

Multi-Scale Urban Spatial Evolution Analysis Based on Space Syntax: A Case Study in Modern Yangzhou, China

Dai Zhimei, Hua Chen

Abstract—The exploration of urban spatial evolution is an important part of urban development research. Therefore, the evolutionary modern Yangzhou urban spatial texture was taken as the research object, and Spatial Syntax was used as the main research tool, this paper explored Yangzhou spatial evolution law and its driving factors from the urban street network scale, district scale and street scale. The study has concluded that at the urban scale, Yangzhou urban spatial evolution is the result of a variety of causes, including physical and geographical condition, policy and planning factors, and traffic conditions, and the evolution of space also has an impact on social, economic, environmental and cultural factors. At the district and street scales, changes in space will have a profound influence on the history of the city and the activities of people. At the end of the article, the matters needing attention during the evolution of urban space were summarized.

Keywords—Space Syntax, spatial texture, urban space, Yangzhou.

I. INTRODUCTION

THE urban form is the comprehensive manifestation of the dual characteristics and process of the material shape and cultural connotation of the city [1]. The growth and replacement of urban space is still the mainstream phenomenon, although zero growth or even negative growth has been proposed in some cities after rapid urban space expansion for decades. Researching the urban spatial evolution process is helpful to understand its internal law and problems, and it has great significance for guiding the urban space to evolve better.

The existing research on urban spatial evolution was always based on a certain city, focusing on its influencing factors [2]-[7], driving forces [8], [9], evolution mechanisms [10]-[13] and its analytical methods [14]-[18]. It laid the foundation for understanding the form of urban space and its changes. Meanwhile, the available research on Yangzhou urban space mostly focused on the ancient period, the most important of which is the study of Yangzhou urban development and spatial form during the Ming and Qing Dynasties, which was finished by Jianhua Yang in 2015 [19]. It examined the geographical factors, cultural space, religious space, hall space and folk lifestyles of Yangzhou during the Ming and Qing Dynasties. It also combined the physical spatial form with the non-material factors in the process of urban development, revealing the

intrinsic motivation of the evolution of urban spatial form in Yangzhou in the Ming and Qing Dynasties. This paper has greatly enriched the study of Yangzhou's urban history. On the study of urban space in modern Yangzhou, most of them were qualitative research, and they always started from the urban planning map. For instance, Sheng et al. [20] and Liu [21] discussed the evolution process of Yangzhou urban spatial form and briefly analyzed its development problems and driving mechanisms from the perspective of urban master plan. Lai et al. [22] gave a detailed review of the driving force of Yangzhou urban space expansion, which was divided into four aspects: economy, population, road traffic, policy and planning. Xu [23] pointed out that less research explores the urban hidden pattern law through the present urban land use map; however, it was used in this paper to identify and extract the urban spatial pattern elements of Yangzhou. This research laid a foundation for the study of urban spatial pattern evolution. In addition, on the scale of the district, more research [24] explored the problem of urban development from the perspective of conservation of historical districts because Yangzhou is a historic and cultural city, so that explore and analyze its ancient city protection strategy.

On an account of the research foundation and the breakthrough points, this paper extracted the street and road system and identified urban texture of modern Yangzhou, then conducted evolutionary analysis and comparative study of urban space in different periods and different scales, attempted to summarize the changing laws of urban space development in Yangzhou and proposed corresponding suggestions for the problems.

II. RESEARCH DESIGN

A. Research Object

As in Fig. 1, Yangzhou is located at the central part of Jiangsu Province, bordering Taizhou in the east, Yancheng in the northwest, Nanjing in the southwest, Anhui province in the west, Huaian in the north, Yangtse river in the south and faces Zhenjiang across the river. The coastline of the Yangtze River in Yangzhou is 80.5 kilometers, and the Beijing-Hangzhou Grand Canal runs through its hinterland. The area of Yangzhou City is 6,634 square kilometers, with a resident population of 4.991 million [19].

