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Research on Spatial Vitality of Historical and Cultural Blocks Based on Space Syntax and POI Data

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Abstract. As an important way of urban sustainable development, the renewal of historical and cultural blocks mostly depends on perceptual cognition and lacks the guidance of quantitative analysis. This study uses space syntax and POI data to analyze the spatial structure of Guangzhou 's traditional central axis historical and cultural blocks, predict the volume of people and use the heat map for verification. Through the coupling analysis, the relationship between spatial structure, tourist attraction distribution and commercial distribution is revealed, and the problem space and potential space are identified. The results show that: the overall accessibility is high, but the crossing degree, Intelligibility (R^2 is about 0.3) and synergy are generally low (R^2 is about 0.17), reflecting the lack of identifiability and attractiveness of streets; Accessibility and commercial network distribution are basically coupled (spatial overlay analysis shows that 65% of high-density commercial POIs are distributed on the streets with the top 30 % of integration), but there are some dislocations; The streets such as Dama Station, Education Road, Gaodi Street and Taikang Road have strong commercial development potential, and some streets connecting Beijing Road have the risk of excessive traffic. Based on the above findings, the study proposes a classification space optimization strategy to provide a scientific reference for the renewal and vitality improvement of historical blocks.

1 Introduction

Historical and cultural districts serve as core carriers of urban cultural heritage. However, they frequently face challenges in spatial structural imbalances, functional format conflict, and congestion in high-traffic areas. Located in the core area of a megacity, the traditional central axis historical and cultural block of Guangzhou has dense historical relics and diversified business forms. The maintenance and improvement of its spatial vitality and quality have important reference value for the sustainable development of similar blocks in China.

In the existing research, the research on spatial vitality has gradually shifted from qualitative description[1-3] to empirical research on multi-source data. Liu et al. (2022) used space syntax to simulate the structural potential of streets in historical blocks but did not fully verify its relationship with actual vitality distribution[4]. Liu Sili et al. (2023) integrated population heat and POI data to construct a spatial form and vitality measurement system[5]. Yao et al. (2025) analyzed the coupling between spatial structure and commercial function configuration through spatial syntax and POI data, and applied it to the study of historical and cultural blocks[6]. Although the above studies have strongly confirmed the statistical correlation between spatial structure and commercial distribution, there are still obvious gaps in the verification and spatial interpretation of their coupling. To fill this research gap, this paper takes Guangzhou 's traditional central axis historical and cultural blocks as an empirical case. By using spatial syntax and POI data, and introducing crowd heat data for verification, it adopts spatial overlay as the core method for analyzing the coupling relationship. It precisely depicts the matching and displacement relationships between the spatial structure and commercial services, scenic spots in the geographical space, identifies the commercial potential space and traffic congestion problem space, and proposes classification strategies for enhancing the vitality of the districts.

2 Research Subjects and Methods

2. 1 Research area

The study area is the traditional central axis historical and cultural block in Guangzhou, which is located in the center of the historical city of Guangzhou and the center of the cultural core area of Beijing Road. It covers an area of 82.7 hectare, extending south to the Pearl River, north to Zhonghai Road, west to Jiefang Road, and east to Zhongshan Fifth Road, Xiaoma Station, Beijing Road and other streets (as shown in **Figure. 1**).

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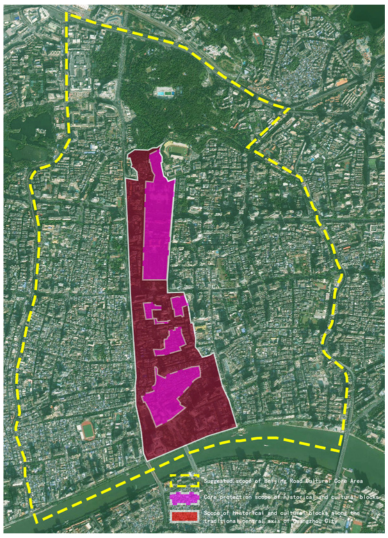

Figure. 1. Research area.

2.2 Research Data and Methods

The data used in this study include POI data, road network data, Baidu city heat map data, etc. Satellite images were obtained through a map downloader, and combined with literature materials, field research, etc., the street and alley axes were selected and used for spatial analysis in the DepthMap10.0 software. The city heat map data was sourced from Baidu Maps and was used to verify the prediction results of the spatial syntax on the flow of people. Based on network data such as Gaode and Baidu Maps, POI data for the study area in December 2024 were crawled, and verified and organized through field research, which was used for kernel density analysis.

