Phenomenon of Shared Living in Residential Historic Areas and Its Unit-Based Identification Method

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Abstract: The phenomenon of shared living, characterized by the high integration of spatial structures and social relations, represents an efficient model of neighborhood residence and is one of the challenges in the renewal of residential historic areas. From both spatial and social dimensions, with the smallest residential unit as a node, this study identifies multiple connection types at the urban, shared, and private levels based on depth and path methods, and constructs a spatial network using spatial gravity. Simultaneously, it constructs an adjacency matrix reflecting relationships among acquaintances, semi-acquaintances, and strangers to form a weighted network with social characteristics. By combining the two through matrix operations, a "relational-spatial" network is developed to reveal the comprehensive structural characteristics and unit cluster features of residential historic areas, deriving a unit-based identification method for shared living. The validity of this identification method is tested with samples under different ownership statuses, and the scientific and practical value of the "relational-spatial" network and unit-based identification method are discussed in terms of spatial cognition, renewal design, and institutional practice in historic areas.

Keywords:residential historic area; shared living; "relational-spatial" network; unit-based identification; urban renewal

1. Background

The study and renewal practices of urban stock spaces should consider not only the material spatial entities but also the connections between residents and the environment[1]. Due to changes in living patterns, policies, and systems, residential historic areas are undergoing continuous reconstruction of spatial and social relationships, which influence each other and are closely intertwined. Taking Nanjing as an example, during the late Qing and Republican periods, urban residential areas formed a residential structure based on family and clan relations, facilitated by the sale of private land [2]. At that time, residential spaces were clearly divided, with courtyard walls marking boundaries, maintaining traditional residential structures within[3]. Marked by a series of policy documents①, land and housing systems were continuously reformed after the founding of the People's Republic of China. The influx of new residents into existing spaces, coupled with the intergenerational inheritance of original residents that led to spatial division, gradually made mixed and shared occupancy dominant. This shift in residential patterns occurred alongside the renovation and expansion of buildings. Spatial structures and boundaries became increasingly blurred, residents began sharing living spaces and facilities, and shared living became the prevailing lifestyle in these areas (see Figure 1).

Fig.1 Common living in residential historic districts

The shared living phenomenon in residential historic areas has two fundamental characteristics: in terms of social relations, residents are familiar with each other, connected by kinship and geographic ties[4], thus creating a social network[5]; in terms of physical space, various residential spaces are interconnected, forming shared living spaces. Although the shared living model involves competition and negotiation over spatial usage rights due to limited resources, there is mutual assistance and collaboration among neighbors, fostering a sense of belonging and identity within the shared space. Compared to the individual-segregated residential models often emphasized in current residential space design, the shared living model promotes better neighborhood connections. This model is related to the unique cultural context in China, embodying close-knit social relationships akin to a community. Additionally, as residential historic areas are often located in old urban districts, utilizing limited shared spaces for residential functions can increase spatial efficiency to meet high-density requirements, providing a distinctive paradigm for efficient neighborhood construction.

Due to the composite characteristics of space and social relations in residential historic areas[6], discussing them separately would not allow for an accurate analysis of the comprehensive attributes of shared living. Therefore, this paper focuses on constructing an integrated method that links spatial and social analyses. Understanding the composite structure of social and spatial aspects in historic areas enables the identification of shared living characteristics and recognition methods, thus providing a foundation for analysis and practice. This approach serves two main purposes: it provides a research methodology for further elaborating the social and spatial relational characteristics of urban stock spaces and offers a scientifically effective design tool for the renewal practices of contemporary residential historic areas.

2 Relationships and Spatial Networks

2.1 Methodological foundations

In the study of the composite relationship between space and society, Hillier et al[7]. introduced early concepts of a “bi-polar system” and “spatial order” in The Social Logic of Space. The bi-polar system abstracts space into a relational model, with the building unit as one pole and urban space as the other. The spatial structure between these two poles is viewed as a means of connecting two types of social relationships: relationships between residents within the system and relationships between residents and strangers, thus linking social relationships to spatial arrangements. Spatial order, on the other hand, abstracts space by establishing depth characteristics through nodes and links[8] to articulate the sequential relationships between spaces, enabling their discussion and analysis. Subsequently, the concept of configuration was introduced to describe the relational attributes of spatial structures[9]. This approach, employing justified graphs, unitizes spatial elements and analyzes urban space composition based on depth and connectivity, forming a broadly applicable method and framework for analyzing urban spaces. Additionally, Stephen Marshall[10] discussed route structures by examining connections between local and global elements, elucidating the structural layout of streets and urban spaces through primary and secondary routes.

Whether by abstracting urban space to discuss structural and topological relationships, or by focusing on connection attributes, these methods point to research approaches that abstract individual relationships. From Conzen's theory of the three elements of urban landscape, Kropf and others constructed a concept of compositional hierarchy, explaining the organizational logic of urban space through hierarchical relationships between city and building. Buildings and areas form plots, which, in turn, combine into plot sequences, creating an urban texture alongside street spaces. Song Yacheng et al[11]. proposed the concept of "material plots," using access patterns as identification features to interpret China's unique, complex urban spaces. By determining plot units based on ownership or management, they addressed the issue of complexity. This theoretical tradition, akin to urban architectural art[12], emphasizes the relationship between land units and urban space[13] and establishes a hierarchy-based spatial segmentation approach.

For the specific characteristics of residential areas in China, these research methods should evolve to address the following issues: first, a deeper explanation of local relational characteristics. Previous methods focused on local-to-global composition and used tree-like sequences to effectively analyze urban space. However, the relationships among local units, such as those between residents and residential units, characteristic of residential areas, also require in-depth analysis. Thus, a "bottom-up" network relational model may be constructed to establish a foundation for relational analysis. Second, a more in-depth examination of the composite nature of social and spatial structures is needed. Changes in a single element of a social relationship impact related elements, making isolated analysis impossible. While the hierarchical composition of space can explain physical dimensions, it does not accurately capture the associated social attributes. Therefore, a spatial model linked to social networks is needed to address the composite structure as a whole[14].