Dai Zhimei and Hua Chen are with the Institute of Urban Planning and Design, Zhejiang University, Hangzhou, China (e-mail: 21712258@zju.edu.cn, huachen1212@zju.edu.cn).

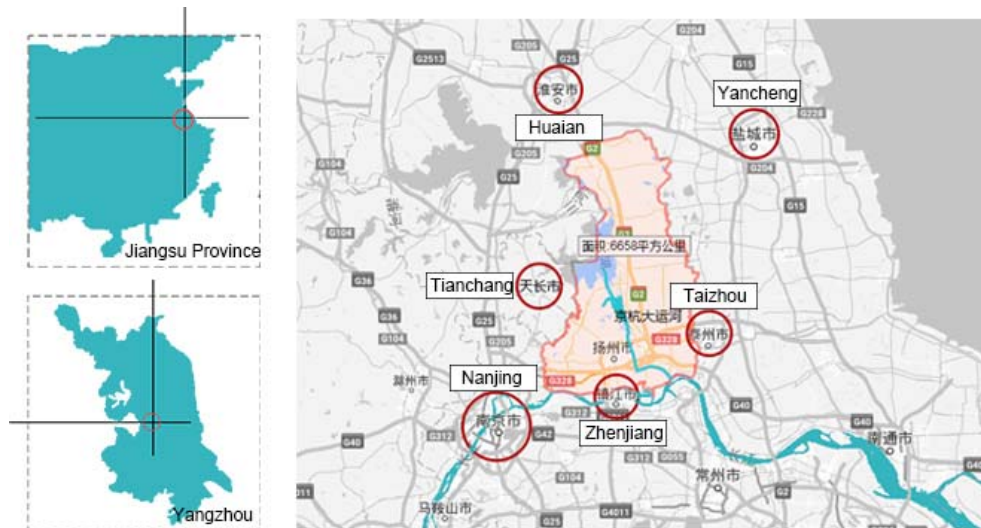
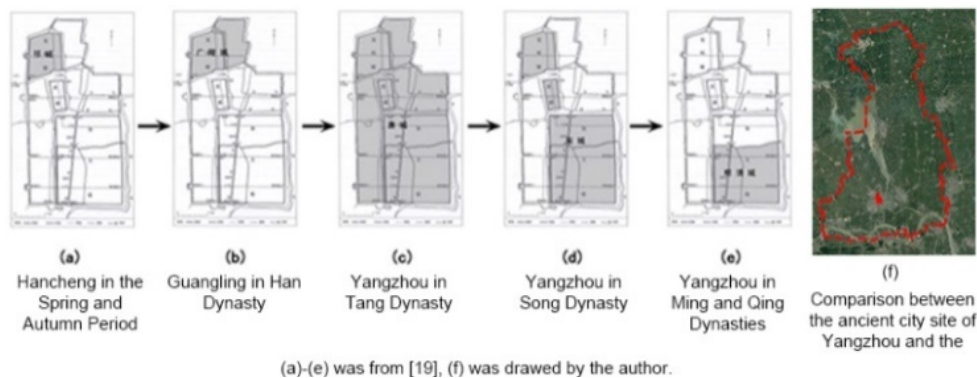


Fig. 1 The location of Modern Yangzhou



(a)-(e) was from [19], (f) was drawn by the author.

Fig. 2 The evolution process of ancient Yangzhou city site

Yangzhou is one of the first 24 historical and cultural cities announced by the State Council of China. As shown in Fig. 2, Shugang was always occupied from the Spring and Autumn Period, when Fuchai was to fight against the Qi to Han Dynasty, whose capital was Guang Ling. During the Tang Dynasty, Yangzhou City consisted of two parts, Zi City and Luo City, and it was the third largest city in China after Chang'an and Luoyang, and its Zi City was still located in Shugang. In the Song Dynasty, Yangzhou City had three parts, including Baoyou City, Jia City and SongDa City. During the Ming and Qing Dynasties, the Yangzhou city developed to the south and was divided into the Old City and the New City. At the same time, the urban space also has undergone tremendous changes in modern times.

