Research on the composition and space utilization of residential neighborhoods in Old Lilong, Shanghai, China: mutual influence between streets and residences from the dual perspective of “activeness” and residential remodeling rate

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**ABSTRACT**
Alongside modern urbanization, traditional Lilong housing structures have undergone tremendous changes in internal and external spatial form and usage status in order to adapt to the needs of modern, social life. In these spontaneous transformations, the street “publicness” and the residential privacy create a set of contradictory relationships that affect the overall morphology of the neighborhood. Taking the traditional lane residential area of Xing’anli, Dongtai Road, Shanghai, China as an example, we analyze the relationship between street “activeness” and the rate of residential remodeling. We attempt to clarify the characteristics of street publicness and housing “privateness” in the traditional Lilong neighborhoods and their mutual effects. This contributes to a comprehensive, workable knowledge of traditional cities and has reference significance for future urban transformation. We analyze the space utilization characteristics of Lilong neighborhoods from two perspectives here. First, with the overflow articles as a medium, we explore the activeness characteristics of different types of roads using the SD method. Second, based on field surveying and mapping, we assess the remodeling characteristics of buildings around different types of roads through remodeling volume and rate statistics. We draw conclusions through careful analysis of the relationship between the street activeness and residential remodeling rate information.

1. Introduction
1.1. Research background and objectives
Shikumen Lilong housing, a traditional residential form, has maintained popularity in Shanghai since 1870. Since they first emerged, about 9,000 Shikumen Lilong houses have been built, ultimately accounting for more than 60% of the total residential area of the city. As the Chinese economy has boomed since the 2008 Beijing Olympics and the 2010 Shanghai World Expo, the social environment in Chinese urban areas has drastically changed. This growth in economy has activated a great deal of city sightseeing, urban beautification, and urban construction projects which have
altered the appearance of streets in Shanghai. More than 70% of Shikumen Lilong houses in Huangpu District, Jing’an District, Hongkou District, Changning District, and Changbei District were demolished as “old cities” across the nation began to be widely remodeled (Figure 1).

Since the 1990s, the Shanghai municipal government has also proposed a series of protective reform policies for Lilong. In 2010, Shikumen-style buildings were identified as an “intangible cultural heritage” by the Chinese government and began to be placed under preservation policies. As the buildings age and the living conditions they provide become outdated, existing Lilong houses have increasingly been utilized as low-cost temporary housing by an increasing number of low-level migrant workers who come to Shanghai, where urban construction is constantly developing. Ensuring the housing for these migrant workers is an important measure for maintaining infrastructure construction in Shanghai as well. Striking a balance between the necessity for preservation and active usage has made existing Lilong housing adaptable, to some extent, though indeed the Lilong environment has changed over the past 150 years. In modern society, the lane residences also play an important role in the city though they are not utilized the same way they once were.

By taking the old Shikumen-style Lilong housing in Shanghai as an example, we defined and analyzed the relationship between building renovations and the external street space during the renewal of urban residential areas in this study. We center our discussion here on the effects of the form and usage of external street public spaces on the residential spaces within the neighborhood, and importantly, the mutual influence between the two. By probing into the relationship between publicness and privateness in the traditional neighborhood, we attempt to understand the utilization characteristics of traditional Lilong space in contemporary life. We believe this work may provide a valuable reference for continued urban transformation.

1.2 Previous research

1.2.1 Previous research on renewal and renovation of Lilong housing

The Transition of the Space and Living Forms in Early Li-Long Housing by Xinming Lu defines the plane composition morphology and residential patterns of Lilong housing in the early stages. It also discusses the management mode and spatial changes in Lilong housing historically (Lu and Shigemura 1992). Succession of Modern Urban Tissues in Shanghai by Metabolizing Li-Long Architecture by Kaori Terada discusses the composition of commercial and residential Lilong neighborhoods and compares various Lilong architectural compositions in terms of the patio position (Terada 2014). A Study on the Redevelopment of Rirou Housing in the inner city of Shanghai, China by Zhengrong Qi chronologically illustrates the renewal of the Lilong housing in Shanghai (Qi 2001).