2.2 Depth-based path type construction

To describe the network structure focused on in this paper, it is first essential to clarify the basic units. According to graph theory notation, this basic unit should be simplified into a node during analysis to discuss mutual relationships. Following Kropf's construction method, rooms can serve as the basic unit (with materials and structural layers that do not occupy usable space). In areas in China with a high degree of spatial and social complexity, such nodes should carry social meaning in addition to spatial significance—the resident within the basic unit can also be simplified as a node in the social relationship network to establish a link between spatial structure and social relations. To more accurately describe the integrated structural features, a basic unit with social significance can be defined—this is an independent residential unit protected by a public housing lease, a property ownership certificate, or other legal documentation. It can consist of one or multiple rooms but must have a lockable entrance, house a single resident or family, and be independent and indivisible②.

By defining the basic units, an "edge" can represent specific relationships between nodes, allowing for discussion of how basic units reach the two-pole structure of the city. Based on usage properties, historic areas can be divided into three spatial depths—private, common, and urban. From the resident's perspective, private space can be defined as depth 0, common space as depth 1, and urban space as depth 2. Using the access path representation in node-line diagrams[15], here, "●" represents private space (P), "▲" common space (C), and "■" urban space (U) (see Figure 2). Type 1 represents a path where a node crosses from the P layer through the C layer directly to the U layer, while Type 2 represents a path where a node reaches the U layer through the C layer from depth in the P layer. Similarly, multiple nodes may have outward path structures. Different from defining depth based on access from public spaces to rooms③, defining depth from the resident's perspective more accurately reflects the actual living situation—depth 0 is the area where daily life is most frequent and is also the area most familiar to the resident.

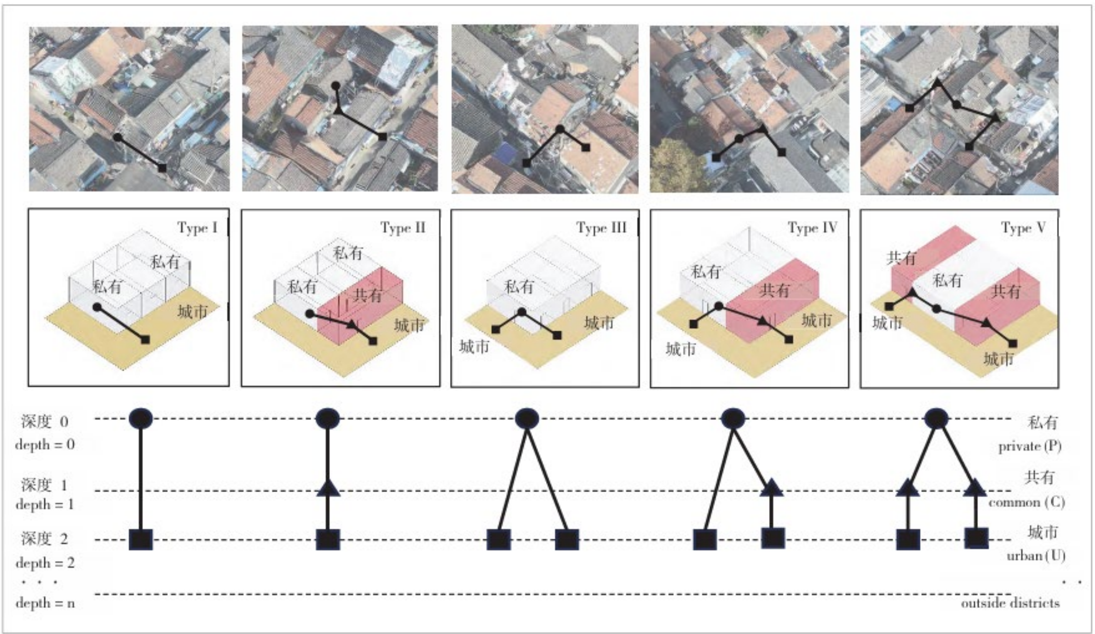


Fig.2 Five types of space connections from private to urban layers

This approach allows us to summarize the path types between basic units: by treating each private residential space in the area as a node, we can represent its topological path structure by the type of path between node pairs (see Figure 3). Spatial topological relationships are often measured by topological steps, so the relationship between node pairs can be expressed by the topological path step count S. In historic areas, the topological path step count is the total number of topological steps combining depth levels and urban space dual steps. For example, Type A represents a path where a node moves from the P layer through the C layer back to the P layer, traversing 2 depth levels, resulting in a path step count S of 2. Similarly, Type B represents a path where a node moves from the P layer through the C layer to the U layer and then back through the C layer to the P layer, traversing 4 depth levels in total, giving a path step count S of 4. Types C and E represent topological paths where the node pairs experience multiple turns in the urban space, shown as "□" in the figure. In this case, each turn in the urban space counts as 1, and if the path has n turns, the path step count is 4 + n. Here, n is a spatial topological structural feature corresponding to depth levels rather than a geometric feature and is confirmed by dual representation[16]. In this way, the topological relationships between basic units can be described to reflect their interaction characteristics.

