

A Quantitative Approach to Morphological Research Based on Public Space

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Conference topic: Methods 1: embedding different approaches into the study of urban morphology.

Abstract: Understanding urban form generation process could add a strong ability for architects and urban designers in urban design, especially in urban renewal projects. Morphological elements, such as block/streets, plots and buildings, play important roles in the form changing process, which are also the elements in urban design projects since they play the role for forming the urban space. Due to tightly integrated together, morphological changing process must cause changes in its spatial characteristics that urban designer cares. Therefore, it is worthwhile to study urban spatial characteristics based on its morphological changing process.

This paper aims to investigate urban spatial characteristics changing process in the urban center based on its morphological study. As the center of Nanjing, Xinjiekou area is selected as the case for morphological integrated study on the physical form of spatial characteristics. Based on deeply studied of its form changing process and social background, we introduced an analytical model to assess the spatial features of the public space within these blocks through the time line of form changing, some spatial characteristics judging indicators including area, average width, circularity and openness have been developed. The results may provide urban designers and architects with not only the changing rules or trends of urban space, but also designing tools, and make them better understand the relationship between the urban form and urban space, and finally may put forward new ideas to morphological research.

1. Introduction

Urban morphology provides a method for studying the process of urban development through the investigation of urban form. Studies in urban morphology focus on the tangible results of social and economic forces (Moudon, 1997), and extensively analyze the buildings, city blocks and streets. By investigating these elements, urban form was shown to be amenable to systematic analysis (Kropf, 2009).

Despite the quantity of research in urban morphology, on the other hand, research on the voids between built structures has been limited (Çelik, Favro, and Ingersoll, 1994; Moughtin, 2003a, 2003b; Woolley, 2003). Osmond introduces the notion of a parallel hierarchy of open space to support urban analysis, planning and design across multiple scales of investigation

(Osmond, 2010). It can describe hierarchy of open space, but cannot express the change of open space. The change of urban form brings about the change of urban space. People feel the change of the city through the change of urban space. Therefore, it is meaningful to make a research on the change of urban space.

On the other hand, China is currently in the process of rapid urbanization. As the result of urban and architectural design, urban form has undergone dramatic changes. However, widely acknowledged principles pertaining to the composition of urban form and the processes that underlie it have been slow to become established (Whitehand, 2009). Due to the lack of theoretical guidance, urban construction is blindly operated, which causes chaotic urban landscape. Under such circumstances, to understand the urban form changing process and urban spatial characteristics based on its morphological changing process is necessary.

As the first step of the research, this paper focuses on public space. Public space is the place that is generally open and accessible to people. The Nolli map represents the city's urban form by figure-ground plan and expresses an understanding of urban structure, urban fabric and public space of Rome. It is actually a relationship between public space and entities. The black part of the map represents the building entity, while the blank part is the public space (Li and Feng, 2017). Unlike Nolly Map, which takes indoor and outdoor public spaces into consideration, this paper focuses on outdoor public space, such as square, streets and path.

2. Method

2.1. *The research area*

As a city in economically developed area of China, Nanjing was chosen for the case study. It is a city with a history of more than 1800 years. As time goes on, the urban functional structure and physical form have undergone profound changes. Like other cities in China, the urban fabric of Nanjing can be recognized as the composition of four main morphological categories: historical blocks, scenic area, residential blocks, and commercial blocks (Zhang and Ding, 2013). Since the different functions of sites within an urban area tend to be differentiated by physical form, each morphological category tends to have distinctive form and can be studied individually (Whitehand, 2009). Among these morphological categories, the space in commercial blocks is particularly complex and has changed dramatically, which has great research value. The Xinjiekou central area is located at the center of Nanjing and has become the business center of this city since 1929. Based on former studies of this area (Zhang and Ding, 2013,2018), a quarter of Xinjiekou central area was used for this study (Figure 1).

2.2. *The research period*

Since the urban construction in China was influenced by the political, economic and land policies at the time, the development of the city can be divided into four period. In 1949, New China was founded, and the planned economy system was gradually formulated. With the Reform and Opening-up Policy in 1978, the planned economy system gradually disintegrated. After 1988, trading of land-use rights through land auctions was legalized, and the former land policy of free allocation began to be phased out. (Zhang, 2018). After decades of economic development, the urban form of Xinjiekou has changed significantly. Therefore, 1949, 1979, 1988, 2000 and 2019 were selected to show the change of urban public space.