In Research on the correlation between pedestrian density and street spatial characteristics of commercial blocks in downtown area: a case study on Shanghai Tianzifang, Kai Fang taking Shanghai Tianzifang as an example, attempted to utilize theories, to build a multivariate model with street spatial characteristics as variables, and investigate the correlation between street spatial characteristics and pedestrian density in commercial blocks using multivariate regression analyses of the variables in this model (Fang et al. 2019).

1.2.2 Previous research on the residential area of Lilong and other housing

In The influence of atrium types on the consciousness of shared space in amalgamated traditional dwellings, Xinpeng WANG through the analysis of household overflow in the shared spaces studies the influence on the occupants’ consciousness of the shared space (Wang et al. 2019).

Study on Residential Territorial Recognition of Lilong and New Residential Quarter in Shanghai by Bin Li clarifies that residents have a strong sense of collective territorial identity due to the fact that Lilong housing

Figure 1. Reclassification of the street pattern of Li-long house group.
has a uniform entrance structure (Bin, Kunio, and Takeshi 1999).

1.2.3. Previous research on evaluation of residents’ awareness

The living conditions in Shaoxing road area, Luwan district in Shanghai by Zhengrong Qi proposes that the willingness of potential residents to live in Lilong housing should be judged based on age, dwelling conditions, financial capacity, range of daily activities, and other factors (Qi and Yamashita 2005). A study on the preservation and improvement of the Li-Long housing in Shanghai, China by Jun Hua analyzes the current situation of Lilong housing and the advantages and disadvantages in the current social context through evaluations of residents’ awareness (Hua and Honda 1994).

1.2.4. Previous research on the internal space composition of the Lilong housing

The Metamorphosis of the Alley Space in the Lilong Housing of Shanghai by Katsuhiko Yashiro states that the original architectural style of Lilong housing has completely changed, but the road space and the internal space of the buildings have gradually become closer in the context of a changing historical living environment (Yashiro and Nasu 2005).

1.2.5. Previous research on the types and styles of Lilong housing

Existing research on the architectural types and styles of Shanghai Lilong housing mainly include Lilong Architecture (Wang and Chen 1987), Old Shanghai Shikumen (Lou and Xue 2004), and The Fading Lilong in Shanghai. These books primarily present the historical development, style characteristics, and details of Lilong housing; the classification of Lilong in the book Lilong Architecture by Wang Shaozhu is utilized in this paper.

1.2.6. Application of the SD method in the field of space research

The article SD Method and Environmental Evaluation of Architectural Space by Zhuang Weimin proposed a method for environmental evaluation of architectural spaces by SD. The SD method allows for evaluation of architectural space not only to a perceptual level, but rather, a rational and quantitative analysis level. The article established the principles for setting evaluation criteria, procedures for evaluation operations, multi-factor variable analysis methods for actual investigations, and the significance of evaluation conclusions. Correlation Analysis Between Psychological Evaluation on River Spaces and the Cross-Section Shapes of Revetment and the Spatial Compositions by Norimichi Suzuki presents an analysis of the effects of the spatial elements on the users’ psychological feelings via SD and factor analysis methods and draws a roughly corresponding relationship between them (Suzuki, Tsumita, and Tsumura 2012).

Unlike the researchers described above, we primarily focus on numerical quantitative comparative analysis on the activeness characteristics of Lilong streets and the rate of residential remodeling in this study. We used quantitative research methods such as the SD method and the factor analysis method to explore the mutually influential relationship between the two, and thus investigated the changes and status-quo characteristics of traditional Shanghai neighborhoods.