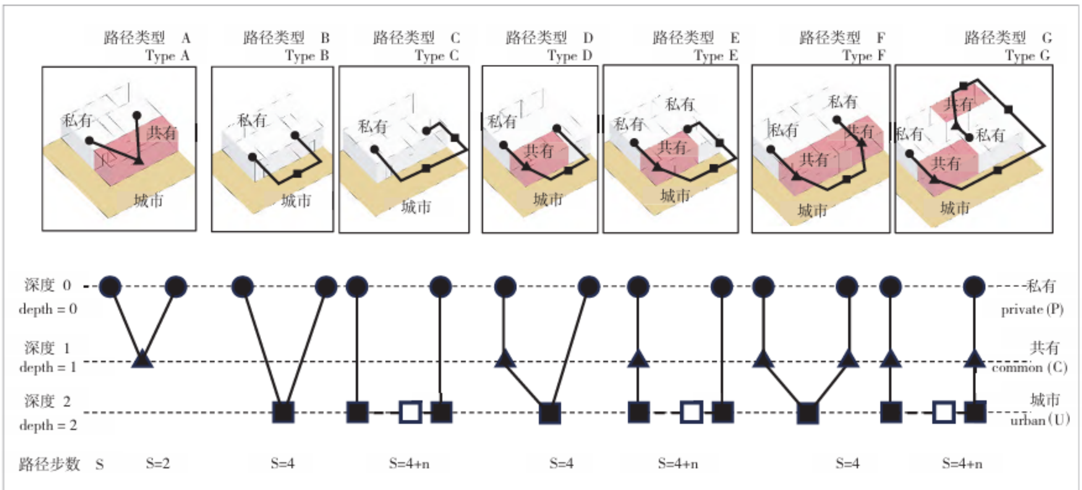


Fig.3 Sevenconnectionpathsbetweenprivatelayers

2.3 Construction of a Social Network Based on Acquaintance Relationships

Simultaneously, the construction of a social relationship network is carried out. Relying on the close kinship and geographical ties of family and clan relations, early historical areas displayed a clearly structured acquaintance-based society, with relatively simple types of social relationships. Subsequently, due to policy changes and intergenerational transitions, social structures gradually became more relaxed and exhibited diverse characteristics[17]. Although kinship ties became less close, they remained significant, with individual residents and small families forming the basic units of the relationship network (see Figure 4). Regardless of factors such as public housing acquisition, policy reforms, inheritance, or purchase and sale, the types of social relationships between the smallest units—such as neighbors and work units—continued to increase, forming close social connections similar to kinship. Thus, the social structure displayed features of a semi-acquaintance society[18], consisting of a ternary social network of acquaintances, non-acquaintances, and semi-acquaintances④. Within this network, kinship, work, and neighborhood relationships are considered acquaintance and semi-acquaintance relationships, while strangers are categorized as non-acquaintances. The distinction between acquaintances and semi-acquaintances is not based on relationship type but rather on whether the acquaintanceship has lasted over ten years or whether they live in the same space[19]. For instance, neighbors who have known each other for a short time and do not live together are semi-acquaintances, while those who have known each other for over ten years but do not live together are considered acquaintances.

When the resident of a basic unit is a single individual, documents such as public housing lease certificates and surveys can be used to determine the type of social relationship between residents. When the resident is a family, the closest relationship of any family member with other residents is included in the social relationship network. After identifying isomorphisms between social relationship nodes and spatial topological nodes, the social network can be converted into a relational weight matrix. During calculation, binarization can be applied, with acquaintances treated as connected and semi-acquaintances and non-acquaintances as unconnected, to construct an adjacency matrix[20] serving as the relational weight matrix S for calculations.