To conduct a spatial interpretation of the coupling mechanism between the spatial form and functional distribution of the urban area, this paper adopts a combined approach of global statistical modeling and local spatial identification. This includes quantitatively analyzing the global coupling of core spatial syntax indicators (such as synergy and intelligibility) using a univariate linear regression model, and conducting a local coupling spatial diagnosis by spatially superimposing the high-value spatial syntax layer (high integration) with the high-density functional distribution layer (POI hotspot area). This is to precisely identify the areas with high spatial and functional synergy, and diagnose and classify different types of coupling misalignment zones.

3 Analysis of Current Spatial Conditions

3.1 Space structure

3.1.1 Integration and synergy

The depth value refers to the shortest topological distance between two nodes in the spatial syntax, indicating the ease of access of the nodes in the spatial system. Integration refers to the sum of the distances from a certain node in the system to other nodes, reflecting the degree of connection and accessibility among various spaces in the system, and can further reflect the attractiveness of this space for transportation. It is positively correlated with spatial accessibility and compactness.

From the perspective of overall integration degree (as shown in **Figure. 2**), the numerical values range from 281.7 to 1241.7, with an average value of 813.38. The overall accessibility is relatively good. The spatial depth shows a trend of decreasing from the main urban roads around to the traditional central axis, indicating that the streets along the traditional central axis have better accessibility. The streets on both sides of Zhongshan Fifth Road, such as Xiaoma Station, Damao Station, and Guangzhou Uprising Road, are directly connected to the boundary roads, and have the highest accessibility. They are important streets that connect the historical and cultural districts within and outside the traditional central axis of Guangzhou. While the streets in the eastern area, such as Gao Di Street, Daxin Road, and Zengsha Street, Taipingsha, have the lowest accessibility. They are generally small alleys used for residents' daily travel. Referring to the walking range of pedestrians, a local integration degree analysis was conducted with R = 1000m, and it was found that the surrounding areas of Xianhu Street 1 and Xianhu Street 2, Xianhu Street, etc. have a high degree of integration. This reflects the close connection of the walking space within the walking range, continuous space, and high accessibility. It indicates that these spaces exhibit strong spatial centrality at the walking scale. The streets undertake the function of connecting the traffic of nearby neighborhoods and are the commercial potential centers of local districts.

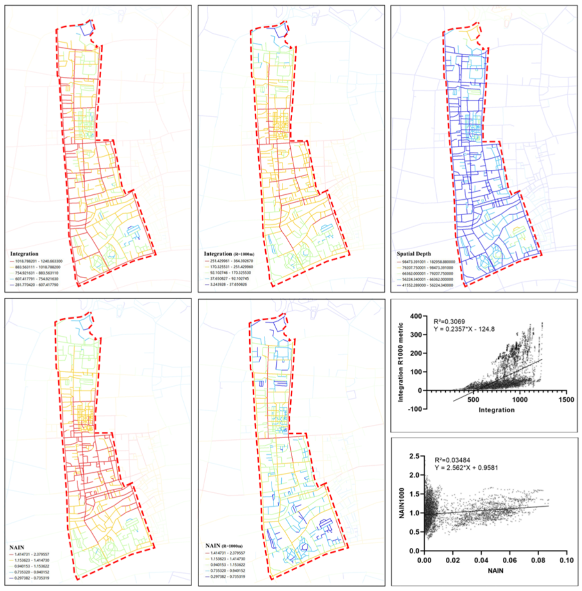

Figure. 2. Analysis of Integration and Synergy.

In order to further eliminate the influence of the number of line segments on the analysis results of the accessibility of the study area, the study selected the standardized angle integration degree (NAIN) for in-depth analysis (as shown in **Figure. 2**). At the walking scale, the Education Road, Jixiang Road, and Da Ma Station undertook the main transportation in the surrounding area. The areas around Lianxin Road and Zhongshan Fifth Road still showed strong centrality and had good development potential.

The regression analysis was conducted with global integration degree as the x-axis and local integration degree (R = 1000m) as the y-axis. R^2 can be regarded as the degree of synergy (as shown in **Figure. 2**). When $R^2 > 0.5$, it indicates that the research scope has a relatively concentrated core axis; if $R^2 \leqslant 0.5$, it means that the position of the core axis within the research area is relatively dispersed. The regression analysis was performed on the integrated degree data before and after standardization, and a univariate linear regression model was constructed. The results were $R^2 = 0.3069$ and $R^2 = 0.03484$, indicating that the synergy degree between the local space and the overall space within the research area is relatively low. The internal structure of the blocks shows a multi-core characteristic, and the effect of different blocks integrating into the overall block is poor. It is necessary to enhance the integrity of the local blocks and the overall space.

