THE EVOLUTION OF KULANGSU’S URBAN MORPHOLOGY IN ITS PERIOD OF PUBLIC SETTLEMENT, BASED ON SPACE SYNTAX

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Abstract. Heritage protection entails the integrated construction of conservation and collective memory based on historical authenticity. Therefore, the study of history is essential for accomplishing the task of heritage conservation. This article applies a space syntax methodology to explore how urban morphology evolved at a heritage site on Kulangsu Island. The analysis reveals the characteristic features of urban morphology and offers suggestions for optimizing the historical space of world heritage. The effectiveness and limitations of the research are also debated and substantiated.

Keywords. Urban morphology; Kulangsu; Historical evolution; Space syntax; GIS.

1. Introduction
Kulangsu, located at the mouth of the Jiulong River, is an island with an area of 1.88 square kilometers that faces the port city of Xiamen in China. At the World Heritage Conference held in Krakow, Poland in July 2017, the decision was made to include Kulangsu in the World Heritage List. Heritage protection entails the integrated construction of conservation and collective memory based on historical authenticity. Therefore, the task of conserving Kulangsu’s heritage necessitates a study of its history.

Many historical studies have been conducted on Kulangsu’s architecture and urban morphology. These studies have focused on differing spatial scales, from a single building to an urban block, and to the entire urban morphology, revealing different research orientations. Examples include “The Architecture Heritage of Modern China, Xiamen” (GUO 1993), “Kulangsu Building Collection” (GONG 1997), which is a study of historical buildings in Kulangsu, and studies on the historical origins, spatial textures, and architectural forms of the Longtou and Neicuoao blocks in Kulangsu conducted by Wang (2008; 2009), who proposed the block renewal mode. Chen (2006) examined changes in historical buildings and land conversion in Kulangsu. However, few existing studies have applied a dynamic evolution perspective to examine Kulangsu’s system of urban morphology as a whole. Furthermore, most previous studies were based on field research and historical literature reviews, focusing on the urban historical context. Therefore, qualitative rather than quantitative research methods were predominant in these studies.
In this study, we applied the theory and methods of space syntax in a case study of Kulangsu. We considered Kulangsu’s urban morphology as a whole dynamic system, thereby introducing a quantitative research perspective. This approach helps to offset the limitations of traditional historical research which mostly focus on facts and experience, thereby contributing to the quantitative research on urban history. Moreover, the study enhancing cognitive value to contribute to the island’s protection and sustainable development, and guidelines are provided for conducting research on the protection of historical and cultural heritage.

2. Methodology

2.1. ANALYTICAL METHODS

In the 1970s, Bill Hiller at the University of London formulated the theory and methods of space syntax from the perspective of spatial configuration. Space syntax differs theoretically from classical urban morphology, because it focuses on open space systems in the pursuit of a form of spatial representation (HILLIER et al. 1984). Space syntax theorists refer to sets of simulated relations between spaces as “configurations” or “accessibility,” with these terms being used to describe what are considered to be the intrinsic properties of space (HILLIER 2002). Space syntax theory explores the relationship between society and space, based on the application of precise quantitative methods. Three primary spatial configuration methods are applied: convex, axis, and segment methods. The main measures applied are depth, integration, choice, and intelligence. In this study, we used the axis configuration method along with the integration and intelligence measures to characterize the evolution of Kulangsu’s urban morphology.

2.2. RESEARCH QUESTIONS AND ANALYTICAL FRAMEWORK

In this study, we applied the theory and methods of space syntax in conjunction with historical maps and literature to analyze the evolutionary characteristics of Kulangsu’s urban morphology during the period of the island’s public settlement. The aim of the study was to address three questions through a comparative study of diachronic changes in Kulangsu’s urban morphology at various historical stages during that period. These questions were: (1) What was the process of evolution of Kulangsu’s urban morphology? (2) What were the typical characteristic of Kulangsu’s urban morphology? (3) How might we begin to evaluate and optimize the historical space of cultural heritage? The last question followed from the first two questions.