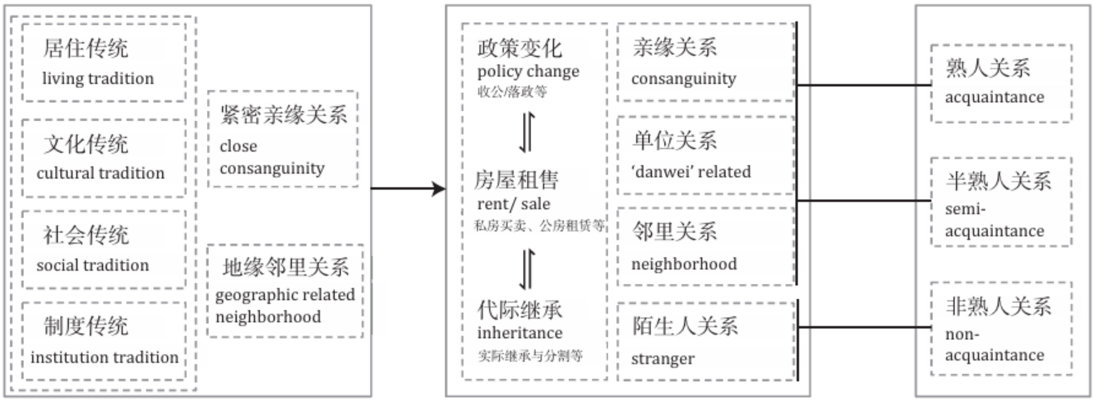


Fig.4 Thedynamicsofrelationalnetworks

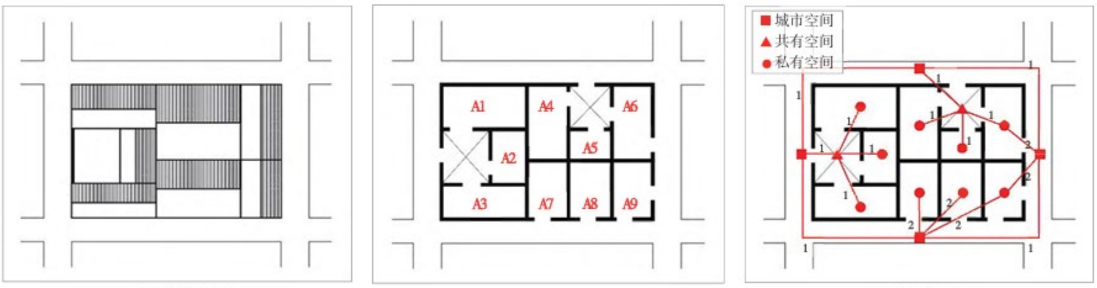
2.4 Relationship–Space Matrix

To explain the methodology, a simple block surrounded by urban streets is used, with some residents sharing common spaces. Based on the classification of path types between nodes constructed above, a depth path plan of the block (see Figure 5) can be drawn to represent the topological spatial relationships and path structures of each node within the block. Each node connects across the three different depth levels—private, common, and urban—forming an integrated topological network. The path structure and step count between nodes in the network can be derived from the depth path plan—for instance, the path step count between A3 and A7 is 5 (1+1+1+2). After obtaining the topological step count between each residential node, the network matrix method by Michael Batty [21] can be used to mathematically abstract the topological relationships between all nodes, representing the overall topological distance network. In the constructed matrix P, the element pnm in the i-th row and j-th column represents the path step count from node i to node j (e.g., p37=5). The significance of matrix representation lies in its ability to network structural attributes, such as space and social relationships, enabling analysis of their interrelations. Thus, the spatial attraction [22] between all node pairs can be calculated based on the topological distance represented by path steps, reflecting the overall spatial attraction relationships. In a simplified form, it can be seen that the spatial attraction between nodes is inversely proportional to the square of their path step count—the greater the step count, the lower the spatial attraction, with the inverse-square law illustrating the rapid decrease in attraction as step count increases. By calculating the attraction between each node pair⑤ (Formula 1), the distance network can be transformed into an attraction network and represented by the spatial attraction matrix G.

$$g_{ij}=k_1\times\frac{M_i\times M_j}{p_{ij}^{\ 2}} \rightarrow$$

$$g_{ij}\propto\frac{1}{p_{ij}^{\ 2}} \rightarrow \qquad (1)$$

$$g_{ij}=\frac{k_2}{p_{ij}^{\ 2}}$$



（a）屋顶平面 （b）一层平面与节点编号 （c）深度路径平面

Fig.5 Illustration of the relational-spatial network method

To examine the social relationships within historical areas, an adjacency matrix is used to represent social relationships as a relational weight matrix S. By constructing spatial attraction networks and relational weight networks, a spatial attraction relationship based on social relationship weights can be calculated through matrix transformation. Using the spatial attraction matrix G, a linear mapping through the social relationship weight matrix yields a new matrix A (A=SG), which represents the "relationship–space" matrix, reflecting the composite structural relationship between space and society. This mathematical operation represents the transformation of spatial attraction relationships within the coordinate system of the social relationship network⑥. This matrix mapping approach has been applied in fields such as computer image recognition and artificial intelligence algorithms, but its application in urban architecture has not been explored. Its coordinate transformation properties allow for overlay analysis of spatial and social relationships, extracting composite structural features. In this context, the associated characteristics of society and space become analyzable entities, offering designers a tool with a social relationship perspective for urban renewal. Furthermore, the structural characteristics of shared living are thereby elucidated.

3 Unitized Identification of Shared Living

3.1 Characteristics and Identification of Units

A small block within a historical district in Nanjing was selected to apply the "relationship–space" matrix. This block includes properties with various ownership types, such as public and private housing, as well as diverse social relationships, such as colleagues and relatives, providing a representative sample [Figure 6(a)]. According to the previously mentioned division method for minimum residential spaces, the block can be divided into 22 basic units [Figure 6(b)], each occupied by an individual resident or family, with at least one entrance and documentation such as public housing rental contracts. Based on this, the path structure of the block can be determined [Figure 6(c)]—four urban space points identified through dual representation, four shared depth points determined by shared ownership, and 22 points identified according to the principle of minimum private residential space. The path type and step count between basic units can be calculated individually. For example, the path type from A1 to A2 is Type B—A1 crosses two depth levels to enter the urban space, then crosses two more depth levels to reach A2, resulting in a path step count of 4. The path type from A6 to A21 is Type G—A6 crosses one depth level to enter shared space, then another to enter urban space, makes a turn in the urban space, crosses another depth level to re-enter shared space, and finally crosses another level to reach A21, resulting in a step count of 5. The topological distance network formed by these 22 node pairs shows some connections with smaller values through shared levels and others with larger values due to multiple turns in the urban level, reflecting actual topological distances consistent with perceived reality. When a minimum private residential space has multiple entrances, the smallest step count between node pairs is used as the path step count. The path step matrix P can be expressed accordingly, and the spatial attraction matrix of the block can be derived based on the attraction calculation formula.

Additionally, through archival research of public housing rental certificates and survey verification, the social relationship network structure of the block can be identified [Figure 6(d)]. For example, kinship relationships between public housing units A6, A9, and A10, and colleague relationships between A1 and A22, are included as connections in the relational weight matrix; neighborhood relationships lasting more than ten years, such as A16 and A17, are also included; however, neighborhood relationships of less than ten years, such as A1 and A5, are excluded as semi-acquaintance connections; residents are connected to themselves; and strangers are excluded as non-connections. The social relationship network exhibits a clustering effect consistent with reality. Based on this relational weight matrix, the "relationship–space" matrix can be calculated to represent the comprehensive attributes of the block's social and spatial relationships. For example, the degree centrality of the "relationship–space" matrix can be calculated to reflect the centrality of each node⑦, indicating the ease or difficulty of connections with surrounding nodes and assisting designers in selecting pilot areas for urban renewal⑧. Importantly, the "relationship–space" matrix of residential historical areas reveals significant clustering characteristics, reflecting the unitized shared living structures within historical districts. These not only demonstrate the clustering features of social relationships but also reveal the clustered features of spatial relationships.