2. Research summary

2.1. Location

Xing’anli is an old-style Shanghai Shikumen Lilong residence located at Lane 15, Zizhong Road, which is surrounded by four urban roads: Zizhong Road, Dongtai Road, Xizang South Road, and Fuxing Middle Road. The Lilong residence style in Xing’anli can be roughly divided into three periods. The first was in 1929 when the structures more prominent in the southern area, three-story wooden brick and tile structures, were completed. The second was in 1934 when the central area began to feature three-story wooden brick structures. The third was in 1937 when two-story wooden brick structures were constructed in the northern area. A total of 17 residential buildings were built during these three construction periods, with a total construction area of 3,391 square meters. To date – 150 years later – gradual renovations have continually, though sporadically, altered the residential environment. At the end of the twentieth century, the residents reached a consensus and decided to demolish the original houses entirely to rebuild the area. This preparatory work is currently underway despite a large number of residents currently living in the area.

In the book “Lilong Architecture” (Wang and Chen 1987), the author divides the layout and structure of Shanghai Lilong into five categories according to the housing structures and residential configurations. In the survey area, four of the five categories were used to define the Lilong in Xing’anli (Figure 2). The Xing’anli neighborhood consists of 14 main lanes and branch lanes. The four areas we defined are connected to Dongtai Road, the urban throughway on the west side of Xing’anli. The types include the “l-character” type, a straight Lilong like the character “l”; the network type, a Lilong where the east-west and north-south roads form a cross network; the trunk-branch type, a Lilong like the trunk and branches of a tree; and the courtyard type, a Lilong enclosed by houses with an open square in the central area (Figure 3).
2.2. Research method

2.2.1. Technical route
The focus of this study is the interactive relationship between the morphology and usage of external streets and the internal remodeling of neighborhood housing. We first divided the Lilong streets in the survey site into four types, as mentioned above: “I-character”, trunk-branch type, network type, and courtyard type. We then applied the SD method and factor analysis to axially evaluate the duration of residence and the possibility of space utilization as per the overflow of living implements in the trunk and branch lanes of Xing’anli and on Dongtai Road. We further examined the effects of street types on the activeness of the common space in the Lilong neighborhood. Finally, we defined the interactive relationship between street types and Lilong housing by analyzing the residential building remodeling statistics (Figure 4).

2.2.2. SD method
The Semantic Differential (SD) method, a well-established approach to psychological evaluation, has been widely used in research on architecture (Weimin 1996). The SD method allows for architectural space evaluation from not only the perceptual level, but a level of rational and quantitative analysis. We quantitatively analyzed the impact of overflow objects on the evaluation of street space using the SD method using a classroom projection system. Thirty-six architecture students were asked to evaluate five overflow phenomena on a scale of −3, −2, −1, 0, 1, 2, and 3 within the range of the impact of 15 overflow objects on the street activeness with the SD method. We then calculated the average value and standard deviation of their evaluations.

2.2.3. Factor analysis method
The factor analysis method is a multivariate statistical analysis technique that reduces some variables with overlapping information and intricate relationships into a few unrelated comprehensive factors based on the dependence within the correlation matrix of the variable indexes. To operate this method, we first measured the utilization characteristics of Lilong public space using the definition of street activeness. We divided the street activeness into three factors for numerical quantitative evaluation: communication, convenience, and cleanliness of public space.

Psychological Factors I are composed of the scales of communication, such as the frequency of visitors (those who “stay”), whether the neighborhood takes special measures to promote communication, whether people find the area “interesting”, and so on. The communicative factor <unwilling to stay-willing to stay> was selected as the representative scale.

Psychological Factors II relate to the convenience of the street space, including whether it is commonly used, whether it is easily traversed, and whether it has markedly changed over time. The convenience factor <convenient-inconvenient> was selected as the representative scale.
Figure 3. Xing’anli’s measured floor plan and classification of overflowed living goods.
Factors III are composed of cleanness scales on the space, such as whether it is tidy, whether there is vitality, whether it is beautiful, and so on. The cleanness factor <disordered-clean and tidy> was selected as the representative scale.

