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Map and Network Urban Analysis: A Case Study on Guangzhou Nanhuaxi Street Historic District's Urban Form

Hong LI[a, b, 1] and Xiaofeng WANG[c]
[a] *Guangdong Mechanical & Electrical Polytechnic, Guangzhou 510515. lehon_1234@126.com*
[b] *Fine Art and Design, Krirk University, Bangkok, 10220. lehon_1234@126.com*
[c] *Fine Art and Design, Sunny Partnership Space Planning co., ltd, Guangzhou, 510515.*

Abstract. This study aims to explore the application of map and network urban analysis methods in urban form research, with a focus on the process and outcome of urban reorganization, using Guangzhou Nanhuaxi Street Historic District as a case study. By adopting map illustration and network urban analysis methods, this study reveals the characteristics and functions of the urban form of Guangzhou Nanhuaxi Historic District, in order to provide new perspectives and methods for urban planning and design. The study is analyzed in terms of the four elements of the network city: node connections, density, boundaries and accessibility. The form of development of this neighborhood in the form of three parcel clusters is analyzed in conjunction with historical documents. There is a positive relationship between the diversity of street types, the direction of pedestrian flow and the flow of goods and information, and the nodes in the system. The "fixed line" in the historical urban form determines the development and evolution of the urban form. This provides new perspectives and methods for urban planning and design. The results of the study help us to better understand the laws governing urban development and provide useful experiences and methods for future urban planning and design. Meanwhile, it offers new perspectives and insights for academic research and practical applications in the field of urban morphology.

Keywords. Map Analysis, Network Urban Analysis, Guangzhou Nanhuaxi Street Historic District's, Urban Form

1. Introduction

With the acceleration of urbanization, the traditional urban organization is undergoing a profound change, and urban spatial reconstruction has become a hot issue in current urban research. As a historical and cultural protected area in Guangzhou, the historical area of Nanhuaxi Street is also facing functional transformation and spatial reorganization in the process of urban change. Therefore, how to protect the historical lineage and at the same time carry out a reasonable update to achieve the community function enhancement and spatial optimization is the key issue facing of Nanhuaxi Street.

[1] Corresponding Author: Hong Li, lehon_1234@126.com

As an intuitive way to express urban form, map illustration can effectively present the evolution of urban space. Combined with the spatial analysis method of network theory, it can quantitatively analyze the correlation and structural characteristics of the elements in the city. The combination of the two methods applied to Nan Huaxi can reveal the urban organization of the region and provide theoretical support for its spatial reorganization. In this study, a combination of map illustration and network spatial analysis is used to analyze the urban morphology evolution process and potential spatial logic of Nanhuaxi neighborhood in Guangzhou, and to provide a theoretical basis for future functional renewal and spatial optimization on the basis of summarizing the historical evolution law of the area. The significance of this study is to enrich the application of graphical and network analysis in urban geography research, and to provide reference for the transformation of the old urban area of Guangzhou.

2. Literature Review

2.1. Map illustrations and networked cities

A city is a complex artificial construct, and this complexity can be seen as objects that influence each other being arranged in different ways on different levels. In order to analyze this complex urbanity in a simple and effective way, an effective way is to visualize its basic features and functions, and map illustration will show its power as an effective tool for expressing urban space. David Harvey calls a simple reproduction of reality a "model", and maps are one type of "model", which can be called map models. "When a model is developed to the point where it can be used to explain all relevant types of behavior, it becomes what can be called a theory." "To seek an explanation is to seek a theory. A theory is a system of representation who can be seen as a set of sentences expressed in specialized vocabulary, a language." (David Harvey, 1977) The coding of map symbols accomplishes such a task, as a language that can be articulated to seek an explanation. Thus the theoretical perspective of the "networked city" was born. This theory views the city as a network of nodes and connections, where each node is a carrier of urban functions and the connections represent the relationships and flows between these functions. Through this network perspective, we can understand the complexity of the city in a more systematic way, organize the seemingly chaotic urban phenomena into an orderly structure, and predict future trends. In addition, the theory of the "network city" emphasizes the interconnections and influences between and within cities, thus providing a new perspective to understand the internal dynamics and external relationships of cities.

