area of Xuhui District, according to different types of infrastructures' POI data, the streets present different functional features. (2) At the overall level, the street vitality shows a certain correlation with the mixing degree and density of the street functions. For example, the streets in the northwest of Xuhui District bordering with Changning and Jing'an District are more active. On the contrary, the vitality of the streets' in the southern part of Xuhui District and the eastern part near the Huangpu River are generally weak, whose overall development are not perfect. (3) At the meso level of street vitality, the street sections at the intersection are more dynamic than the middle sections. (4) Xuhui District has the highest proportion of streets dominated by the functions of public services and public management, followed by commercial and business streets, and finally residential streets. In general, Xuhui District has strong public functional features and high public service capabilities.

Keywords: Street function, street vitality, street function density, street function mixing degree, the functional nature of the street, GIS, POI

1 Introduction

As the main carrier of urban traffic, the street mainly bears two attributes in the development process of the city: the transportation as the medium of communication and the sociality of the public space function[1]. Different street patterns represent different social and economic needs. In the era of pre-management, the street forms all showed small-scale, network-interlaced features, accompanied by a narrow road width[1]. This community-level street organization served the town life at that time, such as the Beijing City Square in Qing Dynasty of ancient China and the streets of medieval European cities[2]. However, this street pattern has gradually declined with the rise of motor vehicles. People's requirements for regional accessibility have gradually increased. In order to adapt to large carriages and trams, the streets have gradually widened, and the infrastructure properties of the streets have gradually surpassed the public space. Social property dominates. People's feelings about the initial "city" culture of the street are gradually decreasing. In recent years, the concept of "revitalization of street space" has gradually been brought forward, and the social attributes of the streets as the public life stage of the citizens have begun to be re-emphasized by the public[3]. The functional layout of the street determines the vitality and nature of the street, which in turn determines the value and atmosphere of the surrounding plots.

At present, the research on the functional layout of the street level is mostly related to the

vitality of the street. It is considered that encouraging the diversified activities in the street is an important method to improve the attraction of the street. The decrease in the diversification of street functions is the main reason for the decline of street vitality[5]. At present, the quantitative research on street function and street vitality in academia is mainly based on the use of facility POI and mobile phone signaling data proposed by Ying LONG et al to establish street vitality quantitative evaluation methods[4][6], and there also are methods based on SD method and the field investigation method from the human perception to describe the street vitality more qualitatively[7][8]. However, there is still not to many methods on quantitatively measuring the vitality of street functions and determining the nature of streets.

This study mainly uses the POI data of urban diversified facilities to determine the vitality of the street from the mixing degree of street functions (that is, the degree of diversification of street functions) and the density of street functions, and further determines the dominant nature of the street through the proportions of each function of the street. This paper aims to conduct a more comprehensive study of the function of urban streets from the above two dimensions, and then to discover the characteristics of spatial function layout of the study area through the street level.

2 Research scope, data and main functional indicators of urban streets

2.1 Research scope and data

(1) Research scope

The scope of this study is Xuhui District, Shanghai. Xuhui District is located in the southwestern part of Shanghai's central city. Xuhui is one of the central urban areas that completed the renovation of the old district in the early time. The railway, waterway, interchange and elevated roads in Xuhui District crisscross, so Xuhui is the main thoroughfare for the city center to enter and exit the districts including Minhang, Fengxian, Pudong New Area, Jinshan, Qingpu and other provinces such as Jiangsu, Zhejiang, Anhui, Guizhou and Guizhou. The interior construction and development of the streets system in Xuhui District is relatively complete, and the urban functions are more diverse and complex, which is more in line with the theme and requirements of this research.

Figure 1. Location map of Xuhui District, Shanghai

(2) Data source

① Road network: The road network of this study is drawn according to the main and secondary roads of Baidu map, and the node is interrupted for the research in the later GIS platform.

② POI map data: In the "Shanghai Street Design Guidelines", it is mentioned in the street function that "passenger transportation is mainly divided into four purposes: commuting, business, life and leisure." In the sixth chapter "Vibrant Street" suggests that functional compounding is one of the primary goals of street furniture[9]. The classification of street function types by Long Yu et al. is divided into eight categories after screening for POI: government agencies, transportation, commerce, education, corporate, residential, green space and others[4].

This paper sets up the street function evaluation indicators based on “Urban Land Classification

and Planning and Construction Land Use Standards (GB50137-2011)", and divides the collected urban multi-type facilities into five categories (see Table 1).