3.1.2 Choice and Intelligibility

Choice refers to the number of times a spatial node appears at the shortest topological radius, reflecting the potential of this space to attract through-type traffic.

Overall, the global selectivity is low, and the local selectivity is not high . It is difficult to attract through-type people, and the linkage ability with surrounding spaces is weak (as shown in **Figure. 3**). Considering the analysis results of integration degree, although most roads in the study area have a high integration degree, the selectivity is low. That is, although the accessibility of the streets is high, it is not the intention choice for people to pass through. The street with the highest global selectivity is Zhongshan Fifth Road at Park Front Station, followed by Jiangnan Avenue North, Guangzhou Uprising Road, and Dongfeng Middle Road. This indicates that Zhongshan Fifth Road in front of People's Park attracts the main traffic flow, while Jiangnan Avenue and Jiangnan Avenue on the traditional axis of Guangzhou attract the secondary traffic flow. At the pedestrian scale (R = 1000m), the street with the highest local selectivity is Education Road, Lianxin Road, and Zhongshan Fifth Road, followed by east-west side roads such as Xihu Road and Tai Kang Road. This shows that in daily life, Education Road, Xihu Road, Tai Kang Road, and Lianxin Road are the streets that residents frequently pass through.

To further eliminate the influence of the number of line segments on the results, the normalized angle selection degree (NACH) of the study area was adopted, which is a type of thoroughfare analysis (as shown in **Figure. 3**). At the walking scale, the east-west streets such as Xihu Road, Huifude Road, Dalong Road, Gaodi Street, and Taikang Road all have high through-type traffic, indicating that the east-west roads have the potential to create a rich variety of commercial types at the walking scale.

Intelligibility is a variable that describes the correlation between local integration and overall integration, and is used to measure whether the local space and the overall space are unified. The higher the intelligibility, the stronger the sense of spatial order, and the better the recognition and discrimination. Regression analysis is conducted with the connection value as the x-axis and the global integration degree or NAIN as the y-axis (as shown in **Figure. 3**). The intelligibility is determined by the value of R^2. When $R^2 > 0.5$, it indicates that the space is relatively orderly and has strong discrimination, which is conducive to understanding the overall space through the local space; if $R^2 \leqslant 0.5$, it indicates that the connection relationship between internal spaces is poor, and it is difficult for individuals to form a cognitive system of the overall space through the local space[7]. The intelligibility R^2 with the integration as the dependent variable is 0.1735, and the intelligibility R^2 with the standardized angle integration degree as the dependent variable is 0.06759. Both are far less than 0.5, indicating that the street orientation of the traditional central axis historical cultural district in Guangzhou is poor, making it difficult to recognize the overall district through the local street space, and it is prone to losing direction and getting lost within the street area. Moreover, affected by historical factors, the dead-end roads and T-shaped roads within the district are relatively common, the road connectivity is poor, the overall spatial distribution of the streets is irregular, the connection degree between local nodes and the spatial system is poor, and there are situations of non-integration. This is not conducive to the commercial development of the historical cultural district.

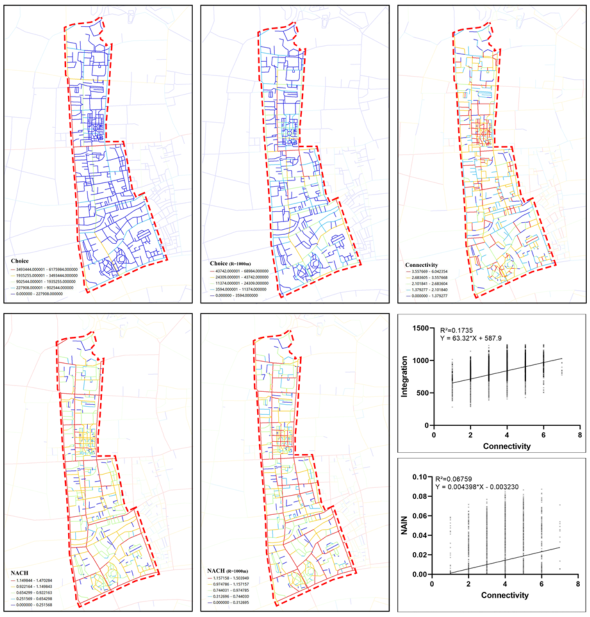

Figure. 3. Analysis of Choice and Intelligibility.