Map illustration and web-based urban analysis methods are used in a variety of fields, including urban planning, social surveys, and environmental studies. Cartography is the art of making maps and has evolved with technology to help us understand our place in the world, analyze location relationships, and reflect on the impact of geography on our daily lives. Such methods include graphic ground maps, street maps, and Nolli type maps (Liu, X., Derudder, B., & Taylor, P, 2014) Thematic map visualization techniques are also used to derive insights from data, tell a powerful story, or to better understand the world around us. Dragica (2016) discusses the importance of having architectural dense complex networks in various scientific fields such as urban science and presents a

methodology for quantifying road network complexity and determining building density using matrix pixel analysis and kernel distribution, using the city of Belgrade as an example. Agust Gudmundsson1 & Nahid Mohajeri2,3 (2013) focused on the orientation, length, density and network evolution of street networks in 41 cities in the United Kingdom, revealing the evolution and organization of the street network and highlighting the resilient and self-organizing structure of the street network.

2.2. Urban Reorganization of Historic Districts

Lu (2008) proposes a conceptual framework for understanding spatial change in Chinese cities, emphasizing the role of institutional frameworks, economic and urban policies, and structural shifts in the economy.Cheng (2017) examines the transformation of development zones into functionally sound cities in the Chinese context, emphasizing the processes of comprehensive urban planning and urban renewal.Shouhon (2003) analyzes the impact of urbanization and coexistence of suburbanization, emphasizing their impact on spatial change. Finally, Li (2023) explores the structure and restructuring of urban networks in Northeast China, emphasizing the need for collaborative urbanization. Li and Feng (2021) selected nine street offices (sub-districts), including 14 historic preservation districts in Old Liwan, and examined urban shrinkage through population growth rate, population aging, economic growth, and public life vitality, and explored the relationship between Old Liwan and changes in the city's development strategy, preservation policies, and urban renewal actions. Together, these papers provide insights into the urban reorganization of Guangzhou's South China West Street.

3. Methodologies

3.1. Take Guangzhou Nanhuaxi Historic District as an example

This study takes the Nanhuaxi historical district as a case study. When the focus of research is on contemporary phenomena, the case study method is deemed a method of choice. The Guangzhou Nanhua West Street historic district is situated in the important Chinese city of "Guangzhou". It was established during the Thirteen Factories era in the Qing Dynasty. The district has undergone the rise and decline of the merchants of the Thirteen Factories era, urban planning transformations during the Republican period, and industrialization in the early years of the People's Republic of China. These transitions have induced changes in its urban form, economic dynamics, and social structure, making it a compelling case for studying urban reorganization.

Figure 1. Morphological Evolution of the South China West Historic District.

The scope of Guangzhou's Nanhuaxi Street Historical and Cultural Protection Area is as follows: To the east, it reaches Baogang Avenue; to the west, it extends to Hongde Road. To the south, it is bordered by alleyways such as Qixing South, Longqing North, and Xinglong Lane, while to the north, it adjoins the Pearl River. The district stretches 950 meters from east to west and is 560 meters wide from north to south, covering a planned area of approximately 45.17 hectares. Nanhuaxi mainly adopts a neighborhood system, characterized by relatively low-rise buildings with high density, representing traditional residential forms. The northern side of Nanhuaxi Street belongs to the riverside residential area and integrated development zone. The buildings in this area face the Pearl River, with the Binjiang West Road and the Zhoutouzui area at its core, which is the traditional maritime business center of Guangzhou. Historically, the maritime industry of the Pearl River facilitated the commercial prosperity of this region.

Before starting the map diagramming work, it's essential to define the observation boundaries. This step incorporates the project boundaries as a part of the network, aiming to connect the system's interior with its exterior. Christopher Alexander believed that "a city is not a tree, but a network." Sifertis (1997) emphasized that urban systems shouldn't be hierarchically categorized; instead, they must be understood as networks with nodes.

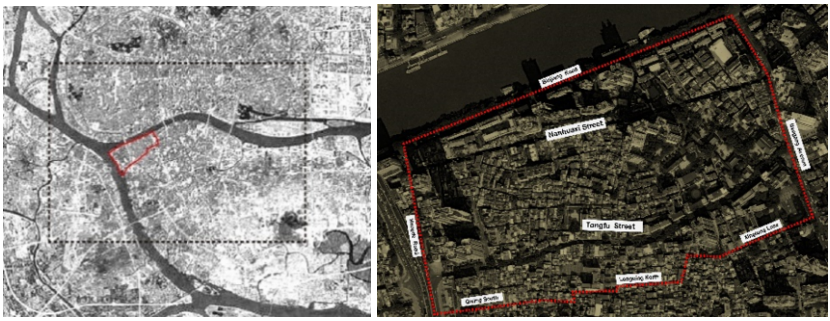

Figure 2. NanHuaxi Street Historic and Cultural District Area Boundary.