Table 1. POI data classification of urban facilities in Xuhui District, Shanghai

Category	Content
A (Public Management and Public Service)	Administrative institutions such as government agencies, libraries, hospitals, schools, etc.
R (residence)	Residential
B1 (commercial)	Commercial service facilities such as shopping malls, supermarkets, restaurants, bars, beauty salons, pedicure shops, etc.
B2 (business office)	Business office building
G (green space)	Parks, street greens, etc.

2.2 Main function indicators of the street

Measuring the vitality of the street and judging the functional nature of the street in the area are the two ultimate goals of building the street function indicator system. Details as follows:

(1) Street vitality indicators - Street function density, Street function mixing degree

Based on the analysis of five types of urban facility POI data, this paper first measures the street functional density and street function mixing degree, and then derives the first-level indicator—street vitality based on the above two secondary indicators.

① Street function density, defined as the ratio of the total number of POIs to the length of each street within the 50m buffer range on both sides of the street.

② Street function mixing degree, according to the definition formula of Ying LONG et al, which can be expressed as:

$$\mathbf{Diversity=-sum(pi\times lnpi),(i=1,...,n)}$$

In the formula, Diversity represents the functional mixture of a street, n represents the number of categories of the street POI, and pi represents a certain type of POI.

The proportion of POIs in the street is normalized. The normalization method is the ratio of the number of POIs in the street to the number of all kinds of POIs in the researching area.

(2) Determination of the functional nature of the street

Defining a certain type of POI exceeds 50% of the total POI in the street radiation range, then this type is the dominant function of this street; if each type of POI on the street is more balanced, there is no more than 50% of the POI, then the street is determined to be a mixed type function; if there is a street that does not judge the proportion of the POI type, it is determined to be of an unknown nature.

3 Street vitality measure

3.1 Analysis by different function types

Based on the five types of urban POI data, namely public service and public management, residential, commercial, business office and green space, the characteristics of the sub-function types of urban streets are analyzed. Measure the number of POIs of each functional type facility in Xuhui District, and use the GIS platform to form a thematic map, and then analyze the spatial layout and characteristics of different functional types of streets (Figure 2).

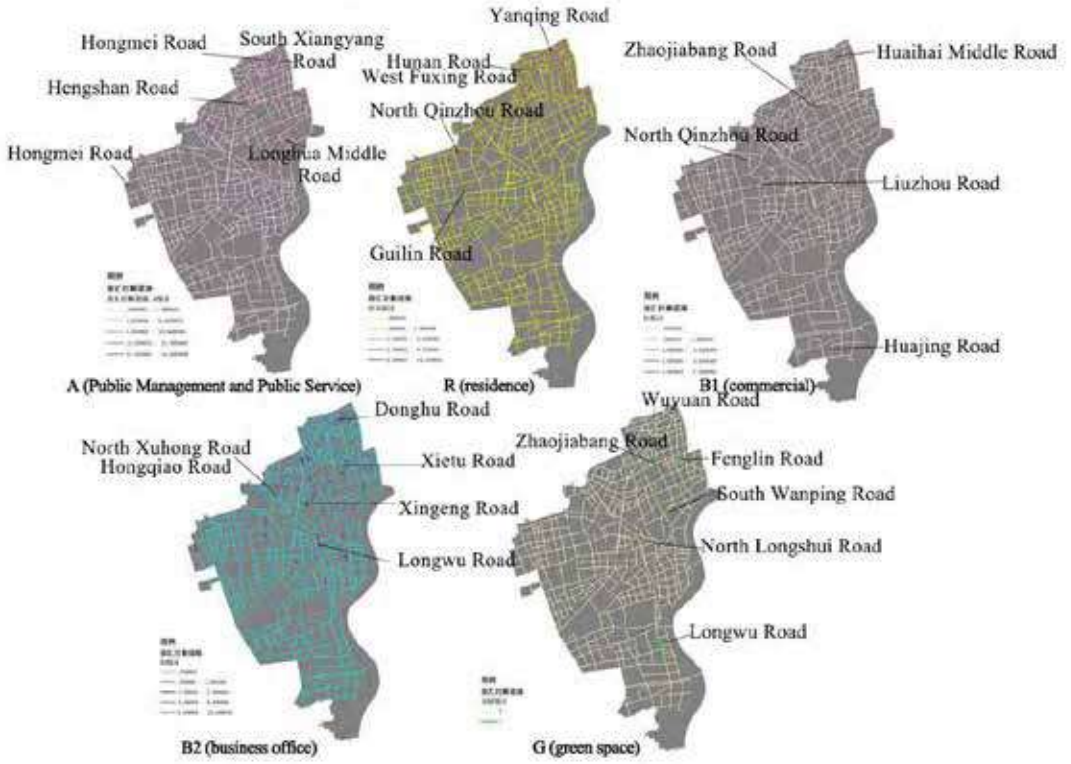

Figure 2. The quantity distribution of five types of facilities' POI in Xuhui District