B. Data Sources

Through the collection and compilation of relevant materials and papers, the data selected in this paper mainly came from the survey of the current situation of construction land in different periods, including the street network of the old district in 1920 from [19], the current status of construction land of Yangzhou built-up area in 2003 and Yangzhou central downtown in 2011

from [23]. In addition, it included the architectural texture map acquired on BDMaP and the street view image from Tencent map.

C. Method

"City street network – district – street" is the analytical hierarchy of this paper because streets are the skeleton of city, and they are also important public spaces for people's daily life. On the city scale, AutoCAD was used to draw the axial maps of the street network in 1920, 2011 and 2012. Then, the axial maps were analyzed with Depthmap to deconstruct the spatial network characteristics of Yangzhou urban street system at different times. Finally, the urban spatial internal structure and evolution law were explored.

As a method different from the traditional methods performing, describing or evaluating urban structure and mode, Space syntax can use a series of variables to objectively assess the features of urban space [16], and it can be closely related to economic, environmental and cultural factors, providing an objective and operational method for urban spatial morphology research. There are three common analytical methods for spatial syntax: axis method, field of view analysis and convex

space method, and there are also many parameters: density of road network, integration, integration-R, choice, intelligibility, intelligence and so on. They can all be used to characterize certain characteristics of urban space. The analysis method used in this paper is the axis method, and the spatial morphological variables involved had integration and integration-R.

- (1) Integration: What the parameter expresses is the relationship between a space in the axis system and all other spaces [15], representing the accessibility of the unit space. Its measurement method is to compare the average value of the shortest spatial length from each unit space to all the other unit spaces. The higher the integration of an area, the greater is the accessibility of streets. It indicates that the street can gather more commerce and vitality, and its street system is more stable. What's more, it also generally illustrates that the area is the central part of a city.
- (2) Integration-R: The relationship between a space and the space within its radius R (the shortest path R steps) [15]. In this paper, R is 3. Integration-R represents the spatial organization property in the region. If the integration-R in a district is greater than its integration, it proves that it has a large difference with the overall structure of the city, or it is unstable [24], often indicating the newly developed and developing areas of the city.

In Space Syntax diagrams, the warmer the color of the line, the larger the value of these two parameters, and vice versa.

III. ANALYSIS OF THE SPATIAL EVOLUTION OF YANGZHOU CITY AT THE CITY SCALE

A. 1920

During this period, the old district continued the pattern of the New City and Old City in the Ming and Qing Dynasties. The roads were characterized by free development, and only the main roads were relatively wide and straight, and the length was long. As in Fig. 3 (d), the streets with large integration and flow density were South Wenhe Road, Guoqing Road, Guandong Street and Guangling Road (they are all current road names). Among them, South Wenhe Road is also a major traffic artery nowadays. As can be seen from Fig. 3 (b), Yangzhou City during this period had no obvious center, but was supported by the main traffic skeleton.

B. 2003

1) Conclusion of Space Syntax Analysis

The Space Syntax analysis in 2003 was based on the current situation of urban construction land use in Yangzhou (Fig. 4 (a)). As in Fig. 4 (d), the roads with higher integration were Cuishang Road – South Wangting Road, Middle Wenchang Road – West Wenchang Road which were in the east-west direction, and North Hanjiang Road – Middle Hanjiang Road, Xinchenghe Road, Weiyang Road, Yangtze River Road and Huaihai Road which were in the north – south direction. Among them, Yangtze River Road was a major traffic road. As shown in Fig. 4 (d), these roads that can relatively gather popularity and commerce were mainly concentrated in the west

side of the old district, moreover, the color of the road to the periphery is colder, indicating that the outlying area was a new development region of the city. It can be seen that urban development during this period was no longer a circle-level development around the old district, but had a tendency to leap to the west. In addition, as in Fig. 4 (c), the roads with higher integration-R were concentrated in the west and southwest of the old district of Yangzhou, which demonstrated its further development.