By conducting community detection calculations on the "relationship–space" matrix, significant unit structures can be identified⑨ [23]. In the above case, dividing the block into five units provides the optimal unit structure⑩ [Figure 6(e)]. This unitized structure, integrating spatial and social relationships, reflects the living characteristics of historical blocks and clarifies unit structures based on shared living attributes. For instance, in Unit 2, nodes (including multi-entrance nodes such as A21 and A17) share a courtyard, and some nodes have kinship relationships, forming a unit of shared living. Similarly, the pairs of nodes A1 and A22, and A21 and A22, although having the same topological distance, differ in their social relationships—A1 and A22 share a colleague relationship, while A21 and A22 do not. Moreover, A22 faces a shared courtyard with nodes such as A17 and A18, so A1 and A22 are classified into the same unit, while A21 and A22 belong to different units. The unit division based on the "relationship–space" matrix aligns with the actual shared living situation, and the method of identifying significant clustering attributes through clustering is highly effective.

（a）南京某街区屋顶平面 （b）街区一层平面与基本单位编号 （c）深度路径平面 （d）社会关系网络图示 （e）可划分为5个单元的街区

Fig.6 Application of the relational-spatial network method

3.2 Unitary properties of co-living

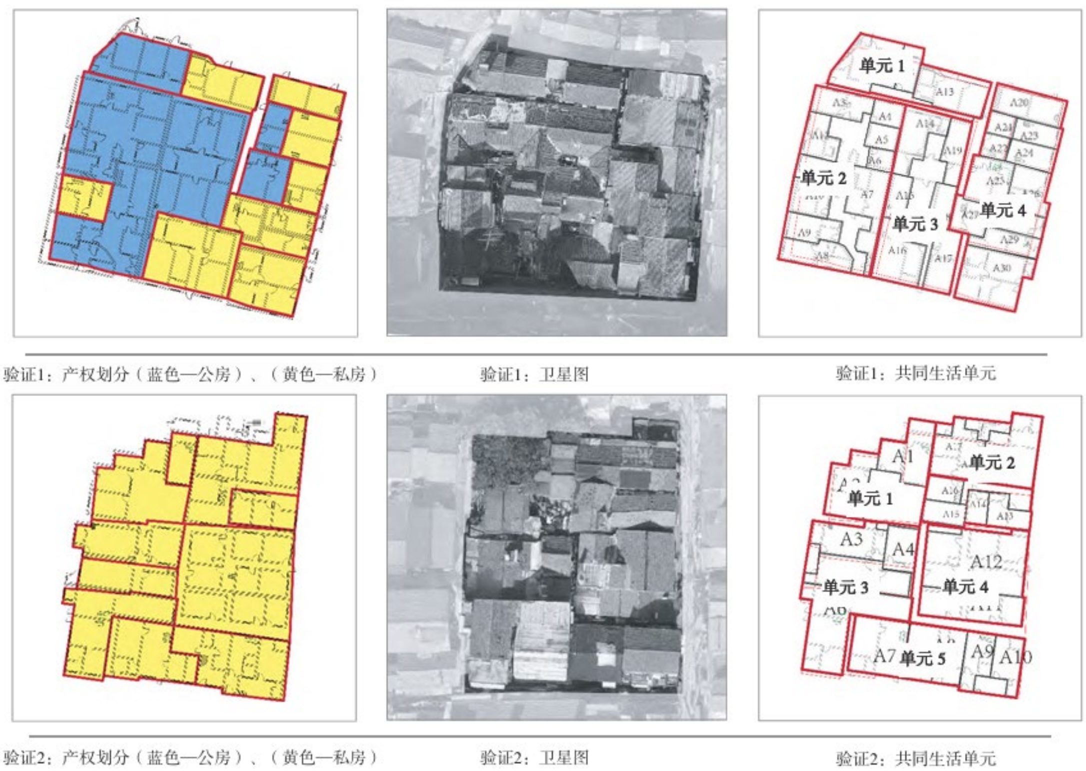
The unitary property of the spatial and social complex network reflects the structural characteristics of the phenomenon of living together. Different types of co-living spaces in historical locations, such as public housing cohousing, flat cohousing, and private housing mixed housing, show obvious unitary properties in their social structures and spatial relations, which distinguish urban space from co-living space with some kind of fuzzy demarcation line[24]. Daily life takes place within the boundaries, and the occupants are highly connected to each other, constructing a psychologically safe domain for co-living. This sense of collinearity[25] is characterized by a certain scale range in physical space, suggesting the inside and outside of common living (Figure 7) [26]. The common living unit, as a manifestation of spatialization of power[27], embodies the superimposed influence of tenure, organizational structure, etc. on the living space, and at the same time, due to the needs of daily life, the transformation of the space by the residents is more essentially influential. On the one hand, through hard structures such as pools and short walls, residents expand their living space; on the other hand, through soft furniture such as cupboards, chairs, and greenery, residents are able to interact with each other and live together in the overlapping space. The scope of co-living is not strictly defined by the combination of material space and boundaries, but rather by the scope of social and spatial aggregation based on daily life. The overall spatial structure of the residential historic district is formed by the loose connection between different common living units.