(1) Public service and public management

The selection of public services and public management urban facilities in this study mainly includes administrative agencies, cultural facilities (schools and libraries), hospitals, etc. The analysis shows that in the Xuhui District as a whole, the number of public service and public facilities in the north is significantly larger than that in the south. The most prominent streets are Huaihai Middle Road, Xiangyang South Road, Hengshan Road, Longhua Middle Road and Hongmei Road. Among them, Hongmei Road is covered by Shanghai Xinmei Art Museum and some science and education cultural facilities in the Caohejing Development Zone. Hengshan Road is located in Xujiahui, Shanghai's vice center. It has relatively complete public service and public facilities. Longhua Middle Road The outstanding performance is due to the concentrated layout of various cultural facilities in Xuhui Riverside.

(2) Residence

The distribution of residential functions in the streets of Xuhui District is similar to that of public services and public facilities, mainly concentrated in the north; but at a more micro level, the streets with dense residential buildings are distributed in the periphery of public service and public facilities. The situation of planning layout in reality, such as Huaihai Middle Road.

(3) Commercial

The performance of Xujiahui streets' commercial functions is different from that of public service and public facilities which gather in the North District. From the entire Xujiahui area, each district has a prominent street in the number of commercial facilities: Zhaojiabang Road, Zhaojiabang Road is an east-west traffic trunk, with various types of commercial plazas and hotels, as well as Liuzhou Road in the Weihe area, and Huajing Road in the Huajing area. Forming the respective commercial centers of each large area meets the realistic requirements of planning.

(3) Business

The streets with more layouts of Xujiahui business facilities are offset to the south, including Longwu Road, Xuhong North Road and Hongqiao Road, Xingeng Road and Nandan East Road, and Donghu Road in the north. The Hongqiao Business District has a radiation impact in Xuhui District.

(4) Greening

The distribution of the streets in Xuhui District with a lot of greenery (parks) is mainly close to the Xuhui Riverside, forming a strip-shaped line. There are north to south including Wuyuan Road, Qijiatun Road, Fenglin Road, Wanping South Road, Longshui North Road and Longwu Road.

3.2 Street vitality measurement

The measure of street vitality is mainly considered from two aspects: the density of street functions and the mixing degree of street functions. Among them, ① street functional density refers to the ratio of the total number of various facilities within the 50-meter buffer zone on both sides of the street to the length of the street, ② the formula of the street function mixture is as mentioned above, Diversity=-sum(pi ×lnpi), (i=1,...,n).