3.2. Data collection and methodology

This study primarily adopts archival research and visual documentation as the main methods of data collection. Archival materials include government planning reports, local literature, and vector map data. The vector map data provide quantitative data such as building floor counts, individual building area, facade length, and street dimensions. Site-specific characteristics are documented through field surveys using visual recording techniques, with photographs capturing features of the buildings, entrance locations, and other information. Table 1 summarizes the morphological elements and their data sources used in the study. Satellite maps are sourced from GOOGLEMAP, and vector maps are compiled by the Guangzhou Urban Planning and Design Survey Research Institute.

Table 1. Data sources for morphological elements

Element	Composition of data	Source of data
Nodes, connecting lines	Number of floors of the building Type of building	Vector map data
Density analysis	Number of floors of buildings street scale and their distribution	Vector map data

Boundary analysis	Building monolithic form	Vector map data \ historical documentation
Accessibility Analysis	Building Street Scale\Building Functional Types	Map Data\Research Photos

3.3. Data analysis methods

The methods of analyzing the data include map graphical analysis with node and connectivity analysis, density analysis, boundary analysis, and accessibility analysis.

3.3.1. Analysis of nodes and connecting lines

In the analysis of network structures, nodes, links, and boundaries of the system play a decisive role in shaping the network formation. Morphologically, nodes are defined by the overlap of residential areas and infrastructural zones, creating hubs of intense human and commodity concentration. Hence, nodes represent the flow of people, goods, and information. Links signify the movement of people, goods and information between two nodes. Nodes and links are two crucial factors influencing the network system.

In the following discussion, “system” serves as a metaphor for the Nanhuaxi historical district. Within this regional system, most are 2-3 story traditional residences (as shown in Figure 5), among which are structures from the late Qing Dynasty and the early Republic of China, including the mansion of the Thirteen Hong merchants from the Qing era, known as the "Pan Family Mansion," as well as villas owned by businessmen from the Republic period. Looking at the nodes and links within this system, the distribution of nodes is notably uneven. In the late Qing Dynasty and early Republic period, there was a bustling market near the Shuzhu Bridge (as shown in Figure 3). However, as the city developed, the Shuzhu Chong was covered and turned into an underground channel, causing the market to relocate. It moved south of Tongfu Road along the line of the Shuzhu Chong, becoming the area in Nanhuaxi with the highest concentration of business and information exchange. This area evolved into a primary node within the system. Secondary nodes of commerce and information exchange formed around the Nanwu Middle School and the Jinsu Garden area (as shown in Figure 6). Due to the "pavilion-style" high-rise residential building type in the system's living areas, there's essentially no provision for nodes of information or commercial exchange, resulting in the loss of links in the residential areas. If more nodes could be established in the residential areas west of the Shuzhu Chong, thus increasing the links between nodes, Nanhuaxi has the potential to form a comprehensive network structure. This could enhance people's overall spatial perception of Nanhuaxi and rejuvenate the vitality of this historic district.

Figure 3. Shu Zhu Chong on Maps and in Export Paintings

Figure 4. street and alley map

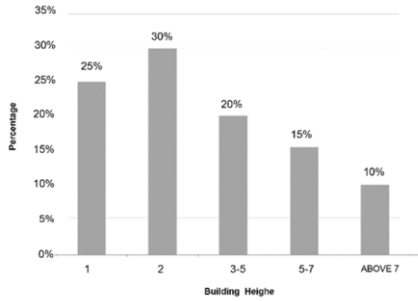

Figure 5. Statistical chart of the number of floors in a building

Figure 6. Network Nodes and Connectivity

3.3.2. Density analysis

3.3.2.1. Particle density

In this context, 'grains' serve as a metaphor for architectural plots. The density of these grains can quickly and accurately manifest specific issues of a particular area at a designated location. The type of grains and the manner of their composition reveal the uniqueness of an area. However, the distinctiveness of a region is not static; it often changes with the evolution of time. On some level, it can reflect traces of characteristics that once existed, distinguishing them from other areas.