3. External: activeness of Xing’anli street space

3.1. Specific steps for analyzing the street space activeness
We analyzed the overflow of living goods into the street using SD and factor analysis methods to assess the activeness of the street space. The steps to this process were as follows:

1. The overflow living goods were measured and photographed, and those goods that have an impact on space activeness were classified into six categories:
   1. Mobile devices, mainly bicycles and strollers;
   2. Cleaning tools, mainly brooms and dustpans;
   3. Ornamental plants and animals, mainly outdoor green plants and aquariums;
   4. Furniture, mainly vegetable washing sinks, tables, and chairs;
   5. Airing supplies, mainly clotheslines and drying racks;

| Evaluation items                                      | 1. Mobile devices | 2. Greening | 3. Furniture and sink | 4. Cleaning appliances | 5. Drying supplies |
|-------------------------------------------------------|-------------------|-------------|-----------------------|------------------------|-------------------|
| 1. Block communication - promote communication        | 2.89              | 4.05        | 6.16                  | 1.92                   | 3.58              |
| 2. Don’t want to stay - want to stay                  | 1.25              | 4.12        | 6.37                  | 1.17                   | 4.36              |
| 3. Longtime placement - short time placement          | 6.08              | 1.22        | 2.73                  | 2.26                   | 1.95              |
| 4. Boring - Interesting                               | 2.53              | 5.23        | 5.15                  | 1.88                   | 4.12              |
| 5. Ugly-beautified                                    | 2.37              | 6.65        | 5.12                  | 1.13                   | 1.96              |
| 6. Arbitrarily stopped - reasonable placement         | 5.15              | 5.97        | 6.11                  | 5.13                   | 4.57              |
| 7. Inconvenient - convenient                          | 6.12              | 2.23        | 6.22                  | 4.63                   | 4.69              |
| 8. Constant-changing                                  | 6.65              | 1.72        | 5.22                  | 1.87                   | 3.56              |
| 9. Single-diverse                                     | 1.95              | 5.68        | 5.88                  | 1.65                   | 4.98              |
| 10. Plain - life style                                | 4.55              | 4.72        | 6.62                  | 5.84                   | 6.55              |
| 11. Hard to move - easy to move                       | 6.88              | 1.12        | 3.23                  | 6.21                   | 2.12              |
| 12. Dispersable - life essential                      | 5.23              | 2.35        | 6.13                  | 6.08                   | 6.24              |
| 13. Space saving - space consuming                    | 2.33              | 5.65        | 6.07                  | 1.57                   | 6.31              |
| 14. Disorderly - clean and tidy                       | 4.66              | 5.85        | 5.11                  | 2.63                   | 2.46              |
| 15. Seldom used - commonly used                       | 6.02              | 4.23        | 5.77                  | 5.35                   | 3.65              |

Figure 5. Fifteen scales of impact of five types of overflowed goods on the Street and the average value of SD method evaluation.
6. Other daily necessities such as trash cans, fire extinguishers, temporary shelters, outdoor air conditioners, ladders, odds and ends.

The number of overflow daily necessities in each street was calculated. According to the above classifications, photos of mobility devices, cleaning appliances, foliage plants, furniture, aired items, and other goods were classified (Figure 5).

(2) Projection was performed in the classroom. The architecture students mentioned above were asked to assess the five types of overflow objects on a scale of $\{-3, -2, -1, 0\}$ based on the positive impact of 15 overflow articles on the street activeness with the SD method. The average value and standard deviation were calculated (Figure 6).

(3) We input these psychological quantities as variables into Statistical Product and Service Solutions (SPSS) software to perform a factor analysis to obtain load and inherent values. The three-factor axes with an intrinsic value of 1.0 or more were marked with a cumulative giving rate of 93.98% and three principal components were obtained accordingly. The axes I to III were extracted as the important psychological factor axes for the psychological evaluation of the impact of overflow on the street space activeness (Figure 7). The factors include communication, convenience, and cleanliness, respectively.