We developed the following analytical framework to respond to these questions. First, basic data on the urban fabric and functions were extracted using the historical map as a base map (see figure 1). Second, focusing on the road network structure, space syntax and GIS analyses were conducted to understand the urban morphology evolution process. Then, based on the findings of these analyses and related historical materials, the characteristics of the evolution of urban morphology were identified and evaluated, and suggestions were offered on the construction of the historical space of world heritage.
3. Outline of the evolution of Kulangsu’s urban morphology in the period of public settlement

With the opening up of Xiamen as a commercial port in 1843, and the implementation of the Land Regulations for the Settlement of Kulangsu in 1903, Kulangsu entered into the period of public settlement (see figure 1a). The period from 1900 to the 1910s marked the early phase of public settlement, during which foreigners in Kulangsu played a leading role in promoting the development of modern residential settlements on the island. They gradually expanded their residential areas in Kulangsu, developing the southern and eastern parts of the island and forming several key western residential areas. The period from the 1920s to the 1930s marked a golden period in Kulangsu’s modernization. Overseas Chinese returnees with ample economic assets became a leading force propelling urban construction and vigorously promoting Kulangsu’s economic development. Therefore, during this period, urban construction on the island advanced (see figure 1b). The boundaries between Chinese and foreigners’ settlements were abandoned, and construction was gradually extended from the southeastern part of the island to the northwestern part. With the outbreak of the Pacific War in 1941, the Japanese army invaded and occupied Kulangsu. Consequently, Kulangsu’s history as an international multicultural zone was brought to a standstill.

4. Quantitative analysis of the evolution of Kulangsu’s urban morphology during the period of public settlement

Based on a spatial analysis of the developmental characteristics of Kulangsu during the public settlement period in conjunction with the use of historical maps, we studied the evolution of Kulangsu’s urban morphology, focusing on four key years during this period: 1863, 1903, 1927, and 1935. The year 1863 signified the incubation period of public settlement, which was established and in its early evolutionary phase by 1903. Both 1927 and 1935 were in the peak period of public settlement. Thus, the periods between these four years cover the public settlement period and evolution process of Kulangsu’s urban morphology.

As shown in Table 1, topological models of the different years were developed.
and spatial syntax parameters were calculated to obtain an accurate representation of diachronic changes in Kulangsu’s urban morphology during the period of public settlement.

During the period of public settlement, the node count value and the mean depth value increased, indicating a significant increase in the density of Kulangsu’s road network. In addition, the integration value and intelligence value increased, indicating enhanced block accessibility, optimized spatial permeability, and greater integration and accessibility of the overall spatial structure.

### Table 1. Syntactic parameters for different years.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1863</th>
<th>1903</th>
<th>1927</th>
<th>1935</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node Count</td>
<td>102</td>
<td>219</td>
<td>431</td>
<td>510</td>
</tr>
<tr>
<td>Mean Depth</td>
<td>14.83</td>
<td>16.19</td>
<td>14.89</td>
<td>15.28</td>
</tr>
<tr>
<td>Global Integration</td>
<td>0.71</td>
<td>0.76</td>
<td>0.46</td>
<td>0.67</td>
</tr>
<tr>
<td>Local Integration</td>
<td>0.72</td>
<td>0.82</td>
<td>0.94</td>
<td>0.95</td>
</tr>
<tr>
<td>Intelligence</td>
<td>0.64</td>
<td>0.70</td>
<td>0.73</td>
<td>0.73</td>
</tr>
</tbody>
</table>

### 4.1. GLOBAL INTEGRATION

Global integration indicates degrees of agglomeration and dispersion between a particular node and other nodes in a system. A higher value of global integration corresponds to greater and more convenient accessibility of the node within the entire system.

As Figure 2 shows, the colors are used refer to high and low values of integration. Thus red refers to higher values of integration, while blue refers to low values of integration. High or low values are then measured through the
natural break method widely used in GIS, which minimizes the average deviation of each class from its own mean values while maximizing the deviation of each class from the mean values of other groups (LI et al. 2016). In 1863, the global integration core was initially cross-shaped and located along Huangyan, Longtou and Fujian Road. In 1903, the global integration core added two new North-South roads, Yongchun and Zhonghua road. In 1927, it formed a stable three vertical and four horizontal pattern eventually, with an outer ring comprising Longtou, Huangyan, and Yongchun Road. In 1935, while the area with a high degree of global integration was retained, the greatest change is that the value of global integration of Neicuoao area had greatly improved.

4.2. LOCAL INTEGRATION

Local integration refers to the relationship between nodes located within a certain range. A higher value of local integration corresponds to greater and more convenient accessibility of the nodes within the specified range. In this research, local integration analysis is defined as five topological steps range.