3.2 POI Analysis

There are numerous historical and cultural heritages within the block area, totaling 121 historical heritages and 91 traditional streets and alleys. Based on the POI core density analysis of tourist attractions (as shown in **Figure. 4**), it can be seen that tourist attractions are distributed in clusters. In the Beijing Road Cultural Tourism Area, they show a high-density aggregation state. In addition, there are no high-density tourist attraction clusters in the study area. Instead, they are mostly scattered.

Based on the research on the commercial business types of historical and cultural districts, the commercial service POI data were classified and analyzed (as shown in **Figure. 4**). Kernel density analysis was conducted on the retail shopping and dining service POI data. From an overall perspective, commercial services show the characteristics of being concentrated in a small part, scattered in some areas, and having an uneven overall distribution. The commercial service outlets are concentrated in the Beijing Road Cultural Tourism Area, forming a high-density commercial cluster. Moreover, in the area centered around the Basilica of St. Francis and Wanling Plaza in Guangzhou, a relatively high-density commercial cluster has also been formed. However, the distribution of the outlets within the surrounding urban villages' internal streets and other streets is relatively sparse. From the classification perspective, the dining outlets show a single-core aggregated distribution feature, concentrating in the Beijing Road Cultural Tourism Area, presenting the highest density at the center of Beijing Road Pedestrian Street. The density of the outlet clusters decreases radially from the center to the periphery. Shopping commercial outlets also exhibit a distinct clustering feature, presenting a point-like aggregation centered around Beijing Road and the Basilica of St. Francis, with the density radiating outward. Overall, the mixed business types are concentrated in the core area of Beijing Road and its surrounding areas, such as squares, etc. These areas have good locations, large traffic flow, and are places where residents' lives and tourists' travels gather.

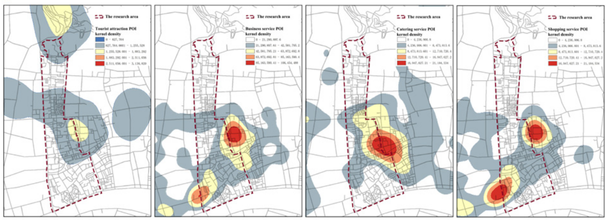

Figure. 4. POI kernel density analysis

3.3 Heat map verification

The study selected the period from 10:00 to 20:00 on both weekdays and holidays, and captured the Baidu heat maps every two hours (as shown in **Figure. 5**). Based on the analysis of the temporal and spatial changes of the heat maps, it can be concluded that the overall flow heat is significantly higher than that of the surrounding areas, and it is distributed in a linear pattern running east-west along Zhongshan Fifth Road. This indicates that the areas along Zhongshan Fifth Road have gathered the main traffic flow of the traditional central axis blocks. In addition, there are certain areas within the space nodes such as the Zhongshan Memorial Hall, the Ancient Buddha Temple, Haizhu Square, and the Guangzhou Liberation Memorial Statue where there are local high heat values, and there are also long-lasting high heat values, which indicates that these space nodes can gather a large amount of people flow from surrounding blocks and attract people to stop and stay. This is consistent with the results predicted by the spatial syntax analysis, verifying the rationality and correctness of the spatial syntax analysis results.

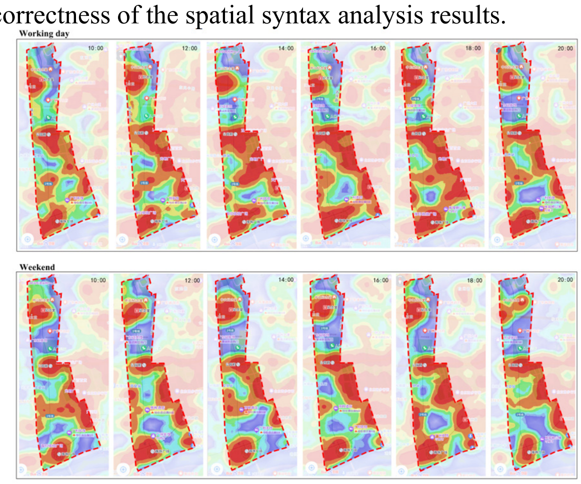

Figure. 5. Population heat distribution map.

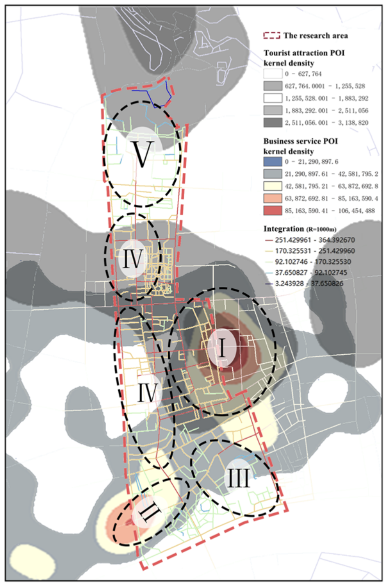

Figure. 6. Coupled analysis of integration and kernel density.