### 3.2. Xing’anli street activeness data

The activeness data of the streets in Xing’anli were derived from the SD analysis and factor analysis results (Figure 8). Higher communication, convenience, and cleanliness scores indicate higher street activeness. We multiplied the assessment scores of the three representative scales by the number of overflow articles in each street. Values were assigned to each of the overflow articles respectively. We added the scores on the three scales to obtain the comprehensive numerical value of the overflow articles in each street, then divided this
value by the street area to determine the comprehensive value per unit area of each street (Figure 9). A larger comprehensive value per unit area of the street space suggests higher activeness of that street (Figure 10).

The activeness values of Street B, for example, were calculated as follows:

- Communication: \(68 \times 1.25 + 10 \times 4.12 + 27 \times 6.37 + 25 \times 1.17 + 0 \times 4.36 = 327.44\)
- Convenience: \(68 \times 6.12 + 10 \times 2.23 + 27 \times 6.22 + 25 \times 4.63 + 0 \times 4.69 = 722.15\)
- Cleanliness: \(68 \times 4.66 + 10 \times 5.85 + 27 \times 5.11 + 25 \times 2.63 + 0 \times 2.46 = 579.1\)
- Comprehensive numerical value: \(327.44 + 722.15 + 579.1 = 1628.69\)
- Comprehensive value per unit area: \(1628.69 \div 86.58 = 18.81\)

### 3.3. Integration of activeness data of four Xing'anli street types

For the 15 roads forming Xing'anli, values were assigned to the street types for analysis according to the classifications described above. The total comprehensive scores of each type of street were divided by the street area to obtain the comprehensive score per unit area of each street. A higher comprehensive score per unit area suggests a higher activeness of that street type (Figure 11). For example, the courtyard street is composed of streets G, H, and O. Its numerical calculation is as follows:

- Communication: \(323.15 + 306.68 + 610.87 = 1240.7\)
- Convenience: \(422.73 + 506.66 + 602.11 = 1531.5\)
- Cleanliness: \(455.43 + 410.56 + 476.55 = 1342.54\)

#### Comprehensive total:

\(1240.7 + 1531.5 + 1342.54 = 4114.74\)

#### Comprehensive value per unit area:

\(4114.74 + 209.59 = 19.63\)

### 3.4. Activeness characteristics of four Xing’anli street types

The composition forms of Xing’anli streets allow the survey area to be divided into four parts representing four types of street. The statistical activeness characteristics of the four types of streets in Xinganli can be summarized as follows.

1. **Courtyard street pattern** appears to be most active, followed by trunk-branch street pattern, network streets, and finally, "I character"-shaped streets.

2. **Courtyard street pattern**, in addition to being the most active, also showed higher levels of communication and cleanliness than other types of streets. Their convenience level was slightly lower than that of trunk-branch street pattern, but significantly higher than those of the other two types of streets. The courtyard street space tends to be a public area featuring a high level of communication with residents.

3. The overall activeness of trunk-branch street pattern is second only to that of the courtyard street pattern. Their levels of communication and cleanliness were slightly lower than those of the courtyard street pattern, but their...
convenience level was much higher compared to other types of streets. The trunk-branch street activeness was found to be relatively high. Compared with the courtyard street pattern, the public attribute as an exchange and assembly place weakened, but the attribute as a functional public space was strengthened.

(4) The overall activeness of the network streets was low, only slightly higher than that of the straight street pattern, and their convenience level was lower than the other three types of street. Overall, the network streets have a low level of activeness and a smaller margin for active usage of the space.

(5) The overall activeness of the straight street pattern was the lowest among the four types. Their communication and cleanliness levels were lower than those of other types of streets, and their convenience level was slightly higher than that of the network streets. On the whole, this type of street has low activeness and basically is not constructed as a public area. The overflow of living goods in the straight street pattern involves only storage, and rarely serves to create an interactive space.

4. Internal: Xing’anli neighborhood housing remodeling characteristics

4.1. Step-wise analysis of remodeling characteristics

We attempted to numerically quantify a type of bottom-up remodeling present in the study area to
varying degrees. By assigning values to changes in the number, location, and area of the reconstructed archi-

Figure 11. The measured distribution maps of residential houses in those street patterns.