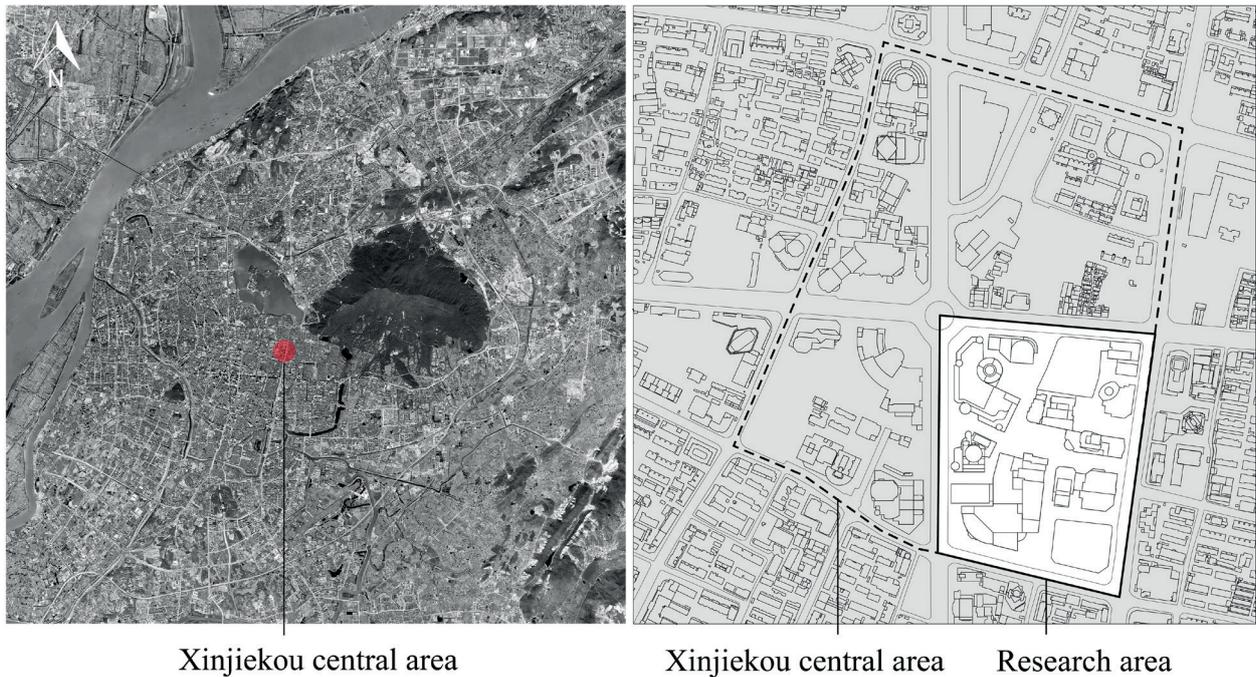


Figure 1. The research area and its location in Nanjing. Source: Google image from 2004 and land-use map of 2019 from the Nanjing planning Bureau.

2.3. Confirmation of public space and sources of the research

Not all open areas are public spaces. Public space is the main place where people are active in the city, including active streets (surrounded by commercial buildings), squares, parks, etc. Private courtyards and internal roads of residential areas are not the public space. The judgment of the current public space can be achieved through on-site investigation, while that of the past public space is more difficult and needs the evidence to infer.

Through the field investigation, the location of public space in the block in 2019 was confirmed. Figure 2 shows the drawings and photos of the spaces in the block in 2019. Among them, all except No. 6 (the dump) and No. 16 (the construction site) are public spaces.

The location of current public space can provide reference to judge the location of the public space before. Some public spaces have not changed during the development of the block, so that the former location was still the public space. While further research is needed on the changed space.

Morphological investigations depend heavily on historical maps and other tangible evidence. It is necessary to synthesize various information to infer how public space evolved in the past. The first step is to collect maps of past corresponding stages. The maps were collected from the Nanjing Urban Construction Archives (NUCA), which is the organization in charge of all urban planning and construction documents in Nanjing. NUCA can provide documents including land ownership and building block-plans in 1952, examination and approval archives of land use planning and engineering planning in 1979 and 1988, and digital map in 2000. Based on these maps, we can get maps containing information about buildings, walls, roads and some land use function in 1949, 1979, 1988, 2000 and 2019. In addition, through interviews and collecting photos from the past, the land utilization can be further distinguished (Figure 3).