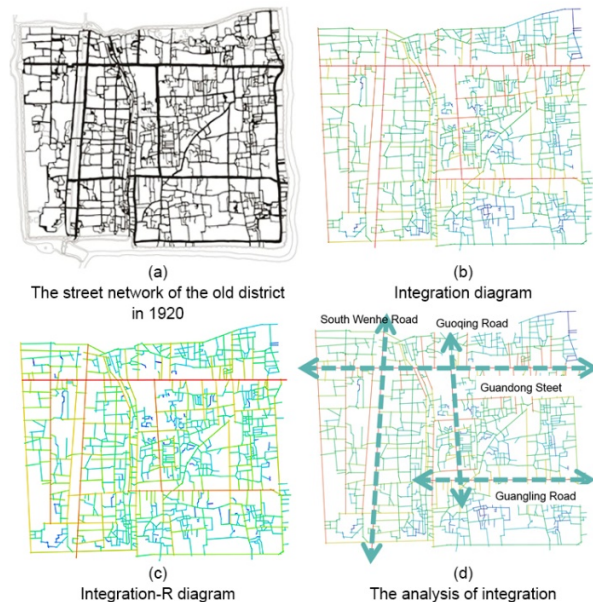


Fig. 3 Space Syntax analysis of the street network of the old district in 1920

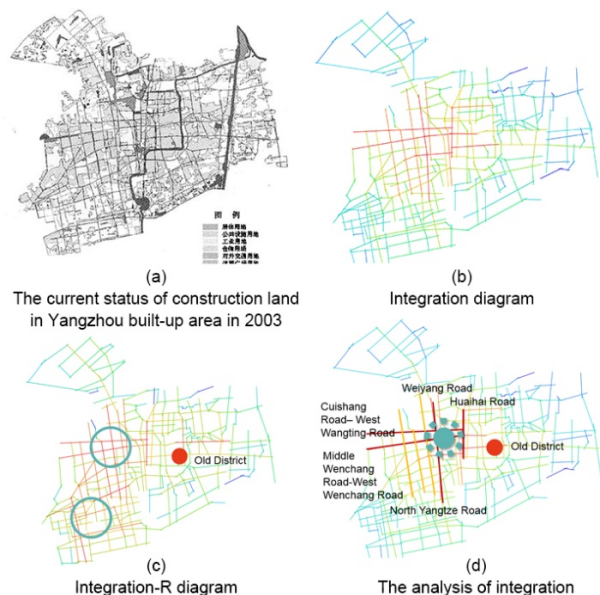


Fig. 4 Space Syntax analysis of the street network of built-up area in 2003

2) Analysis of Factors Affecting Urban Spatial Form in 2003



Fig. 5 Analysis of Influencing Factors of Urban Space form in 2003

The urban spatial form in 2003 was mainly affected by policy and the construction of transportation. As for the planning policy, through the combing of Yangzhou's urban master plan from 1982 (Table I), it can be seen that the status of urban construction land in 2003 was affected by the 1996-2010 version of Yangzhou's master plan (Fig. 5). Yangzhou's urban space development direction planning for 1996 to 2010 was "westward and southward", with an economic development zone in the south and a new urban zone in the west, and the analysis of the integration-R in 2003 was consistent with this idea, moreover, it was also reflected that the Yangzhou government intended to build a new district in the western part of the city because the accessibility of streets in this region was high. In addition to the influence of planning policy, the expansion of urban space during this period was also guided by the construction of transportation. Regarding the railroading, the construction of Ningqi Railway promoted the development of Yangzhou to the west. As for the road, the construction of the ring expressway strengthened the connection between the Yangzhou and the surrounding areas, laying a foundation for finding new urban growth points.