As shown in Figure 3, in 1863, the areas with the highest value of local integration were originally scattered. In 1903, the core area with a high value of local integration had become concentrated to Longtou, Huangyan, Fujian, Zhonghua and Fuxing Road. Eventually, in 1927, this core shifted to the Northwest direction, such as the newly added Fuzhou road and Yongchun road. In 1935, the local integration core remained stable. With the construction of branch roads in the Neicuoao area, the value of local integration of Neicuoao area increased.
4.3. INTELLIGENCE

Intelligence refers to the correlation between global and local integration. It describes the coordination between local space and the overall space. It is relatively easy to understand the overall space from the local space when space is characterized by a high value of intelligence. As shown in Table 2, Pearson’s correlation coefficient was used to calculate the extent of intelligence. These results indicate that a space characterized by a high value of global integration also entailed a high value of local integration, resulting in a clearly comprehensible spatial structure.

As shown in Figure 4, the number of scattered points during the four years increased gradually, whereas the shape of the scatter plot did not change significantly, indicating that the relationship between the overall and local spaces in Kulangsu was stable and symbiotic. An examination of changes that occurred in the time spans between these four years indicates that areas located along Longtou and Huangyan Roads in the southeast of the island retained their characteristic of high intelligence, and the intelligence of Neicuoao Area in the Northwest of the island increased but still low.
5. Characteristics of the evolution of Kulangsu’s urban morphology during the period of public settlement

5.1. DEVELOPMENT OF EFFICIENT SELF-ORGANIZATION

The protection of the natural landscape was stipulated within the Municipal law, resulting in the categorization of the Sunlight Rock, Drum Wave Stone, and ten other stones as “scenic stones” and the prohibition of mountain quarrying. A record of the construction and maintenance of roads was also included in the Municipal Council’s executive report. However, given the focus on protecting the existing landscape and urban form prescribed in the Municipal law and in the Municipal Council report, no plans were introduced for the island’s development. Therefore, during the period of public settlement, Kulangsu’s urban morphology formed spontaneously and evolved through actions undertaken within a self-organizing system, with little organizational influence, for example, in the area of policy planning. The findings of the syntactic analysis, described above, indicate the increased integration and intelligence of Kulangsu’s spatial system and coordination of the local and overall spaces, demonstrating the characteristics of highly efficient self-organizing development.

5.2. EVOLUTION OF THE URBAN MORPHOLOGICAL CENTER

The following characteristics were identified in the evolution of Kulangsu’s urban morphological center. First, in spite of the marked increase in road networks in the interludes between the four years of the study, the global integration core remained stable in the area of Longtou Road, developing along this road and extending towards the northwestern part of the island (see figure 2). Extensive changes in the local integration core occurred, beginning in the area south of Longtou Road. In 1927, the core shifted to Huangyan Road and Yongchun Road, that is, the area north of Longtou Road (see figure 3). Second, the locations of Longtou Road and Huangyan Road in the island’s center showed a high value of integration at the local and overall levels. Especially after 1927, the local integration core shifted to this area. Subsequently, the global and local integration of the area evidenced a stable and symbiotic relationship and good spatial quality.

5.3. THE SOCIALITY OF SPACE

Spatial syntax, which is based on spatial configuration, enables an exploration of the relationship between space and society. The theory of space syntax holds that space is a part of society. Social activities achieve their own development through the organization of spatial forms, and spatial forms also affect human social behavior. As discussed in the preceding section, the area of Longtou Road

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Table 2. Pearson correlation coefficients based on syntactic variables.

<table>
<thead>
<tr>
<th>Year</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1863</td>
<td>0.635**</td>
</tr>
<tr>
<td>1903</td>
<td>0.709**</td>
</tr>
<tr>
<td>1927</td>
<td>0.731**</td>
</tr>
<tr>
<td>1935</td>
<td>0.729**</td>
</tr>
</tbody>
</table>

Note: ** denotes a significant correlation at the 0.01 test level (two-tailed test).
constituted the integration core of the entire island. This was also reflected in the city’s social characteristics, as the island’s business district was located in the same area. Buildings in this location were designed such that their bottom section was used for shops and the second and third floors were for residential use. Building density was also high and the area was vibrant (see figure 5). With the growing prosperity of the Longtou Road area as a result of commercial activities, a large number of active stall vendors operated here, and the Longtou Road square served the function of a “market” in this residential area (see figure 6).