During the study of judging the past public space, we find that the information of the 'work unit system', or danwei, is a very important reference. After 1949, danwei became the basic unit

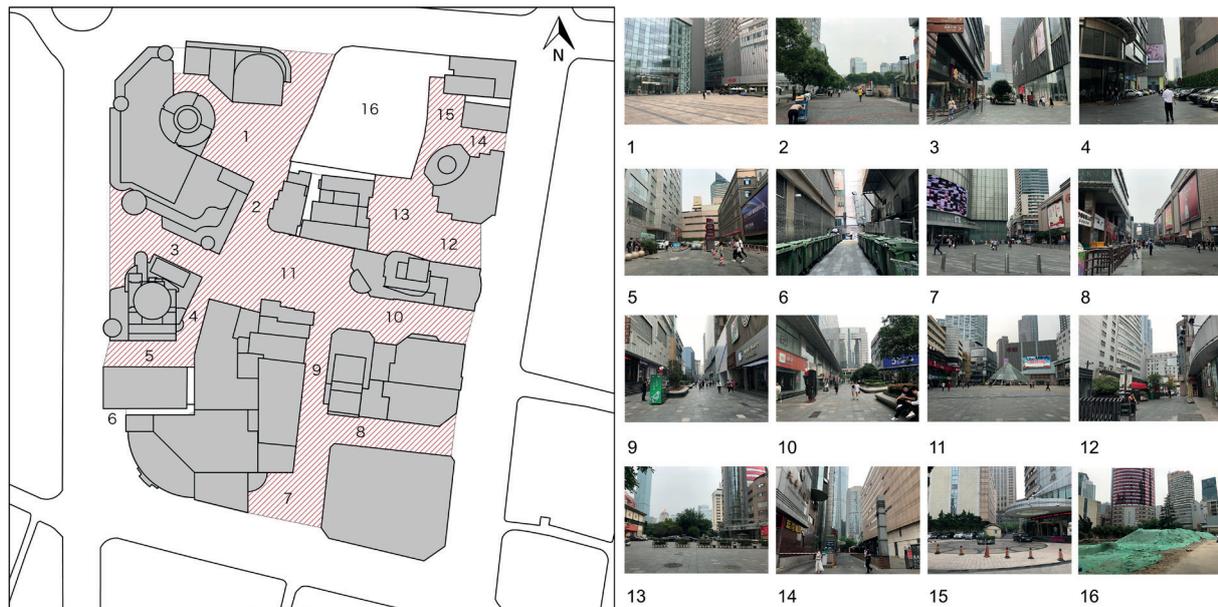


Figure 2. The drawing of the public space and the photos of the spaces in the block in 2019.



Figure 3. Different maps and photos of the research area. Source: (a-b) Nanjing Urban Construction Archives (NUCA); (c) Local chronicles of Jiangsu province; (d) www.picturechina.com.cn. (a. Land ownership and building block-plans in 1952; b. Examination and approval archives of engineering planning in 1988; c. Aerial view of Xinjiekou district in the 1930s; d. The photo in the 1950s.)

and subsystem of urban society in China (Bray, 2005). A danwei is actually a social tax payment entity, such as a department store, cultural institution, government body, factory or school. For the sake of security and privacy, danweis usually build walls on the boundary of the plot.

Therefore, the method for determining the public space of the block is as follows. Firstly, according to the position of the wall on the map, the inside and outside of the danwei are determined. The inside of the wall is basically the private space, and the outside of the wall may be the public space. Then, according to the land use of the surrounding plots of the space, and referring to the distribution of the public space afterwards, the distribution of the public space of each research period is finally determined (figure 4).

3. Analysis on changes in public space in the block of Xinjiekou

3.1. Three types of public space

Since 1949, there have been three types of public space in the block: street, semi-square, and square (figure 5). A street is a strip space and a public thoroughfare in the built environment.

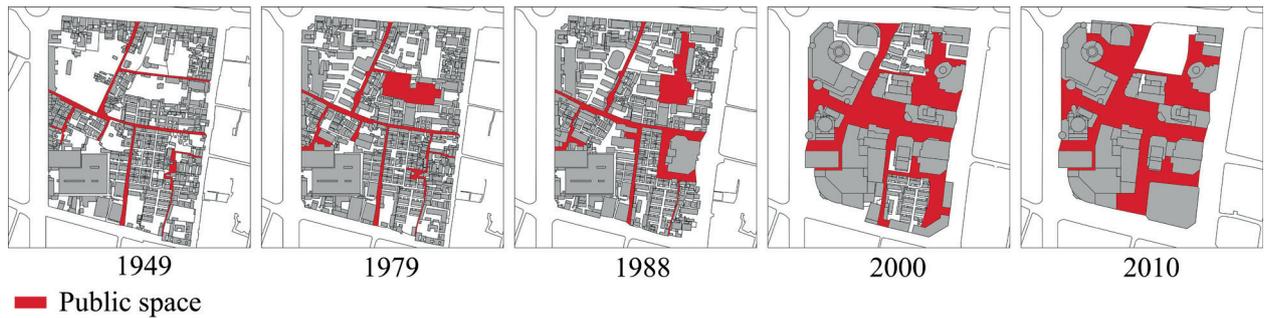


Figure 4. The transformation of public space in the block of Xinjiekou central area.