TABLE I
THE INFORMATION ON YANGZHOU'S MASTER PLAN IN DIFFERENT VERSIONS

Version	Reported time	Time of approval	Notes
1982-2000	1982	1985	-
1996-2010	-	1999	Affected the urban spatial form of 2003
2002-2020	2004	-	Affected the urban spatial form of 2011
2010-2020	-	2010	In this year, Yangzhou administrative divisions were adjusted, and after planning integration, this version of the master plan was formed
2012-2020	-	2012	-

C. 2011

1) Conclusion of Space Syntax Analysis

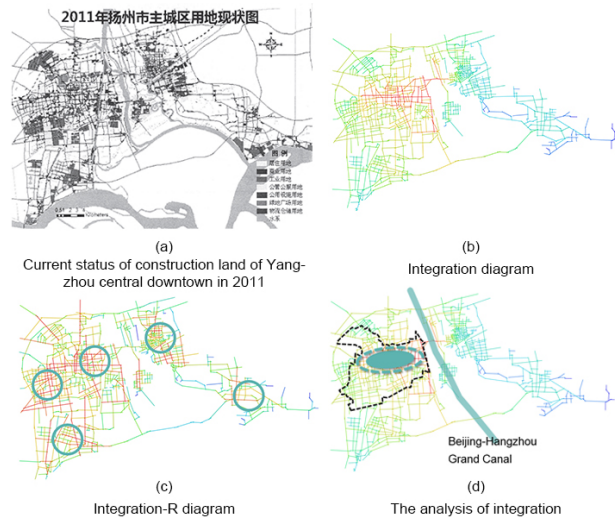


Fig. 6 Space Syntax analysis of the street network of central downtown in 2011

The Space Syntax analysis of 2011 was based on the current situation of the land use in the central downtown of Yangzhou. As in Fig. 6 (b), the streets with higher integration were mainly concentrated in the west side of the Beijing-Hangzhou Grand Canal. Compared with the scope of the core area in 2003, it had expanded, and the urban construction land had extended to the east of the canal (see Fig. 6 (d)). From the point of view of integration-R, there were five main areas with dense red lines, indicating that their street systems were expanding and needed further subdivision to integrate with the surrounding areas.

2) Analysis of Factors Affecting Urban Spatial Form in 2011

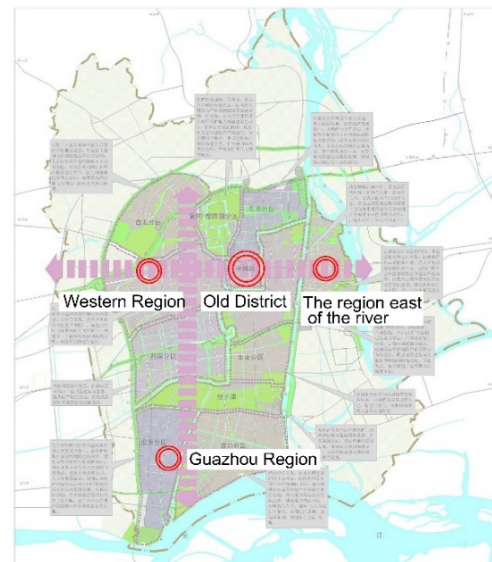


Fig. 7 The master plan of Yangzhou (2002-2020)

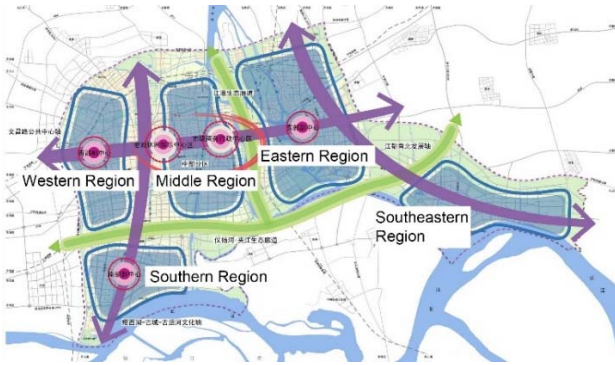


Fig. 8 The master plan of Yangzhou (2012-2020)