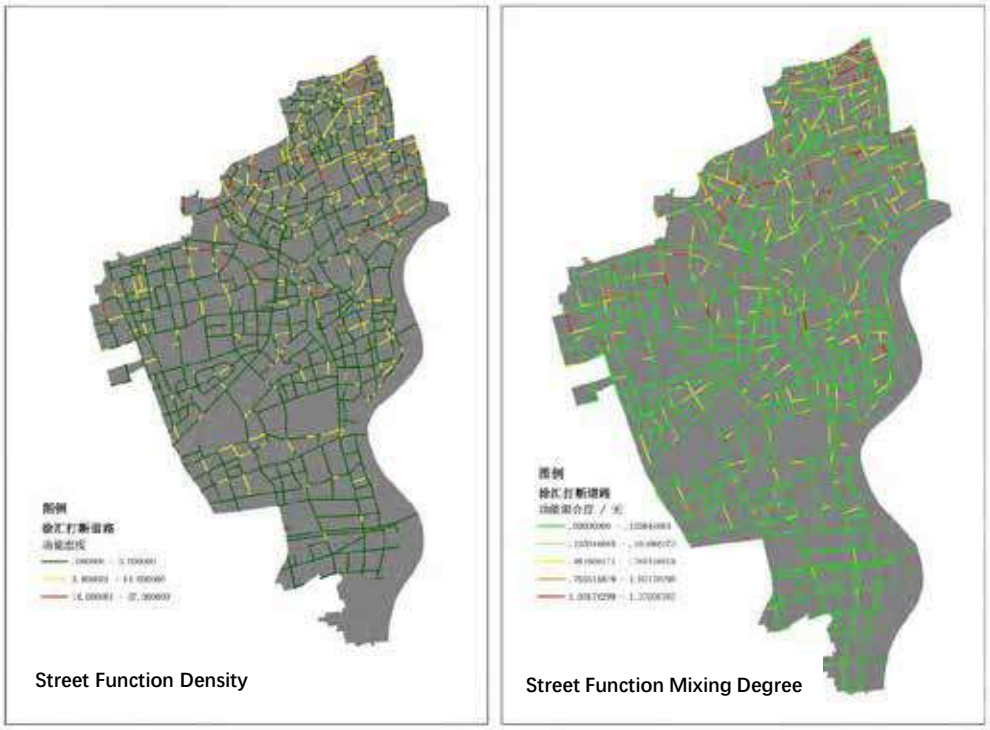

Figure 3. Street function density and street function mixing degree

The density and the mixing degree of street function map are formed by the superposition of five types of POI facility data.

Based on the above two sub-indicators, they are weighted and superimposed at a ratio of 50% each, and finally form a thematic map of street vitality and its nuclear density (Figure 4). From the maps, it can be found that Shanglin Road and Guilin Road around Huaihai Middle Road, Xuhong Road, Xietu Road and Caohejing Development Zone are all high-energy streets. From the analysis of the entire administrative area of Xuhui District, the northern and western parts of Xuhui District are areas with high street vitality, while the opposite is true for the southern part of Xuhui District

and the riverside area. Among them, the number of facilities in the southern part of Xuhui District (Huawei District) is very small, and the overall level is weak. The public service and public management and greening facilities in the Xuhui Riverside area perform well, but in residential, commercial and business areas. Functional development is weak, which directly reduces the function mixing degree of streets in the area.