Figure 12. Schematic diagram of the measured residential houses reconstruction rate.
(1) Our statistical data showed that the original structural type of each household before remodeling could be defined as the initial state for comparison with remodeled structures.

(2) The architectural elements were selected as the basis for evaluating the degree of remodeling and divided into three categories according to their nature:
   a. Building components including front doors, back doors, exterior windows, patios, interior walls, stairs, ground, and other elements;
   b. Architectural installations including canopies and air conditioners, and other elements;

| Pattern of the building’s street | House No. | Area of reconstruction(m²) | Total area of the original building(m²) | Reconstruction rate | Average reconstruction rate |
|---------------------------------|-----------|-----------------------------|------------------------------------------|--------------------|----------------------------|
| Courtyard pattern               | 31        | 183.82                      | 153.70                                   | 1.20               |                            |
|                                 | 32        | 188.16                      | 145.30                                   | 1.29               |                            |
|                                 | 33        | 133.33                      | 122.80                                   | 1.09               |                            |
|                                 | 34        | 72.57                       | 103.10                                   | 0.70               |                            |
|                                 | 35        | 271.86                      | 254.80                                   | 1.07               |                            |
|                                 | 36        | 48.61                       | 55.90                                    | 0.87               |                            |
|                                 | 37        | 10.97                       | 56.70                                    | 0.19               |                            |
|                                 | 38        | 7.89                        | 37.20                                    | 0.21               |                            |
|                                 | 39        | 120.27                      | 37.80                                    | 3.18               |                            |
|                                 | 40        | 13.22                       | 37.40                                    | 0.35               |                            |
|                                 | 41        | 17.90                       | 37.60                                    | 0.48               |                            |
| Mesh pattern                    | 01        | 135.63                      | 55.00                                    | 2.47               |                            |
|                                 | 02        | 126.49                      | 52.00                                    | 2.43               |                            |
|                                 | 03        | 147.67                      | 54.70                                    | 2.70               |                            |
|                                 | 04        | 164.00                      | 120.20                                   | 1.36               |                            |
|                                 | 05        | 85.97                       | 149.40                                   | 0.58               |                            |
|                                 | 06        | 3.98                        | 54.50                                    | 0.07               |                            |
|                                 | 07        | 93.95                       | 54.30                                    | 0.99               |                            |
|                                 | 08        | 59.95                       | 54.60                                    | 1.10               |                            |
|                                 | 09        | 53.21                       | 54.10                                    | 0.98               |                            |
|                                 | 10        | 28.80                       | 54.30                                    | 0.53               |                            |
|                                 | 11        | 109.60                      | 83.90                                    | 1.31               |                            |
|                                 | 12        | 61.80                       | 52.20                                    | 1.18               |                            |
|                                 | 13        | 92.06                       | 54.60                                    | 1.69               |                            |
|                                 | 14        | 104.98                      | 52.00                                    | 2.02               |                            |
|                                 | 15        | 27.98                       | 46.60                                    | 0.60               |                            |
|                                 | 16        | 104.08                      | 46.50                                    | 2.24               |                            |
|                                 | 17        | 87.18                       | 46.60                                    | 1.87               |                            |
|                                 | 18        | 84.16                       | 44.50                                    | 1.89               |                            |
|                                 | 19        | 44.37                       | 45.40                                    | 0.98               |                            |
|                                 | 20        | 22.15                       | 46.10                                    | 0.48               |                            |
|                                 | 21        | 22.15                       | 46.10                                    | 0.48               |                            |
|                                 | 22        | 22.15                       | 46.10                                    | 0.48               |                            |
| Trunk-branch pattern            | 14        | 104.98                      | 52.00                                    | 2.02               |                            |
|                                 | 15        | 62.06                       | 52.30                                    | 1.19               |                            |
|                                 | 16        | 90.43                       | 104.30                                   | 0.87               |                            |
|                                 | 17        | 27.98                       | 46.60                                    | 0.60               |                            |
|                                 | 18        | 104.08                      | 46.50                                    | 2.24               |                            |
|                                 | 19        | 87.18                       | 46.60                                    | 1.87               |                            |
|                                 | 20        | 84.16                       | 44.50                                    | 1.89               |                            |
|                                 | 21        | 44.37                       | 45.40                                    | 0.98               |                            |
|                                 | 22        | 22.15                       | 46.10                                    | 0.48               |                            |
|                                 | 23        | 109.12                      | 52.40                                    | 2.08               |                            |
|                                 | 24        | 88.80                       | 49.90                                    | 1.78               |                            |
|                                 | 25        | 74.40                       | 43.00                                    | 1.73               |                            |
|                                 | 26        | 62.10                       | 46.60                                    | 1.33               |                            |
|                                 | 27        | 89.88                       | 48.00                                    | 1.87               |                            |
| Straight pattern                | 28        | 196.29                      | 87.70                                    | 2.24               |                            |
|                                 | 29        | 148.29                      | 59.10                                    | 2.51               |                            |
|                                 | 30        | 146.09                      | 65.90                                    | 2.22               |                            |
|                                 | 31        | 183.82                      | 153.70                                   | 1.20               |                            |
|                                 | 32        | 188.16                      | 145.30                                   | 1.29               |                            |
|                                 | 33        | 133.33                      | 122.80                                   | 1.09               |                            |
|                                 | 34        | 72.57                       | 103.10                                   | 0.70               |                            |