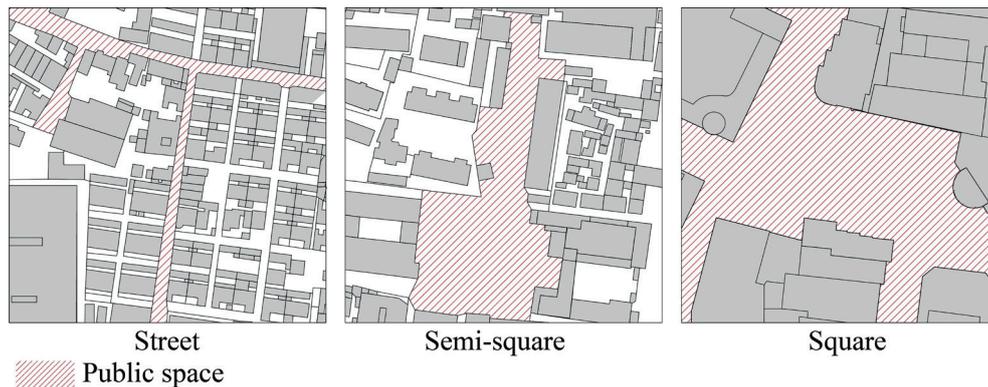


Figure 5. The types of public space: street, semi-square, square.

Semi-square is the square inside the danwei, such as Workers' Culture Palace. Semi-square is closed by walls or gates and is only open to specific groups of people, such as workers. A square is usually a flat open place for people to meeting or rest. In ancient Chinese cities, apart from the front of the temple, there is a lack of squares.

Kropf proposed a multi-level diagram to represent the generic structure of built form (Kropf, 2018). It also highlights the three types of void that constitute the 'usable spaces' of the built environment: rooms, open areas and street spaces (Figure 6 a). Based on the void in the multiple diagram, this paper further defines the scope of outdoor public space: semi-squares, squares and public streets (Figure 6 b). It helps to understand the meaning of different kinds of public spaces.

3.2. Preliminary comparison

According to the maps of the public space from 1949 to 2019, the changes in the area of the public space, the area of the different types of the public space, and the length of the streets are calculated and compared.

Figure 7.a shows that the area of the public space is constantly increasing from 1949 to 2019. There is a sharp increase from 1949 to 1979, and from 1988 to 2000. While in the 10 years from 1979 to 1988, there was basically no change in the area of public space.

By comparing the changes in the area of specific types of public space (Figure 7.b), we can find that semi-square appeared in 1979 and disappeared in 2000. The semi-square belongs to the Workers' Cultural palace. At the beginning of New China, the palace was inserted into this central city area as a symbol denoting the improvement in social status of the workers. With the development of the city, the palace has lost its past glory. After many times of government

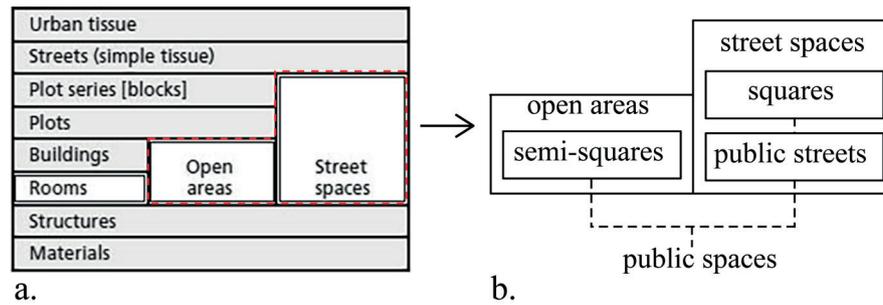


Figure 6. (a) The multi-level diagram of generic structure (Kropf, 2018). (b) The scope of public space.

planning and demolition, the area of the palace has been shrinking and moved to another location finally. The first square appeared in 2000. When land markets were authorized after 1988, the creation of new danweis gradually ended and the past danweis are gradually relocated and demolished. The Xijiekou central area has gradually developed into a commercial center gathering commercial complexes. The square surrounded by many commercial buildings appeared.

The streets have always existed from 1949 to 2019. Although the area of streets is getting bigger and bigger, the length of the street is almost constant (figure 7 c). This implies that the width of the street has increased.