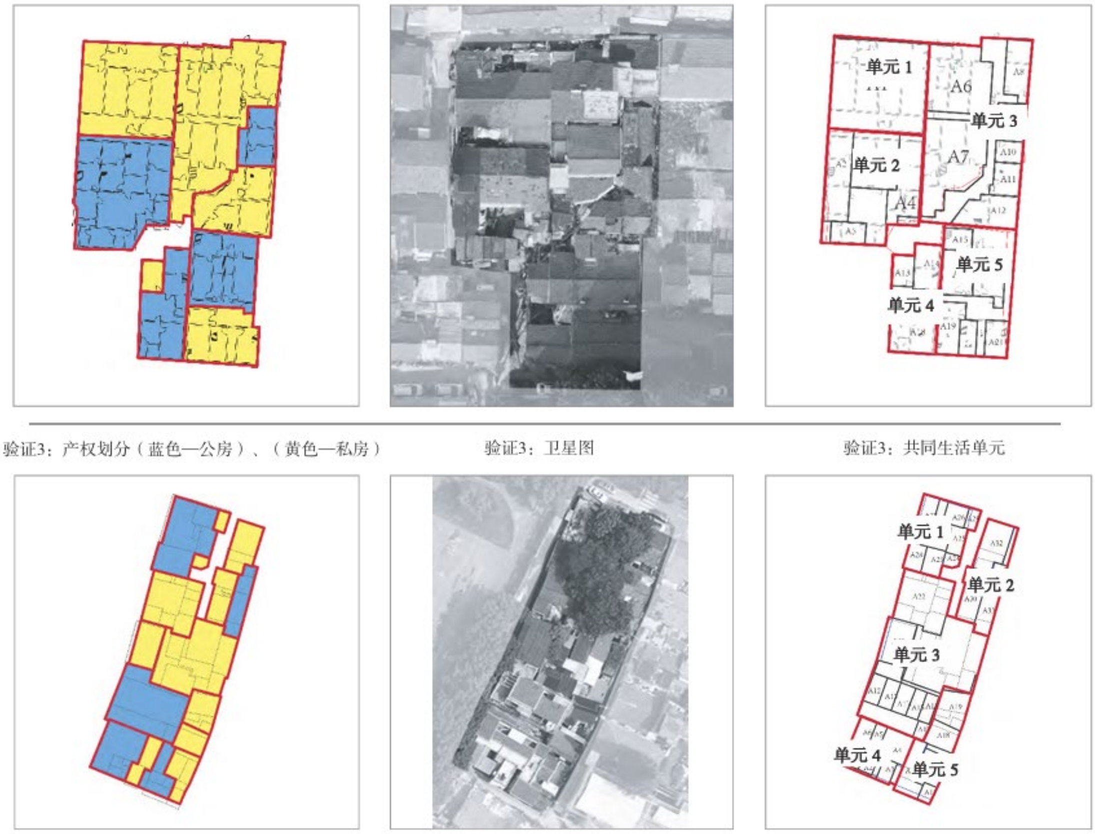
Fig.7 The spatial construction of common living
Note: Red - Spatial boundaries spontaneously demarcated by residents

The unit structure of shared living reflects the cumulative influence of multiple factors within historical areas. The complex kinship and geographical relationships among residents within the unit, combined with the synchronic characteristics, align with the overlapping results of the historical evolution of the area. For example, a shared living unit in Nanjing initially belonged to the first generation of the Yuan family, who purchased and inhabited it during the late Qing Dynasty. By the 1950s, it had transformed into three relatively independent courtyards, inhabited separately by one family with the surname Weng and two families with the surname Yuan. Today, it accommodates 18 households (some with kinship ties) and continues to evolve. The residents within the unit have moved in and out over time due to policy changes, gradually constructing a shared living network and maintaining dynamic balance. This unit structure of shared living exemplifies the typical characteristics of residential historical areas.

3.3 Method Validation

This study selected four blocks in residential historical areas as samples to verify the practical effectiveness of the shared living unit identification method (Figure 8). The basic units within each block range from 19 to 35, with varying ownership statuses. Sample 1 primarily consists of public housing, sample 2 includes entirely private housing, while samples 3 and 4 have an equal proportion of mixed public and private housing. The four validation samples cover an area of approximately 1,000 to 1,600 square meters and represent spaces developed on the foundation of historical residential areas. These spaces exhibit the typical characteristics of residential historical areas with a high degree of social and spatial integration. In terms of spatial structure, there are variants of the courtyard-style spatial prototypes from the Ming and Qing Dynasties (Validation 1 and Validation 3), as well as high-density spatial structures with intense land use (Validation 2 and Validation 4). The data on basic residential units were sourced from relevant departmental records and verified through field surveys, showcasing various social relationship connections.





验证3：产权划分（蓝色—公房）、（黄色—私房）　验证3：卫星图　验证3：共同生活单元

验证4：产权划分（蓝色—公房）、（黄色—私房）　验证4：卫星图　验证4：共同生活单元

Fig.8 Empirical testsofunitizationidentificationmethods

After constructing the relationship–space matrix, the samples exhibit distinct clustering characteristics within the composite network⑫.First, by analyzing the basic units connected through shared spaces, a significant spatial attraction is observed due to their smaller topological step distances. This is especially pronounced when there are familiar relationships, highlighting high modularity and unitization features. Second, while basic units with similar topological distances do not show significant clustering at the spatial attraction level, they demonstrate clustering characteristics when social relationship weights are applied through matrix transformations. Thus, unitized characteristics cannot be calculated based solely on spatial or social relationships; they must be determined through composite network computations. Moreover, shared living units do not necessarily correspond to property units based on land parcels. Throughout historical development, spatial and social changes have been complex and diverse. For instance, some families sold portions of their houses due to financial changes (Validation 1); some handed over their properties to public housing while retaining only a room as private housing (Validation 2); and even some public housing, which theoretically should not have inheritance rights, is inherited in practice (Validation 3). These factors result in a discrepancy between the ownership structure and the actual living characteristics of residential historical areas, sometimes significantly so. Therefore, only by focusing on the living attributes of historical areas and conducting a comprehensive structural understanding can their essential characteristics be grasped, providing a scientific basis for spatial cognition and practice.