In the illustration below, lighter shades represent areas with low grain density, while darker shades represent areas with high grain density. Within the red circled area in the illustration, a 'pavilion-style' high-rise commercial residential zone emerges (as indicated by the red circle in Figure 7). It evidently disrupts the historical street and alley texture, resulting in heterogenous spaces that don't harmonize with the surrounding environment. Historical documentation reveals that to the left of this area was the bustling 'Shuzhu Bridge' from the mid-Qing Dynasty. However, today, due to the emergence of these heterogenous plots, the continuity of the plot texture is severed. This disruption is not only a destruction of the historical street fabric, but it also creates spaces that are out of sync with the surrounding environment. This area is close to Shuzhu Bridge and precisely where the entrance to the Wu Family Ancestral Hall is located. If one were to utilize mapping systems to analyze cities, adopting a perspective that respects cultural and

historical continuity in urban development, designs that treat sites as mere blank slates would be avoided.

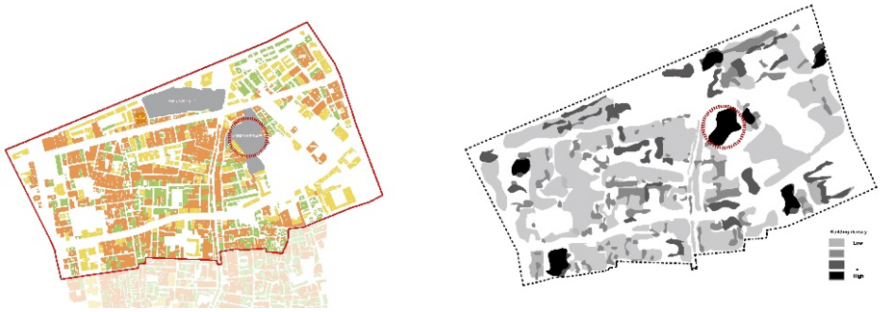

Figure 7. Particle density analysis

3.3.2.2. Degree of fragmentation

Fragmentation is intrinsically linked with coherence. When coherence shifts, fragmentation will inevitably change along with it. The greater the degree of fragmentation, the lesser the coherence. Here, 'fragments' metaphorically allude to the density of streets and alleys. The west side of Shuzhu Chong continued to develop on the basis of the Pan family's garden plot, forming the current street pattern. This plot has the highest degree of fragmentation, with a uniform distribution, weaker coherence, and smaller street scales. The numerous cul-de-sacs indicate a pedestrian-centric lifestyle of the time.

From Figure 8, Block A consists of buildings of smaller scale. This is mainly due to the decline of merchant families, the multiple divisions of the Pan family's garden, and the simple and unpretentious urban life during the late Qing Dynasty. The streets and alleys in the Shuzhu Chong area either run parallel or perpendicular to the water channels, signifying the influence of waterway transportation on the surrounding urban spaces at the time. Block B in the illustration was originally the garden of merchant Wu Bingjian during the Qing Dynasty's Thirteen Hongs period. Many dead-end streets have emerged in the Wu family's plot over the years. This pattern is primarily due to the emergence of enclosed small residential communities and high-rise commercial buildings. With the decline of the merchant class, by the late Qing period, the function of the Wu family's garden began to shift. During the early Republic, this plot was mainly used as a police station. In 1945, it served as an armory for the Guomindang and was bombed and later reconstructed. The plot now consists of diverse architectural types, including middle schools, elementary schools, police departments, and modern high-rise residential buildings. Block C in the diagram represents a vast enclosed area, primarily comprised of institutions like elementary schools, theaters, youth palaces, inspectors' offices, and temples.

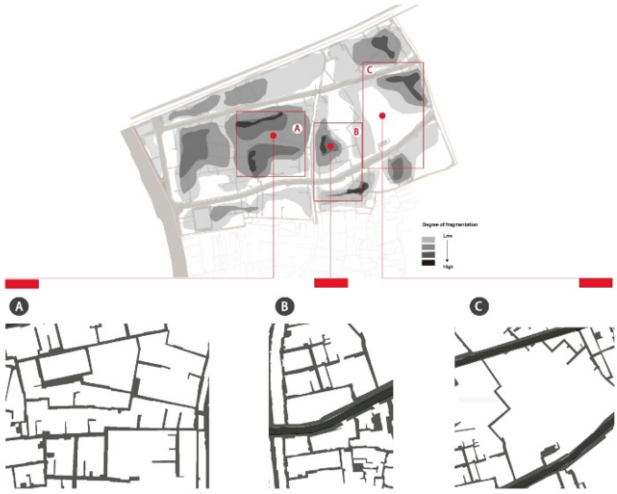

Figure 8. Degree of fragmentation.