4. Quantification of spatial morphological characteristics

4.1. The object of comparison

During the development of the block, there are three streets that have always existed, namely Pobuying, Zhenghong Street, and Zhenghongli (figure 8). Among them, Pubuying and Zhenghongli were renamed Xijiekou Pedestrian Street after 2000. Zhenghong Street is an east-west street, and the other two are north-south streets. Only the public space that has always existed has the comparability of spatial morphological features. Therefore, the three streets are chosen as the object of quantitative comparison.

4.2. The method of comparison

There are many methods to quantify the characteristics of space. Various simulation tools have been developed based on the concepts of 'convex space', the 'viewshed' and 'isovists' (Turner *et al.*, 2001). As a network form, the accessibility, proximity, integration and connectivity of urban space can be analyzed by means of the "space syntax" methodology. Wowo Ding (2011) proposes a new kind of pattern: street spatial related line to indicate the street spatial characters based on the viewshed analysis in GIS. Starting from the human movement within an urban configuration and the visibility of spaces, the Space Syntax method analyzes open spaces by isovists, which are 'the set of all points visible from a given vantage point in space' analyzed according to six parameters: area field, perimeter, visible perimeter, compactness, occlusivity, variance and the skewness of radial distances (Benedikt, 1979). Batty suggests a new approach to analyzing isovist spaces. In this approach, the polygonal structure of an isovist field is changed with tessellation based on a regular grid (Batty, 2001).

Due to the complexity of urban space, the indicators for measuring spatial characteristics are

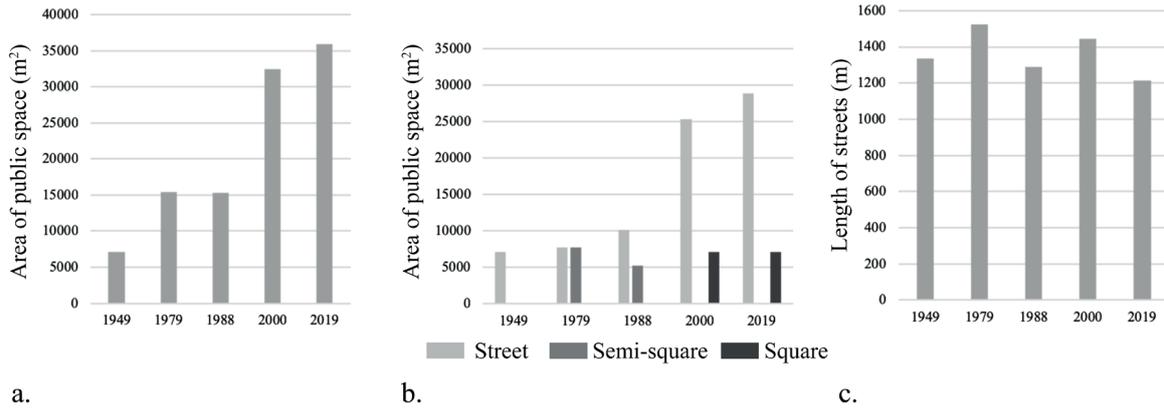


Figure 7. The statistics of the transformation of public space: area of public space, area of 3 types of public space, length of streets.