First, the urban space development of Yangzhou in 2011 was affected by the master plan (2002-2020) (see Fig. 7). From the perspective of planning structure, it planned the old district as the core of the city, and each had a sub-center in the west, east and south of the city, which were the center of western, Hedong and Guazhou divisions, and the core area from the 2011 integration analysis was consistent with the region of the old district plus the Hedong sub-center in the master plan (2002-2020). Besides, the changes of urban spaces were also related to urban policies. In the 2002-2020 master plan, the Jiangdu district on the east bank of the Beijing-Hangzhou Grand Canal was not reflected, the reason was that Jiangdu changed from a city to a district in Yangzhou in 2010, and therefore the 2012-2020 master plan was compiled (see Fig. 8). The new urban development areas obtained from the integration-R analysis in 2011 were the same as the urban group proposed in the 2012-2020 master plan, which also revealed the guiding role of current urban development status in urban planning.

D.Summary of the Evolution and Influence Mechanism of Urban Space in Modern Yangzhou

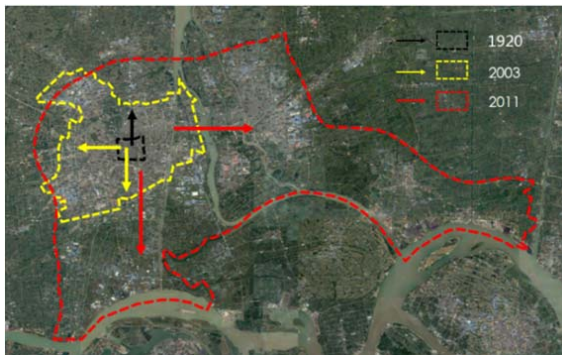


Fig. 9 Analysis of the evolution of urban spatial proportion and development direction in Modern Yangzhou

After the analysis of the current road network structure of Yangzhou in 1920, 2003 and 2011, it can be concluded that the changes of Yangzhou urban space include the following aspects: the expansion of urban space, the transformation of urban development direction and the difference of urban spatial development structure. First, from the direction of urban spatial

development, it has experienced the process from initial northward development to the later “westward and southward” and then the continued southward development and the eastward expansion across the Beijing-Hangzhou Grand Canal (see Fig. 9), which reflected the different strategies of city in different periods. Second, from the development structure, in the early days, it was a circle-level development around the old district, later, due to the pressure of the protection of the old district and the demand for urban space expansion, it developed into a fan-shaped expansion form to the west and south, and now to the group-type, multi-center development structure. This was a process in which a city seeks for more space for development.

The main factors affecting the development of urban space in Yangzhou are the following: natural geographical factors, policy and planning factors, and road transportation factors, and the specific performance as shown in Table II.

TABLE II
ANALYSIS OF FACTORS AFFECTING URBAN SPACE IN YANGZHOU

Factor	The impact on the modern Yangzhou urban space
Natural geographical factors	Limiting its spatial expansion to some extent
Policy and planning factors	Affecting the direction of urban development and the scope of administrative divisions
transportation factors	Promote the expansion of Yangzhou urban space for many times