Validation demonstrates that the unitized identification method can clearly analyze the composite status of residential historical areas, effectively organizing spatial and social characteristics, and is both valid and representative. The unitized identification method constructed in this study is based on topological structure and connection characteristics, differing from methods like Euclidean distance and network distance[28], as it emphasizes spatial structural properties[29]. The significant clustering and unitization characteristics of historical areas indicate that the living patterns in residential historical areas are not chaotic phenomena of indefinite expansion but possess clear shared living unit structures.

4 Application of Unitized Identification in Renewal Practices

At the cognitive level, by overlaying spatial and social relationships, a relationship–space network with dual attributes is formed, offering a new perspective for analyzing the spatial structures of high-density residential historical areas. The significant clustering and modularity features exhibited by residential historical areas in the relationship–space network provide scientific tools for understanding the spatial structures of historical areas. The unitized method derived from this network effectively expresses the structural connotations of spatial and social composites. However, as historical areas in cities continue to evolve, the migration of new residents and the departure of old residents will become the norm. The main subjects and interaction patterns of shared living will also continuously change. The advancement of renewal practices will further modify existing composite relationships. Future research needs to consider social relationship and material space variables to analyze structural changes and to determine the dynamic characteristics and indicators of the composite social and spatial structure[30], as well as the corresponding relationships of various elements. This would help clarify the constant structures within the evolution of historical areas, providing a more objective description of unitized characteristics and enhancing systematic and dynamic analysis and evaluation methods for the protection and regeneration of residential historical areas. See Figure 9.

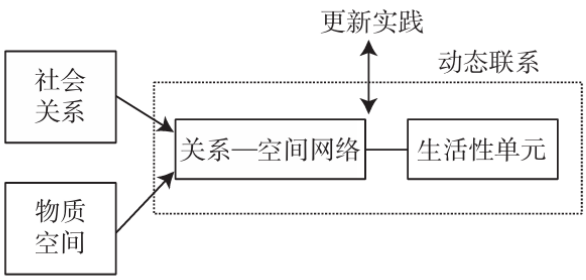


Fig.9 The dynamics of combined relationship

At the design practice level, the shared living unit identification method effectively organizes social and spatial relationships, analyzing the complex living unit clusters of historical areas, thereby making urban renewal projects more protective and feasible. This practice, which coordinates interpersonal networks and living environments while integrating physical spaces with social relationships, has been piloted in various locations. In Nanjing’s Xiaoxihu district, projects such as the Shared Courtyard and the Symbiotic Courtyard incorporated different types of living spaces, including private and public housing, to form shared living domains through spatial and kinship ties. The design team introduced some non-residential functions while maintaining part of the original living structure, not only securing funding support for the renewal projects but also creating vibrant samples[31]. Similarly, in the renewal design project of the Shared Courtyard at Zenggong Temple in Nanjing's Hehuatang area, attempts were made to preserve the original social relationships and historical spaces within the shared living units. These efforts aimed to balance the protection of private living privacy with the attributes of shared living, offering a new approach to urban renewal. While current pilot projects largely rely on the designers' intuition, the shared living unit identification method provides a scientific framework to objectively determine the structure and boundaries of socio-spatial coupling units, offering design and analytical foundations for specific renewal projects in historical areas.

At the institutional practice level, developing regulatory guidelines based on research content can better guide practical applications[32]. Aligning spatial unit divisions in urban renewal planning with shared living units helps maintain the living structure of historical neighborhoods at the regulatory level. The division of urban public spaces, shared living spaces, and private spaces clarifies public and non-public rights, aiding in the delineation of responsibilities in renewal practices. Urban spaces, due to their public nature, are primarily governed by government platforms, while shared living spaces are co-managed by residents through joint consultations. This combination of rigid regulation and flexible negotiation aligns with hierarchical control and guidance in planning and design.

As a regulatory tool, planning and design guidelines implement control intentions through rigid indicators on the one hand and express guiding intentions of urban design through constrained provisions on the other[33]. Currently, "hierarchical control units" are being piloted and promoted in urban renewal in the form of regulatory guidelines. For example, planning control units, as a tier in the planning management system[34], adopt simple and clear division methods. However, the delineation of micro-renewal units often relies on subjective experience and seldom considers the social relationships of historical areas, resulting in significant uncertainty⑬. There have been attempts to define control units based on spatial morphological elements[35], and unifying control units with shared living units could strongly support the dual goals of protection and renewal. Combining these two as the basic units for renewal practice could enhance the effectiveness of protecting spatial and social relationships. In renewal practices such as the Sijiao district in Lishui, Nanjing, efforts have been made to integrate shared living units with micro-renewal units and compile urban renewal guidelines (Figure 10). By combining gradual social structure renewal, these practices not only provide practical social momentum for renewal efforts but also preserve the value of "living fossils" of social relationships.