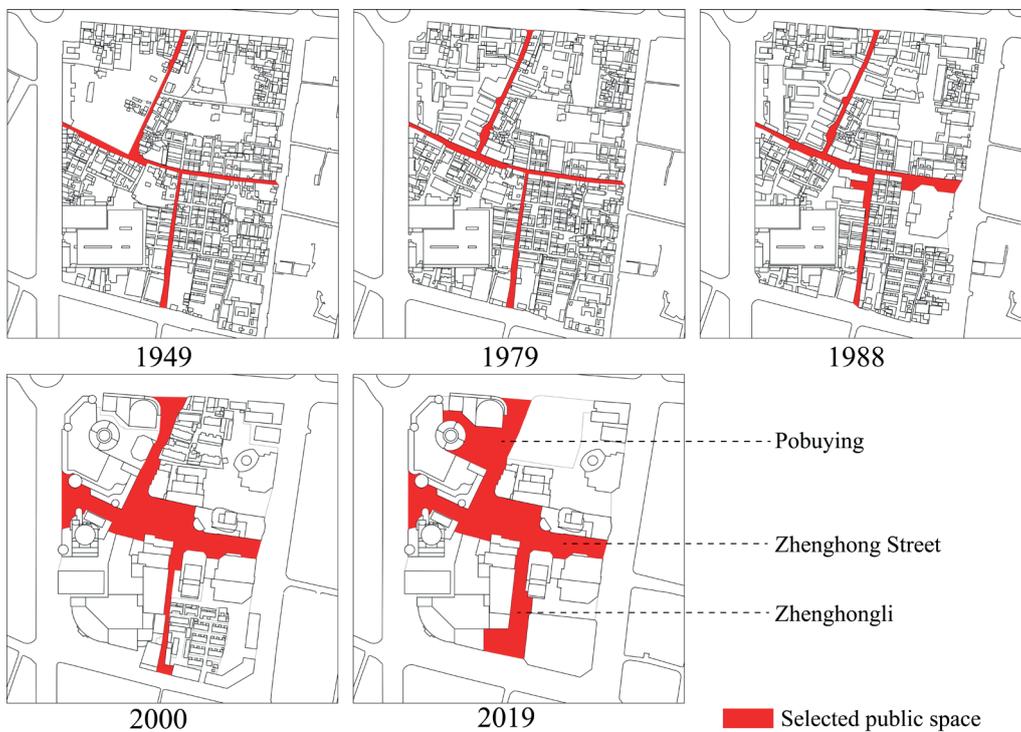


Figure 8. Three streets in the block from 1949 to 2019: Pobuying, Zhenghong Street, and Zhenghongli.

diverse. For urban activities, the size of space determines the function and carrying capacity of space, affecting the perception of space and the physical environment. In the case of the same size, the shape often determines whether a space is a square or a street. Even if the space is the same size and shape, the degree of enclosure can determine the nature of the activity, changing the openness and ventilation quality of the space.

Based on the former research (Ji, You and Ding, 2018), a new analytical model to assess the spatial features of the public space within the blocks has been developed. The model uses four indicators including area, average width, circularity and openness to quantify spatial features.

The area is the area of the enclosed space. The average width is the average of the width of the street taken every 30 meters. The circularity is the ratio of the perimeter to the area. The openness is the ratio of the length of the opening to the total length.

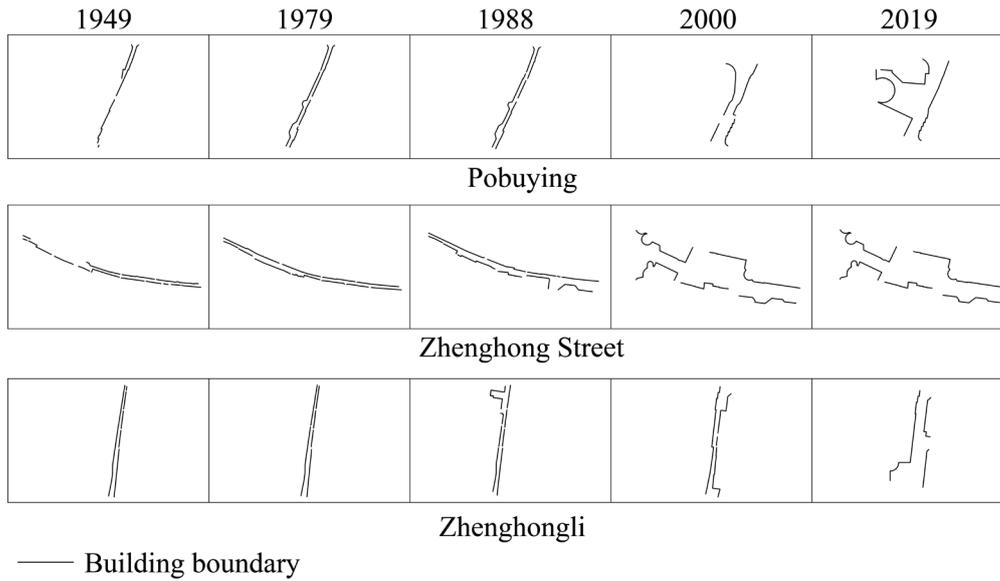


Figure 9. Three streets for comparison: Pobuying, Zhenghong Street, and Zhenghongli.

5. Experimentation on three streets in the block of Xinjiekou

6.1. The three streets

Figure 9 illustrates the three streets: Pobuying, Zhenghong Street and Zhenghongli from 1949 to 2019 respectively. Building borders of the space are indicated by solid lines and the openings are indicated by dashed lines.

5.2. Data calculation and analysis

There are four measures to describe the configuration of the public space: area, average width, circularity and openness. We calculate the measures and use these data for comparison and analysis (Table 1).