From this, the degree of fragmentation evident in today's Nanhuaxi reveals two points:

Its development is primarily in clusters. The basic division of these clusters evolved from the original development of the Haitang Temple (Block C in Figure 8), the Pan merchant family (Block A in Figure 8), and the Wu merchant family (Block B in Figure 8).

The texture of streets and alleys within the system is intrinsically linked to the lifestyles of the time. For instance, the relationship between the water channels and the alleys hints at a lifestyle that was closely associated with this waterway. One can imagine how people's lives were deeply connected to this channel. It seems that these lifestyles were not considered by planners and designers during the planning process. However, in the analysis of the map diagram, they are clearly presented.

3.3.3. Boundary analysis

Regional boundaries serve as tools for defining, demarcating, arranging, and preserving areas, with urban systems comprising both regions and their respective boundaries. In the illustration below, streets and alleys together form the various boundaries within the Nanhuaxi area. These boundaries are clearly visible, connecting, separating, traversing, or penetrating different regions across all scales, thereby linking this area together. However, in reality, not all boundaries are always clearly visible. At times, they only exist on maps, showcasing the power and significance of cartography.

Figure 9. Boundary analysis

In Figure 9, all building textures are isolated, leaving only streets and alleys, revealing the traces of history on the map. Shuzhu Chong becomes clearly visible, and the boundaries of the Pan merchant family's ancestral hall, and the late Qing and early Republic commercial buildings also emerge one by one. The appearance of these boundary lines aligns with the theory of the "fixation line" proposed by Kevin Lynch. "A fixation line is a linearly characterized site that sometimes obstructs the development of settlements. Rivers and city walls often signify the fixed edge of traditional towns. During subsequent development of the settlement area, it forms a line between the inner fringe and the nearest outer fringe. Fixation lines can represent natural features like rivers, man-made features like railways, and even intangible boundaries such as those delineated by local authorities, parish boundaries, or land ownership."

The boundaries of the once-prosperous Haichaung Temple, the Pan family mansion, and the Pan family ancestral hall, as well as the boundaries of the late Qing and early Republic commercial buildings, are still clearly visible on the map, even beneath today's Tongfu Road. This situation can be explained using Kevin Lynch's (1984) "morphological framework" theory. He believes that the "morphological framework is a kind of prior planar feature, topographical contour, or a set of topographical contours, which exerts a morphological influence on subsequent development in terms of consistent planar layout, and often inherits certain features as inherited contours. The morphological framework forms the development pattern of the town's core area, often limiting future development trends. Thus, street and plot patterns have a morphological influence on subsequent development." All these relationships become even clearer with the separation and overlay of map layers.

3.3.4. Accessibility analysis

Accessibility is a critical feature for determining a place's advantage and can also serve as the primary criterion for differentiating entrance and exit roads and identifying suitable nodes. The level of accessibility in a particular location is mainly determined by opportunities for connections between different scales, including getting from one place to another, either quickly or slowly. The more diverse and numerous the road scales connected to a specific regional node, the higher its accessibility degree, and vice versa. Therefore, when a regional node is located on pathways of different scales, its accessibility index is relatively high.

In this topological depth difference map, roads are categorized into primary formal streets, inner streets, secondary inner streets, and alleys (as depicted in Figure 10). Formal streets represent those planned and funded by the government. They can accommodate vehicular traffic. Inner streets, formed due to the original river channel morphology, have reduced traffic capacity compared to formal streets, with a width of about 4-6 meters, and are directly connected to formal streets. Secondary inner streets have a width of 2-4 meters, while alleys are the narrowest channels, approximately 1-2 meters wide. Alleys connect to inner streets, have the weakest traffic capacity, and often lead to dead-ends. From the map, it's evident that along the Shuzhu Chong line (areas circled in black), due to connections to roads of various scales, several nodes emerge. These nodes are also the spots in the regional system with the highest foot traffic and the most goods and information exchange.