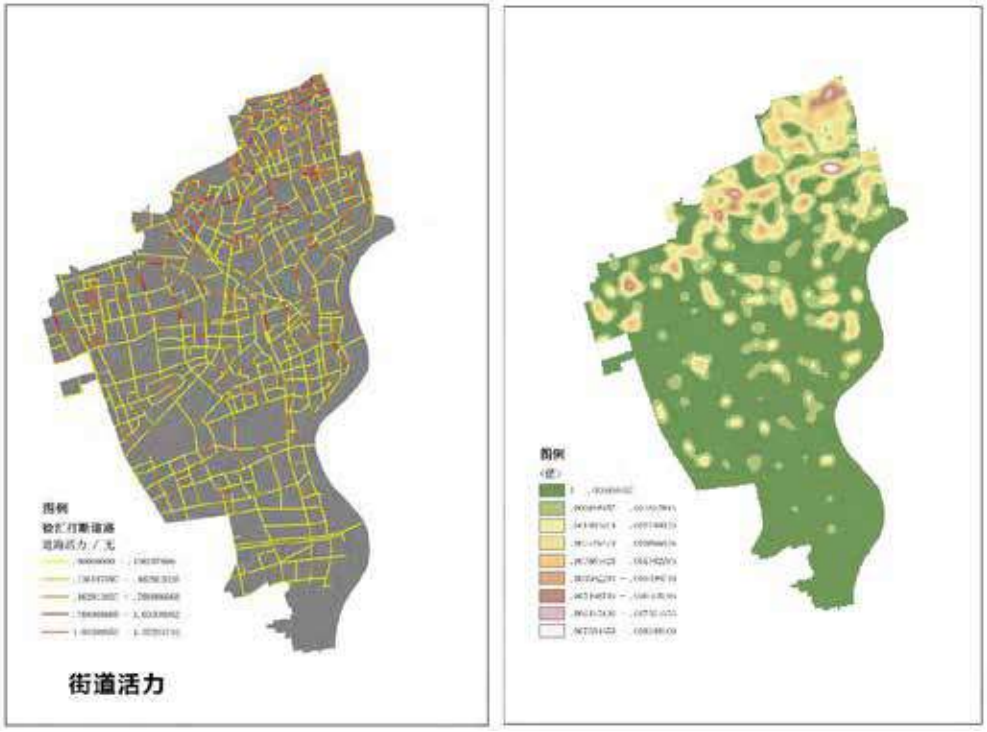

Figure 4. Street vitality and its nuclear density map of Xuhui District

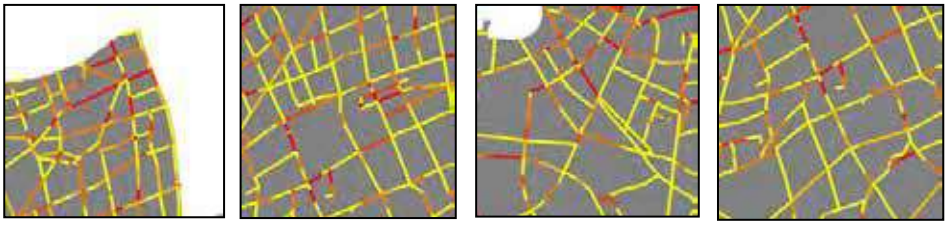

Figure 5. Street vitality at the intersection of Xuhui District

When breaking the road, this paper breaks a street into three sections according to the intersections at both ends, and finds that even in the same street, the streets at both ends of the intersection are more energetic (Figure 5). This aspect reflects that in the layout of various types of facilities in the city, the overall tendency is to arrange facilities around road intersections with better accessibility to obtain higher popularity and consumption.

4 Identify the functional nature of the streets

According to the criteria for determining the nature of urban streets mentioned above, the nature of the streets in Xuhui District is divided into four categories (there is no street dominated by the functional nature of green space), and a thematic map of street nature is established on the GIS platform (Figure 6). After excluding streets of unknown nature, the results showed that the number of the function nature of public service and public management streets accounted for up to 50.64%,

the residential nature of the streets accounted for 15.18% of the total, the commercial nature of the streets the least, accounting for 0.28%, the nature of business office The streets accounted for 31.21% of the total.

Therefore, within the scope of Xuhui District, the number of non-profit public service and public-managed streets accounts for the largest proportion, followed by business and commercial streets with offices and markets, and finally residential streets. It is found that in the Xuhui District, the public social property of the street is strong. Most of the street functions in Xuhui District are for the public service. The number of streets dominated by residence is not large. In addition, there are very few streets dominated by the nature of commercial facilities. This shows that in the configuration of facilities on both sides of the street, the number of facilities mainly based on commercial shopping consumption is very small. This function is usually associated with other functions such as office and residence. Such as the use of configuration, such as Huaihai Middle Road K11 and other commercial office square development model.

At the level of the inner area of Xuhui District, the streets of various natures in the north are more balanced and more complex in the south. This is related to the development of the southern district, and various facilities, especially commercial and business office facilities.

Figure 6. The functional nature of the street

5 conclusions and discussion

From the perspective of street function, this paper conducts quantitative measurement and judgment on the street vitality and street functional nature of Xuhui District in Shanghai through the analysis of POI data of various facilities in the city. This paper mainly uses the GIS big data

analysis method, which is different from the traditional method based on spatial syntax analysis of street vitality, and it is more explanatory than the latter[4]. At the same time, this study aims to construct a street vitality assessment system at the urban level. The street function density and street function mix are the two main sub-indicators of street vitality; the two sub-indicators are based on five categories (public service). It is superimposed on POI data of different cities with public management, residence, business, business office and greening.

(1) Main conclusions

This study mainly draws four conclusions:

① In the scope of Xuhui District, the street functions under different types of POI data are different. The streets with outstanding public service, public management and residential functions are mainly concentrated in the north. And all small areas have several outstanding performance commercia streets. Streets that performants better in commercial are shifted to the south part of Xuhui District, and the streets with outstanding greening functions are distributed along the riverside.

② In the overall vitality of the street, the streets in the northwest of Xuhui District are adjacent to Changning District and Jing'an District. On the contrary, the streets in the south of Xuhui District and the riverside are generally weak, and the number of facilities in the city is small and the mixing is low. The overall development is not perfect.

③ At the local level of vitality of the street, the street sections at the intersection are more dynamic than the middle section in the street.

④ Through certain evaluation indicators, the functional nature of the streets in Xuhui District is identified. It is analyzed that the streets with the same public service and public management nature in Xuhui District have the highest proportion, followed by the commercial and business office streets, and finally the residential streets; therefore the function of streets' in Xuhui district of the district has strong public attributes and a high service capacity for the public.

(2) Disadvantages and improvements

In this study, only Xuhui District of Shanghai was selected as a single research object. Without horizontal comparison, other objects should be added to the future research to conduct comparative analysis of multiple cases, making the nature of the research object more prominent.

At the same time, the article has not tested the relevance of the segmentation type of POI data and the correlation between various POI data and street function vitality indicators. In the future, we can further study the impact of various POIs on the final street vitality index and conduct in-depth analysis.

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