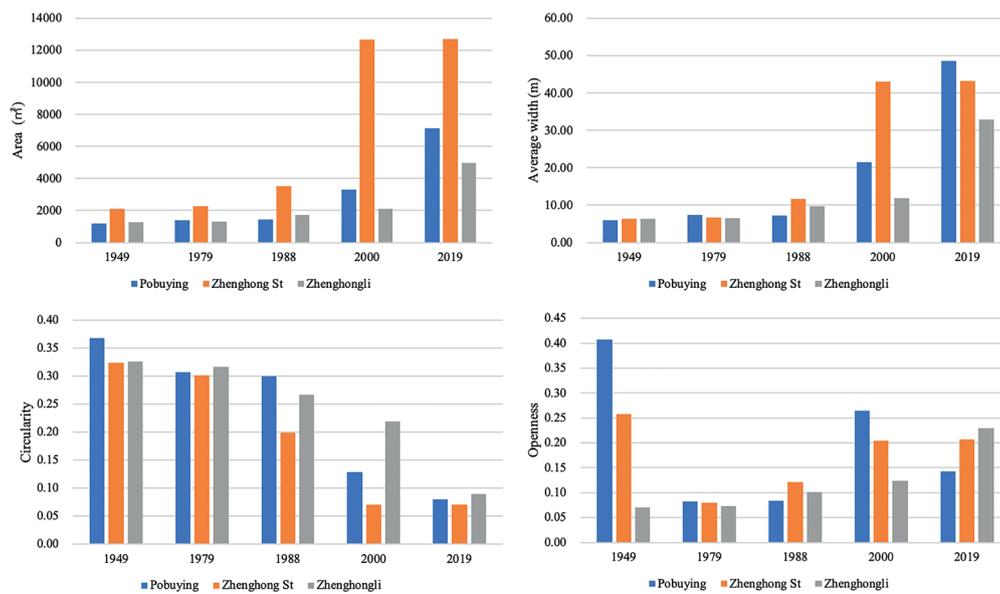
Based on the statistics, we could compare changes in the characteristics of the public space.

1. The three streets are constantly growing in area and have grown significantly from 1988 to 2000, with little or no change before and after. Because in China from 1949 to 1988, the land unit for urban construction was freely allocated land. The process of plot metamorphosis was dominated by the planned economy system and develops through the creation and change of danweis' physical form. When land markets were authorized after 1988, the creation of new danweis gradually ended and the past danweis are gradually relocated and demolished. This block has gradually become a modern business district with multiple commercial complexes and office buildings, so the roads widen and the area of the public space increases.
2. The trend of average street width is similar to that of the area of the street, which shows an overall trend of growth, especially after 1988, which has hardly changed before. This change is particularly evident on Zhenghong Street.
3. The circularity of the three streets is getting smaller and smaller. This means that the shape of the space is becoming more and more spacious. This change is also particularly obvious

Table 1. The statistics and bar chart of four measures of the space.

Streets	Indicators	1949	1979	1988	2000	2019
Pobuying	Area (m ²)	1191	1393	1421	3323	7125
	Average width (m)	6.00	7.40	7.20	21.43	48.57
	Circularity	0.37	0.31	0.30	0.13	0.08
	Openness	0.41	0.08	0.08	0.26	0.14
Zhenghong St	Area (m ²)	2111	2252	3508	12699	12712
	Average width (m)	6.35	6.71	11.67	43.14	43.36
	Circularity	0.32	0.30	0.20	0.07	0.07
	Openness	0.26	0.08	0.12	0.20	0.21
Zhenghongli	Area (m ²)	1263	1306	1716	2089	4960
	Average width (m)	6.30	6.50	9.78	11.80	33.00
	Circularity	0.33	0.32	0.27	0.22	0.09
	Openness	0.07	0.07	0.10	0.12	0.23

a.



b.

on Zhenghong Street. Because the first square appeared in the middle section of Zhenghong Street around 2000, which made the space more spacious.

4. However, in terms of the change in openness, the three streets are not consistent. The openness of Zhenghongli is getting bigger and bigger. Because Zhenghongli was surrounded by danweis at the beginning. Then danweis were gradually demolished, and three commercial buildings were built around, which made the space in Zhenghongli more open. The openness of Zhenghong street was the highest in 1949, then shrank rapidly, reaching its minimum in 1979. Since 1979, it has continued to grow. Like Zhenghong Street, Pobuying was the most open in 1949 and then decreased. It increased after 1979 and decreased again after 2000. Because in 1949, the space in the northwest of the block was farmland, which is very open. After that, the land was quickly occupied by danweis (Xinbai Department Store and the Commercial Bureau Staff Dormitory), which made the space feel more closed. After 2000, danweis were demolished and replaced by commercial complexes. The space became open



Figure 10. Perspectives and the photo from the same location in the block from 1949 to 2019.

again. Due to the demolition of the building on the west side of the road, the openness of Pobuying decreased in 2019.