Figure 13. The average reconstruction rate of the four street patterns.
4.2. Types of different neighborhood rebuilding

A. Xing’anli

Figures 12–14 show the overall rebuilding rate distribution of different types of streets in Xing’anli. The rate of streets that underwent remodeling fell into the following categories:

1. Courtyard pattern
2. Mesh pattern
3. Trunk-branch pattern
4. Straight pattern

The pattern of the first half of the houses 1–14 and houses 17–22 belongs to the mesh street pattern. The houses 14–27 fall into the trunk-branch street pattern. The houses 28–34 fall into the straight street pattern. The houses 31–41 fall into the courtyard street pattern.

4.2. Data on residential remodeling rate of four types of streets in Xing’anli

The remodeling rates of residential buildings in the Xing’anli neighborhood were calculated and used to classify the residential buildings by street type to obtain the average value of the remodeling rates of houses in different types of streets (Figures 13 and Figures 14). A higher rate of remodeling indicates a higher degree of remodeling. The remodeling rate was calculated as follows:

\[ \text{Remodeling rate} = \frac{\text{area of addition and rebuilding/total area of original building (S1+S2+S3+S4...)}}{\text{St}} \]

4.3. Characteristics of remodeling rates for Xing’anli structures by street type

According to the above statistics, the characteristics of the remodeling rate of the four types of streets in Xing’anli are as follows:

1. The remodeling rates of structures in the study area can be ranked from high to low as straight street pattern, trunk-branch street pattern, mesh street pattern, and courtyard street pattern.
2. Internal remodeling occurred in greater amounts than external remodeling, so the overall remodeling rate was largely dependent on the internal remodeling rate. The external remodeling rate and the internal remodeling rate were negatively correlated on the four types of street.
3. The overall remodeling rate of houses in the courtyard street pattern was significantly lower than that of other types of street. The houses in the courtyard street pattern showed a low internal remodeling rate but a higher external remodeling rate than the other three types of street.
4. The remodeling rates of trunk-branch street pattern and mesh street pattern were moderate – slightly higher than on the mesh street pattern, mainly due to the rates of internal remodeling. The external remodeling rates of the two were basically the same.
5. The straight street pattern showed the highest residual remodeling rate among all four types of street. The straight street pattern had an internal remodeling rate significantly
higher than other street types but lower external remodeling rate than the others.