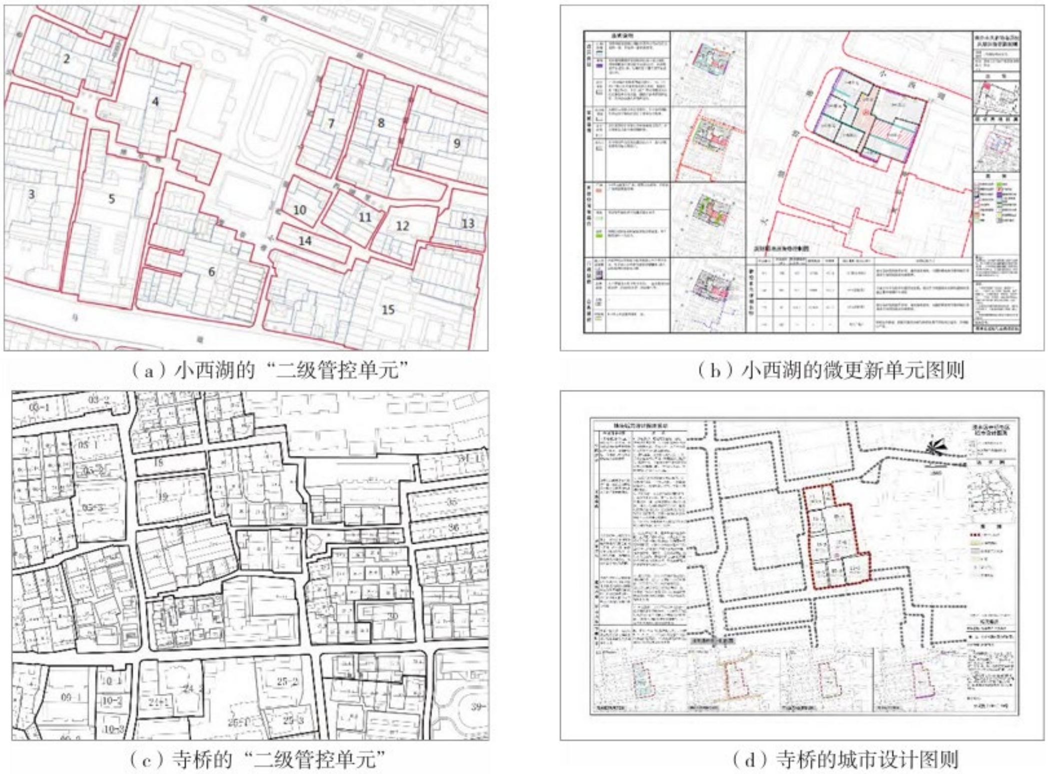


Fig.10 Urban design guidelines integrated with common living unit

Annotations

① Documents such as the "Opinions on the Current Basic Situation of Urban Private Real Estate and Socialist Transformation" (1956), "Opinions on Handling Issues Left Over from the Socialist Transformation of Urban Private Rental Housing" (1985), "Implementation Plan for Gradually Promoting Housing System Reform in Urban Areas" (1988), and "Notice on Further Deepening Urban Housing System Reform and Accelerating Housing Construction" (1998) reflect key milestones in the reform of the housing system.

② The basic unit here differs from a property ownership unit and is not based on land parcels. Instead, it is determined by the specific living space in use, with the smallest private living space defined as the basic unit. This approach is effective for addressing residential historical areas characterized by strong living attributes. For example, in the case of public housing, many residents may share the same land parcel. Using land parcels as the basis for division would ignore living attributes and focus solely on ownership, thus failing to accurately understand and analyze the current situation. When divided by the smallest private living space, it allows for discussions about social relations among residents and path connections between living spaces as indivisible elements.

③ Previously, the depth of rooms was incrementally nested, with some rooms reaching a depth of 5, 6, or even more, effectively representing the spatial sequence from urban space into the interior of a building.

④ "Semi-acquaintances" are typically defined as individuals who are known to each other but do not live together in the same space. In this article, semi-acquaintances are considered an intermediate state, describing a relationship that lies between acquaintances and strangers, determined by either time or cohabitation. Unlike acquaintances, this type of relationship results in more dispersed social connections.

⑤ In the formula gij is the interaction between basic units i and j, Mi and Mj are the sizes of the two minimum spaces i and j, which can usually be replaced by the population size; pij represents the distance resistance between i and j, which can be calculated by the number of path steps in a space dominated by the phenomenon of common life like a residential historic lot. In the calculation of residential historic lots, the weight of the household population in the smallest private space can be regarded as essentially the same, by which the constant k can be added to express the inverse square relationship of spatial gravity.

⑥ When the dimensions of two matrices involved in a transformation are consistent, the result of the transformation retains the same dimensions. This mapping transformation represents a one-to-one linear relationship, preserving the original interaction characteristics while assigning new positions based on the transformation matrix.

⑦ Degree centrality is a key metric in network relationships. Here, it reflects the tightness of connections between basic units within a block. The higher the degree centrality of a node, the easier it is to reach that node from surrounding nodes. In residential historical areas, degree centrality reflects the centrality of a single node and is directly related to the core of social relationships, spatial location, and the number of exits of a basic unit. The more people a basic unit is connected to and the tighter its spatial connections, the higher its degree centrality.

⑧ Basic units with higher degree centrality possess greater spatial and social centrality and serve as better demonstration points.

⑨ Community detection is based on clustering principles, identifying which nodes are significantly more connected to each other than to other nodes. Modularity values are typically used to determine whether grouping features exist and which grouping structure has the highest modularity, serving as the final result of community detection. In natural networks, modularity typically ranges from -1 to 1, with values above 0.2 indicating significant unitization features.

⑩ At this stage, the internal connection density of each unit is relatively high. While shared living phenomena and unitization identification methods in residential historical areas may include connections spanning multiple units, most connections are concentrated within units.

⑪ Residents' shared living also permeates urban life through open entrances and exits, blurring the boundaries of shared living domains.

⑫ By performing an overlay operation of the relationship weight matrix and the spatial gravity matrix, a relationship-space matrix for each validation object is formed. Community detection of the relationship-space network reveals modularity values above 0.4, indicating strong grouping and community characteristics. Within blocks, connections between certain basic units are significantly stronger than with others, demonstrating the unitization properties of residential historical blocks.

⑬ Architects and urban designers delineate micro-renewal units based on their own experience, resulting in variations depending on perspective, experience, and background. The lack of clear delineation methods makes the definition of micro-renewal units less scientifically grounded and less convincing.

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