4 Coupling analysis and strategies

By superimposing the analysis results of street integration degree with the core density of POIs (points of interest) related to commercial services and tourist attractions, a more intuitive picture can be presented showing the connections between the spatial characteristics of the streets (as shown in **Figure. 6**), the distribution of business types, and the distribution of attractions. The commercial business type distribution in traditional central axis historical districts is closely related to the distribution of attractions. 65% of the high-density commercial POIs are located on the streets within the top 30% of integration degree, indicating that most business types are distributed on streets with higher accessibility. The overall coupling degree is strong, but there are also some local differences. Therefore, based on the street and alley spatial accessibility and business type density, five types of characteristic spaces are classified: high accessibility - high business type distribution, high accessibility - low business type distribution, medium accessibility - medium business type distribution, low accessibility - high business type distribution, and low accessibility - low business type distribution. And it can be organized into a problem space and three potential space categories, and specific optimization strategies can be proposed for each category:

4.1 Problem Space

4.1.1 High Tourist Attractions - High Commercial Services - Low Accessibility Space

This type of space is mainly located on the tourist hotspots along Beijing Road. There are issues such as insufficient street space, excessive tourist volume, and reduced visiting experience. Enhancing street connectivity, using small alleys with low accessibility - low business type and medium accessibility - medium business type to connect the main streets, increasing walking route options, and dispersing the dense flow of tourists in the narrow streets. At the same time, management regulations should be introduced to strictly limit commercial encroachment on street space to avoid affecting tourist passage and exacerbating congestion; ensuring the openness of spaces near important nodes such as intersections and bridge sides, avoiding setting up dining and selling windows in areas with high pedestrian traffic on streets and intersections, and strictly restricting the parking of non-motorized vehicles such as bicycles.

4.2 Potential Space

4.2.1 High Tourist Attractions - Low Commercial Services - Low Accessibility Space

This type of space is mainly located in the southern area of Yuexiu Park. There are issues such as lack of business types, insufficient commercial vitality, and lack of visiting routes. Low business type distribution can increase the vitality of back alleys. Choosing business types such as cafes, restaurants, and homestay hotels for layout can meet the conditions of such commercial spaces, such as elegant environment, rich surrounding business types, and guaranteed pedestrian flow. It can also serve as the "backstage space" of the historical district, preserving more authenticity of residents' lives, and facilitating the development of in-depth experience tourism.

4.2.2 Low Tourist Attractions - High Commercial Services - Low Accessibility Space

This type of space is mainly located along the Baijiang section of Jiefang South Road. There are issues such as commercial aggregation attracting tourists and poor pedestrian system. High business type distribution in alleys should maintain good street quality, control the density of business types, ensure residents' service business types, and encourage sharing. Try to separate logistics and commercial services to reduce the passage of freight and delivery vehicles.

4.2.3 Low Tourist Attractions - Low Commercial Services - High Accessibility Space

This type of space is mainly located on Guangzhou Yige Road. As a core street, it can gather tourists, and the presence of tourists and residents can generate high commercial potential. Increasing experience-based commercial, cultural creative commercial, etc., to serve tourists, through creating hotspots and nodes of space, attracting tourists, enhancing the penetration of the space used by tourists, increase the recognizability between different cultural areas and attract pedestrian flow.

5 Conclusion and Outlook

This paper interprets the street spatial structure and business distribution of the historical and cultural blocks along the traditional central axis in Guangzhou through spatial syntax and POI core density analysis. It identifies five different types of streets and proposes optimization strategies for the problems and potential spaces of low accessibility - high business street segments that are overly commercialized, and high accessibility - low business street segments that are resource-inefficient: First, leverage the advantages of each street to connect the blocks and exert the cultural linkage effect; second, optimize the distribution of businesses, balance tourism and residence, and encourage sharing; third, smooth the transportation system and create a pedestrian-friendly tourist area. However, this paper also has some shortcomings. For instance, spatial syntax cannot fully accurately reflect the dynamic and changing spatial characteristics, and the crowd heat is restricted by the time of collection and the level of detail. This research focuses on the content of physical space such as POI facility distribution and spatial characteristics, lacking a comprehensive study of social non-material space such as culture and community governance with multi-factor coordination. In the future, this part will be improved.

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