IV. ANALYSIS OF THE SPATIAL EVOLUTION OF YANGZHOU CITY AT THE DISTRICT AND STREET SCALES

A. Research District

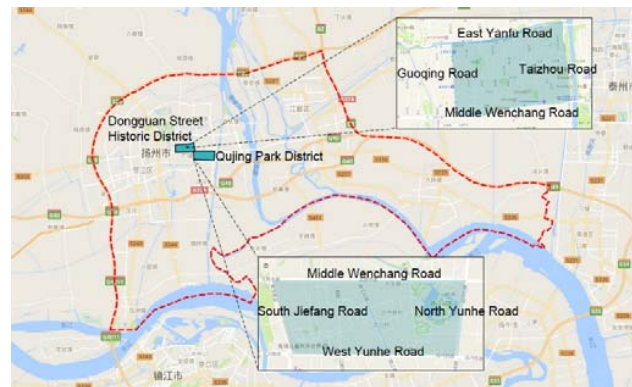


Fig. 10 The location of research districts

In the district and street scales, an old district and a new district in Yangzhou were selected. The idea of Space Syntax was used to analyze and compare the street network structure, scale and open spaces of them. What's more, the changes of urban space from the scale of people were also observed. After the data and papers were sorted, as in Fig. 10, the Dongguan Street Historic District was selected in the old districts. Among the new districts, Middle Wenchang Road – South Jiefang Road – West Canal Road – North Canal Road (hereinafter referred to as Qujiang Park District) was selected as the research object. Dongguan Street Historic District is the most abundant area of Yangzhou's historical and cultural heritage.

As the center of the occurrence and dissemination of many folk activities, it shows the customs and local cultural characteristics of the ancient Yangzhou City. Qujiang Park District is located in the core area of Yangzhou, with many commercial facilities around it, which is a dynamic area of the city. The two areas are representative of ancient and modern Yangzhou urban space, and have great research value and significance.

B. Dongguan Street Historic District

1) Urban Spatial Analysis at the District Scale

Some scholars divided the urban texture into the organic, the geometric, and the composite one [25]. As shown in Fig. 11, firstly, the difference between the texture of the inner historic district and the peripheral part can be discerned. It is obvious that the internal texture is organic. The scale of their buildings

is also very different, and the buildings along the outer streets are new construction (see Fig. 11 (a)). Secondly, the street texture of Dongguan Street Historic District is fish-bone, with Dongguan Street as the main street, branching to the next-level small streets and small alleys. The distance between the two small streets is generally about 100 meters. Finally, there is a lack of large public space in the Dongguan Street Historic District, among them, only the East Gate Plaza in the east is open to the public, the rest are mostly in the interior of schools, gardens of private houses, such as Yangzhou University and Yangzhou No.1 Middle School (see Fig. 11 (b)), however, according to the characteristics of the inner space of the old district, the alleys are the places for residents' daily public activities.

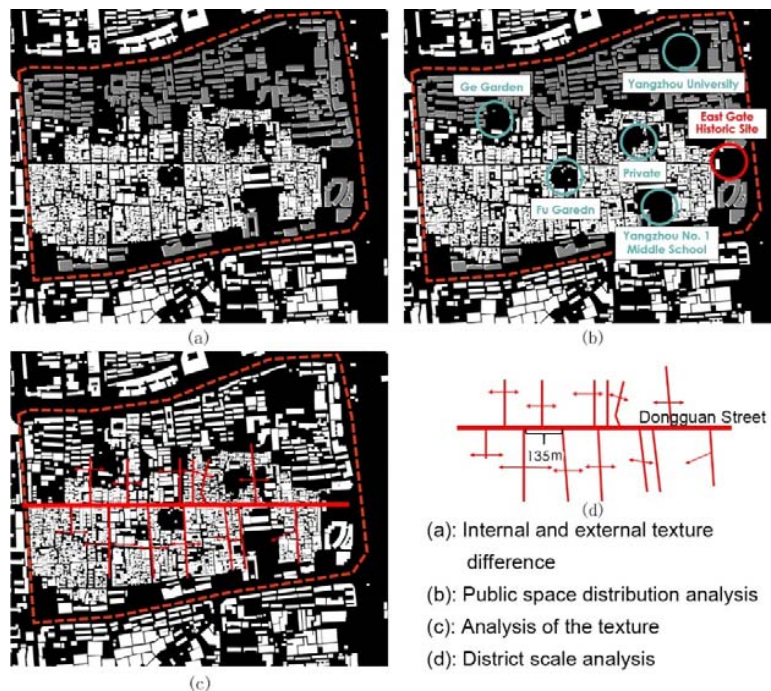


Fig. 11 Texture analysis of Dongguan Street Historic District at the district scale