Figure 10. Accessibility analysis

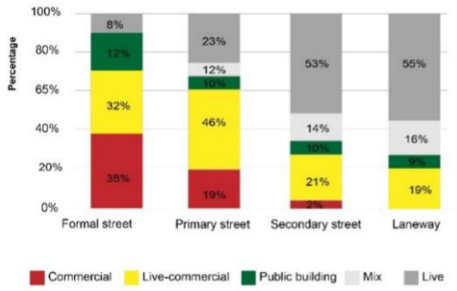

Figure 11. Building Function Type Analysis

4. Research Results

If we refer to the objective phenomenon presented within a system as a "regional phenomenon", there must be various reasons influencing this phenomenon behind the scenes. The phenomenon presented by a specific region should be analyzed by synthesizing various cultural, political, and economic factors. The method of map interpretation aims to reveal hidden phenomena, apply geographical concepts, and connect these hidden phenomena with cultural, political, and economic elements. This enhances our understanding of cities and provides a foundation for their future development.

From the analysis of nodes and connections, it is evident that the phenomena presented by these network factors are influenced by elements like human interaction, goods exchange, and information flow. One could argue that the density of human interaction, goods, and information exchanges within a region will become a significant factor affecting its urban network characteristics. From the accessibility analysis, we observe that the main road nodes in Nanhuaxi are concentrated south of Nanhuaxi Road and south of Tongfu West Road, along the Shuzhu Chong line. These nodes are also where the density of human flow and goods exchange is the highest. It can be deduced that when a region is connected to more roads of diverse scales, its accessibility is higher, making it more likely to form nodes, preparing it for the city's future development.

From the boundary analysis within the region, it is clear that in the process of urbanization, Nanhuaxi's history has been forgotten. Its current state is merely an urban village with some preservation value or soon to be demolished. However, in the boundary interpretation, we can still see traces of Shuzhu Chong and merchant gardens in history, providing strong evidence for the inheritance of the city's regional context. From the density analysis, Nanhuaxi is primarily residential, with the spatial geographical structure developing into three clusters, each evolving from Hai Chuang Temple, Merchant Pan's family, and Merchant Wu's family. The spatial characteristics within these clusters are distinct, with the most communicative space being the Shuzhu Chong node. As a city with a network structure, overlaying today's network nodes with those from the Qing Dynasty's prosperous period reveals a lack of nodes in the Nanhuaxi system (as shown in Figure 12), resulting in a loose network structure, much like a fishing net with many holes. Commerce and information exchange are limited to Shuzhu Chong, Nanhuaxi Road, and Tongfu Road. Hence, for the sustainable development of historical and cultural districts, it's necessary to mend this city net based on its historical context, with the primary condition being the identification of nodes to connect the lines.

The power of map interpretation will provide the conditions and basis for further design and planning. The acquisition of these conditions and bases, that is, using the map as a tool for interpretation, reveals the subtle conditions within a city, recombines them, and thus presents a new world.

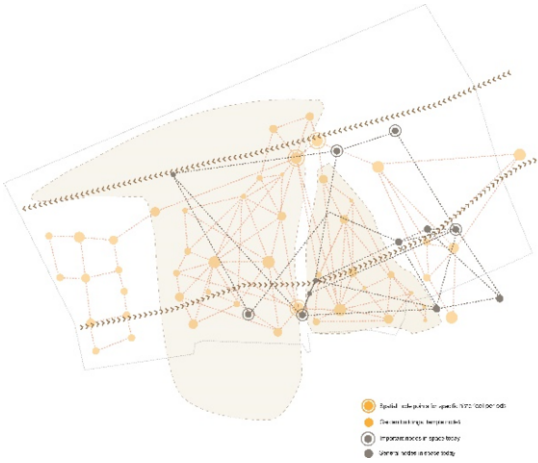

Figure 12. Overlay of present and past network nodes

5. Conclusion

From its inception to today, the development of urban space always follows a logical progression. If urban planners and designers can grasp this deductive logic, they can provide suitable new strategies for the transformation and development of urban spaces. This study aims to demonstrate that map interpretation and urban network, as research tools, can reveal hidden conditions within a city. In doing so, they help decipher the logic behind urban development, laying the groundwork for the city's future growth. Through

the method of map interpretation, even if the urban morphology of a certain area gets disrupted during a developmental phase, one can still discern the culural structure revealed throughout the city's development.

During the map translation and interpretation process for Guangzhou's Nanhuaxi historical and cultural district, it was discovered that Nanhuaxi is a region with significant historical and cultural features. It bears the memories of Guangzhou's merchant golden age, once exhibiting the essence of life along its water alleys. However, in today's urbanization process, these historical continuities have been utterly disregarded, leading to the existence of numerous spatially heterogeneous areas today. Faced with these issues, the analytical mode of the mapping system can offer robust evidence and constructive strategies for the city's future direction and development.

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