Quantitative description the change of urban form from the perspective of space coincides with people's perception of space. For example, figure 10 shows the perspective of people from the same location in the block from 1949 to 2019. From these photos, we can intuitively feel the space of this place from empty in 1949 to narrow in 1979 and 1988, then to high and spacious in 2000 and 2019, which are consistent with the statistics of above measures of the space.

6. Conclusion

This study shows that it is feasible to use spatial change to express urban morphological change. The steps are as follows.

1. Select the study area and get maps of the area containing buildings, walls, and building functions. The materials can be found in the local urban construction institutions, such as Urban Construction Archives in Nanjing.
2. Through the on-site investigation, get the location of the public space in the block at present. Then, combined with historical information and interviews with local residents, the location of public space at various stages in the past is deduced.
3. Select the public space that has existed from the beginning to the present and calculate the spatial characteristic indicators: area, average width, circularity and openness.
4. Analyze the above indicators and get the changes of the public space.

Taking the block of Xinjiekou central area in Nanjing as an example, this paper studies the change of urban form by quantitatively describing the spatial change. The area and average width of the streets are getting bigger and bigger, while the circularity is getting smaller and smaller. The change of openness is not absolute, but it tends to become bigger in the end. The area of traditional public space is usually about 2000 square meters, while that of modern space is often more than 4000 square meters. Traditional streets are 6.5 meters wide and modern streets are 40 meters wide. The circularity of traditional public space is usually about 0.32, while that of modern space is about 0.08. The minimum openness of the public space is 0.07, when the

surrounding buildings are danweis; the maximum openness is 0.41, when the space is surrounded by the farmland. The openness of modern public space is about 0.2.

The advantage of this method is that it combines with people's perception of space and can tell people where the public space has changed. It also provides a numerical reference for urban designers and architects who want to restore the traditional image of urban public space. However, the disadvantage of this method is that it does not describe the three-dimensional information of the space, which needs further study.

7. Acknowledgement

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References

- Bray D. (2005) *Social space and governance in urban China: the danwei system from origins to reform*, Stanford University Press, Stanford.
- Benedikt M.L. (1979), *To take hold of space: isovists and isovist fields*, in *Environment and Planning B* 6, pp. 47-65.
- Batty M. (2001), *Exploring isovist fields: space and shape in architectural and urban morphology*, in *Environment and Planning B: Planning and Design*, 28, pp. 123-150.
- Çelik Z., Favro D.G., Ingersoll R. (1994), *Streets: Critical Perspectives on Public Space*, University of California Press, Berkeley and Los Angeles.
- Ding W., Tong Z. (2011), *An approach for simulating the street spatial patterns*, in *Building Simulation* 4(4), pp. 321-333.
- Ji H., You W., Ding W. (2018) *An approach to describe the spatial configuration based upon the block*, 25th ISUF International Seminar on Urban Form, Krasnoyarsk, Russia.
- Kropf K.S. (2009), *Aspects of urban form*, in *Urban Morphology* 13, pp. 105-20.
- Kropf K. (2018), *The handbook of urban morphology*, John Wiley & Sons.
- Li M., Feng J. (2017), *An analysis of the value of the Nolli map's analytical method*, in *New Architecture*, (4), p. 3.
- Moudon A.V. (1997), *Urban morphology as an emerging interdisciplinary field*, in *Urban Morphology* 1, pp. 3-10.
- Moughtin C. (2003a), *Urban Design: Method and Techniques*, Butterworth-Heinemann Architectural Press, Oxford.
- Moughtin C. (2003b), *Urban Design: Street and Square*, Architectural Press, London.
- Osmond P. (2010), *The urban structural unit: towards a descriptive framework to support urban analysis and planning*, in *Urban Morphology*, 14(1), pp. 5-20.
- Whitehand J.W.R. (2009), *The structure of urban landscapes: strengthening research and practice*, in *Urban Morphology*, 13(1), pp. 5-27.
- Woolley H. (2003), *Urban Open Spaces*, Spon Press, London.
- Zhang L.N., Ding W.W. (2013), *Urban plot characteristics study: casing central district in Nanjing, China* (http://issuu.com/linda_carroli/docs/isuf_2013_v2_final) accessed 11September 2013.
- Zhang L., Ding W. (2018), *Changing urban form in a planned economy: the case of Nanjing*, in *Urban Morphology* 22(1), pp. 15-34.