2) Urban Spatial Analysis at the Street Scale

Tuning to the scale of human beings, the research transformed into an analysis of street space. In "The Aesthetics of Street" [26], it was proposed that when $D/H > 1$, the sense of distance would gradually appear as the ratio increased, and it would produce a roomy sense when it exceeds 2; when $D/H < 1$, a close sense was produced as the ratio decreased; when $D/H = 1$, the relationship between height and width would produce a sense of symmetry. As in Fig. 12, First, D/H of Dongguan Street and Middle Wenchang Road are 1 and 1.9 respectively, and D/H of East Yancheng Road is in the range of 1 to 2.5, and its D/H is mainly affected by the height of buildings on both side of the street. Second, judging from the width of streets, the widths of East Yanfu Road and Middle Wenchang Road are 20 meters and 38 meters respectively, which are both designed at

the scale of the car-using. On the contrary, the width of Dongguan Street is more pleasant, and the shops along the street can promote people's staying behaviors and communication activities.

C. Qujiang Park District

1) Urban Spatial Analysis at the District Scale

For the new urban area, first, it can be intuitively seen that its texture is more regular than that of the Dongguan Street Historic District. Second, from the perspective of spatial size (see Fig. 13 (a)), the longer distance between streets is about 650 meters, and the smaller one is about 212 meters, moreover, there are large residential areas between the roads, which leads to the lack of streets connecting urban roads. From the distribution of public space (see Fig. 13 (b)), the Qujiang Park

area contains three relatively large open public spaces: Qujiang Park, Puhading Garden and Wanda Plaza, whose range of services far exceeds this area. However, unlike the historic

districts, the Qujiang Park District has many residential areas, but lacks small public spaces for residents.



Fig. 12 Analysis of Dongguan Street Historic District at the street scale



Fig. 13 Texture analysis of Qujiang Park District at the district scale

2) Urban Spatial Analysis at the Street Scale



Fig. 14 Analysis of Qujiang Park District at the street scale

In the street scale of the new district, in Fig. 14, the width of Middle Wenchang Road in this area is widened, and the height of the buildings on both sides of the road is also heightened, therefore, D/H of it is appropriate, but on the whole, the street is designed for the car using. What's more, because of the boundary of the buildings along the street and the discontinuous street interface, the overall feeling of the street is relatively empty. The section of D/H of North Canal Road and West Canal Road increases because the construction along the two roads is undulating and the sense of surrounding of the two streets is always seriously deficient. In addition, the reasonable planting of trees along the street enhances South Jiefang Road's sense of enclosure.

D.Results of Comparison at the District and Street Scales

Through the comparative analysis of the urban space between Dongguan Street District and Qujiang Park area, it can be seen that the scale of the old district is more pleasant at district and street level, including the three aspects: D/H, the width of street and the size of the district. From the point of view of open public space, Qujiang Park area is more dominant in the setting of large public space, but Dongguan Street Historic District is superior in the quality of street spaces. As a place where various activities take place, the street space has social attributes, which can also provide venues for residents' daily activities. Combined with the setting of ancient buildings and shops along streets, it is easier to create a sense of place.

V.CONCLUSION

From the scale of "urban street network – district – street", the law of urban space evolution in Yangzhou and its driving factors were explored. At the city scale, based on the map of current urban status in 1920, 2003 and 2011, using Spatial Syntax, the spatial expansion, the transformation of the development direction and structure were analyzed and summarized. At the same time, combined with social,

economic and cultural backgrounds, the influencing factors were also studied, which mainly include natural geographical factors, policy and planning factors and transportation factors. At the district and street scale, through the comparison of the spaces between a new district and an old district, the size of the district and street spaces, and the setting and the distribution of the public space were analyzed from the perspective of people. It is concluded that in the spatial arrangement, the urban new district should pay more attention to the scale requirements of people and consider the feelings of people when they are using spaces. For the old districts, history and culture are undoubtedly important, but it is also necessary to provide better living space for the resident, and the living space is needed to be optimized properly.

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