6. Suggestions for evaluating and optimizing the historical space of world heritage

6.1. ATTENDING TO THE SOCIAL NATURE OF SPACE, CREATING GENIUS LOCI, AND PROTECTING CULTURAL FEATURES.

Maintaining the sociality of space requires the protection of spatial heritage, which entails not just the protection of the spatial texture but also the construction of collective memory and the reconstruction of a sense of the historical field. The evaluation report of the advisory body on world cultural heritage described Kulangsu as follows: “Kulangsu is unique. It has witnessed the mutual understanding and cultural integration among different cultures in the organic City, as well as slow self-transformation.” Thus, the construction of Kulangsu’s memory space as a multicultural space could entail ceremonial activities relating to architecture, scenery, or historical sites. This can be realized through various
modalities, such as museums, theme planning, art exhibitions, and storytelling.

6.2. INTRODUCTION AND REVIVAL OF VARIOUS FUNCTIONS BASED ON DIFFERENT SPATIAL CHARACTERISTICS AND STREET RESOURCES.

Spaces manifesting different values of integration often have different functions. Most of the urban business events are concentrated in the area with high integration, whereas the functions of the middle and low integration areas are mostly related to cultural and life events. Protection of cultural heritage requires comprehensive knowledge of the resources of streets and lanes, and of their roles, and the creation of a harmonious genius loci, which is the key to successful rehabilitation. For example, the Longtou Road area is the integration core of Kulangsu’s spatial system, and has historically been the site of the commercial block. Business functions relating to tourism and entertainment could be developed in this area. The Neicuoao area, where the living function is dominant, has limited accessibility. Therefore, a community culture comprising a combination of historical resources and the living culture of the city could be created based on the daily lives of the residents. The Art and Design Academy of Fuzhou University in the western part of Neicuoao could be transformed into a creative base for musicians and artists.

6.3. INCREASING THE ACCESSIBILITY OF IMPORTANT HISTORICAL PLACE AND ENHANCE SPATIAL INTENTIONALITY.

Reopening some of the currently closed off paths to improve the accessibility of important historical place should be considered. However, given the requirement of maintaining the authenticity of historical sites, there is limited scope for changes in street actualities. Exhibitions of historical events, setting up historical scenes, and improving spatial intentionality could also enhance the standing of important historical place.

7. Strengths and Limitations

7.1. STRENGTHS

This study has methodological and empirical strengths. Urban morphology was conceived, methodologically, as a whole and dynamic system, and a combination of quantitative and qualitative methods were applied in relation to space syntax theory, thereby contributing to the quantitative research on urban history and providing guidelines for the protection of sustainable historical spaces. The empirical strengths of this case study of Kulangsu relate to the fact that it provides an exemplary model of the protection of historical space for many world heritage sites. This study contributes not only to conservation issues in Kulangsu, but it also provides an evaluation and offers guidelines for achieving the optimization of a number of historical towns in China.

7.2. LIMITATIONS

Spatial syntax is based on a typology of urban road networks that is applied in the study of urban morphology. This approach can be integrated with more quantitative approaches, such as the space matrix and mixed-use index
methods, to facilitate a more comprehensive understanding of urban morphology. Furthermore, because the urban form entails complex economic, cultural, and social processes, the space syntax method could be applied in quantitative analyses of narrative environments. These are areas for future investigation.

8. Conclusion

Three conclusions were drawn. First, during the period of Kulangsu’s public settlement, its urban morphology had transformed from small to large, and from isolated to integrate. From the perspective of space syntax, both the overall space and local spaces tended to be efficient and accessible. However, the separation trend revealed in the intelligence index map highlights the differential characteristics of particular regions. Second, the evolution of Kulangsu’s urban morphology demonstrates an efficient, self-organizing developmental process. The urban morphological center shifted in line with the changing spatial structure. In turn, the spatial structure reflected the social culture and provided the material foundation for social activities. Third, protection of cultural heritage is based on the social nature of space. Thus, the genius loci can be created according to different spatial characteristics and street resources. Increasing the accessibility of important historical place and enhance spatial intentionality could also enhance the standing of that space.

The protection of heritage sites not only relates to the protection of past time and space, it also relates to future changes. Activities such as integrating historical resources, reconstructing historical space and contemporary life, and retaining rights to space in the daily lives of residents create new values and enable avoidance of the fate of “museum preservation”. In the words of Gerd Staff Maher, the Austrian writer, “Tradition means the transmission of fire, not the worship of ashes.” These words aptly convey the spirit underlying the protection of cultural heritage.

References