5. Discussion

5.1. Characteristics of four types of street in Xing’anli

Based on the data analysis and the results of field investigations, the space utilization characteristics and residential remodeling characteristics of the four types of streets in Xing’anli as identified here can be summarized as follows.

(1) The activeness of street space was high for courtyard street pattern and the houses along them. The use of space there tended to be public and feature a high level of communication. The degree of residential remodeling was relatively low, but the degree of remodeling of the external space facing the street was higher compared to the other types of street. Our survey also showed that the public attributes of the space after renovation of courtyard street houses was higher compared to other types of street. For example, newly remodeled patio spaces tended to be shared among residents, rather than private patios, after being rebuilt.

(2) The activeness of street space was relatively high along trunk-branch street pattern and tended to have higher functional, public attributes compared to the courtyard-style streets. The internal remodeling rate of surrounding residential buildings was relatively high there as well. Compared with the courtyard street pattern, the residential remodeling was more internal.

(3) The activeness of space along mesh street pattern and their residential structures was relatively low. The traffic attributes of these streets were stronger than the others and the spaces along them were less frequently shaped as public living spaces. The degree of residential remodeling of the mesh street pattern was similar to that of the trunk-branch street pattern, but slightly lower than that of the trunk-branch street pattern. Unlike the patio renovations on courtyard street pattern, the patios on this type of street were usually capped and used as private spaces.

(4) The straight street pattern showed the lowest degree of activeness, suggesting that these streets are generally not utilized effectively. The overflow space alongside them was generally only used for storage. The surrounding residential remodeling rate was the highest there, and this remodeling was internal; the external remodeling rate of this type of street was lower than along the other types of street.

5.2. Internal and external correlations between the activeness characteristics of the four types of streets in Xing’anli and their characteristics of residential remodeling rates

Trunk-branch street pattern, mesh street pattern, and straight street pattern in Xing’an decreased in sequence from the perspective of street space activeness. Activeness thus appears to be affected by the specific form of the street. For example, the courtyard street pattern were more likely to be used as public gathering spaces, while the strong traffic attributes of straight street pattern tended to lower like likelihood that they were used as public living spaces. The increase in street space activeness also appears to correspond to a decrease in the remodeling rate. This decrease primarily depends on the internal remodeling rate, while the external remodeling rate exhibits an opposing relationship. Based on our survey results, the activeness of external space has made the remodeling of houses relatively more open.

This finding does not align with the conventional expectations. In East Asian culture, the conceptual expression of public versus private is complicated; neighborhoods usually do not have strict public-private boundaries. Previous research has mostly centered on the spillover of private space. Here, we found that the blurring of the boundary between public and private spaces in Xing’anli cannot be simply regarded as an encroachment on public space by private space. Rather, the effects of the two are mutual. For example, the external remodeling of courtyard-type street residences has formed a public space for gatherings and communication. For the straight street pattern showed stronger functional attributes and their street spaces were characterized more as an extension of private space.

6. Conclusion

We used the Xing’anli neighborhood as a research object in this study to explore the characteristics of street publicness and home privateness in traditional Lilong neighborhoods. We also examined the interaction between them as per street activeness and residential remodeling rate data. We centered our analysis on the effects of the form and usage of external street public space on the residential space within the neighborhood, as well as the interactive relationship between the two. Our conclusions can be summarized as follows.

(1) We divided Xing’anli Lilong streets into four types: courtyard, trunk-branch, grid, and
“I-character”. We successfully measured the characteristics of the use of public space in the neighborhood using the street activeness, then determined the activeness characteristics of the four types of streets primarily using the SD method, factor analysis method, and other quantitative research methods.

(2) We successfully established a mathematical model to simulate the dynamic changes of bottom-up remodeling behavior in Lilong housing by assigning values to changes in the number, location, and area of the remodeled building elements.

(3) We defined the interactive relationship between street activeness characteristics and residential remodeling rate characteristics. Our results indicate that in the case of Xing’anli, the activeness of different types of street and the degree of residential remodeling have a somewhat negative correlation.

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