

Research on Functional Evolution of Existing Rural Dwellings in Western Zhuhai: Based on Diachronic Analysis and Statistical Modeling

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Abstract. Rapid urbanization and industrialization in the Global South have reshaped rural societies and triggered fundamental shifts in residential life; however, the evolution of housing at the micro level—as a reflection of macro-level social change—has not yet been fully studied. Taking the western region of Zhuhai, China—an area undergoing intense urban-rural integration—as a case study, this research explores the functional evolution of rural dwellings to understand the dynamic interactions between socioeconomic transformation and the domestic sphere. Through a diachronic analysis of 105 representative rural dwellings across 31 villages, supplemented by household surveys and statistical modeling, this study traces the changes in rural housing forms over the past half-century. The findings reveal a distinct evolutionary trajectory: from the traditional “Courtyard Hub” model, through a transitional “External Corridor Linkage” model, to the modern “Living Room-Front” model. Pearson correlation analysis quantitatively confirms this shift. This evolution signifies not only a change in architectural form but also reflects a profound socio-spatial transformation: rural dwellings have shifted from being centers of production to spaces that prioritize privacy, comfort, and the needs of nuclear family life.

Keywords. Western Zhuhai, China; Rural Dwellings; Functional Evolution; Statistical Modeling

1 Introduction

Rural urbanization in the Global South is characterized by intense spatiotemporal compression^[1]; industrialization and demographic shifts have forced rural settlements to undergo drastic spatial reorganization within a short period of time, and China’s rural development policies serve as the key mechanism for managing this transition. In 2022, the State Council issued the “Implementation Plan for Rural Construction,” establishing a new framework for rural development, and in December 2023, Guangdong Province launched the High-Quality Development Project for Hundreds of Counties, Thousands of Towns, and Myriads of Villages (“100-1,000-10,000 Project”). As a core city in the Guangdong-Hong Kong-Macao Greater Bay Area, Zhuhai exhibits the typical spatial duality^[2] of the “Global South”: the eastern part comprises a modern metropolitan core, while the western part consists of traditional rural areas undergoing rapid transformation. As long as rural areas are not demolished, village planning ultimately remains stock planning^[3]. To address the challenges of spatiotemporal compression, Zhuhai has prioritized urban-rural integration and introduced supporting policies such as the “Implementation Opinions on

Accelerating Project Approval” (2024) and the “Interim Measures for the Management of Rural Residential Land” (2024). Currently, rural Zhuhai is transitioning from extensive and disorderly expansion to a phase of refined renewal of existing stock. The development paradigm has shifted from “supply-driven” to “demand-led,”^[4] advocating for the “coexistence of old and new”^[5] and the revitalization of idle assets. The existing management system emphasizes facade aesthetics, construction approvals, and circulation mechanisms; however, this top-down approach prioritizes visual uniformity over functional feasibility. This has resulted in a fragmented architectural landscape, where uniform exteriors mask actual needs, leading to a disconnect between economic viability and residential functionality^[6].

Existing research largely discusses rural development at the macro and meso levels: the macro level focuses on policy orientations^{[7][8]} under the Rural Revitalization Strategy, while the meso level explores renewal pathways through multi-stakeholder collaboration^{[9][10]}. However, research at the micro level—particularly on the functional aspects of the interior spaces of individual rural residences—remains insufficient. Existing studies often concentrate on northern China^{[11][12]} or overall satisfaction^[13], neglecting the social spatial characteristics of the Lingnan region, and tend to focus on public outdoor environments^{[14][15]} while overlooking adaptive renovations within the private interiors of rural residences.

There remains a research gap regarding existing rural dwellings in western Zhuhai. Against the backdrop of the “100-1,000-10,000 Project,” this paper examines the functional evolution of rural dwellings to fill this gap. By analyzing field data from western Zhuhai, the study aims to reveal how rural households adapt their living spaces under the pressure of spatiotemporal compression, thereby providing empirical evidence for functional renewal that integrates farmers’ actual needs.

2 Field Survey and Analysis of Existing Rural Dwellings

2.1 Survey Subjects and Content

From January 2023 to April 2025, the research team conducted field surveys on existing rural housing and development conditions within the study area (Figure 1), employing a mixed sampling strategy combining stratified sampling with representative sampling to ensure that the sample reflected the region’s heterogeneity: First, the study area—which encompasses all districts in western Zhuhai as well as adjacent rural areas of Jiangmen and Zhongshan—was stratified by geographic location, dominant industries, and transportation accessibility to cover rural environments at different levels of development. Next, 31 typical villages with distinctive agricultural or fishing characteristics and driven by complementary industries within the Greater Bay Area were selected. From each village, 3 to 5 representative rural residences were randomly chosen, resulting in a total of 105 farmhouse samples to enhance the representativeness of the sample.

Data collection employed a triangulation approach:

1. Field surveys: Direct measurement and observation of building structures.

2. Questionnaires and interviews: Face-to-face collection of qualitative data on residents' needs.

3. Secondary data analysis: Statistical analysis of 9,308 rural residential samples extracted from the “Guangdong Province Housing and Municipal Facilities Survey System” to provide a quantitative baseline.

The research data centered on six core dimensions: homestead conditions, household livelihoods, building information, functional layout, building dimensions, and permanent residents.

The objectives of this study are:

1. To examine the characteristics of changes in residential indicators across different eras and summarize the patterns of functional and spatial evolution

2. To analyze the impact of social factors—such as population structure and modes of production—on villagers' housing needs at different stages of development

3. To explore the interrelationship between technical indicators of rural housing and rural social factors



Fig. 1. Distribution of Sampling Samples and Partial Photo Display

This study employs descriptive statistical analysis to process the multidimensional information obtained from surveys and interviews, quantifies indicators across the six core dimensions, calculates statistical measures such as mean, median, and standard deviation, and presents the basic characteristics and distribution patterns of rural housing in western Zhuhai.

2.2 Survey Findings Overview

By analyzing data from a sample of rural dwellings constructed across different periods in the region, this study reveals trends in changes related to homestead area, residential floor space, building structure, and population size (Figures 2a-2d).

2.2.1 Residential Population. In terms of geographic distribution, the southern villages in western Zhuhai, which are close to the industrial park, have a relatively large

permanent resident population, while villages farther from the industrial park suffer from severe “empty-nest” and aging issues (Long & Li, 2022)^[16] and have a smaller permanent resident population. Data shows that the average household size is 5.15 people, and the average permanent resident population per household is 3.03 people; households with two or fewer permanent residents account for 39%, and households consisting solely of elderly residents account for 33.3%, with these concentrated in the northern villages of Doumen District.

2.2.2 Household Industries (Figure 2a). According to data from the Zhuhai Municipal Government portal, rural industries in western Zhuhai are dominated by traditional agriculture, centered on aquaculture and grain cultivation, with a high degree of specialization and scale; specialty agriculture, e-commerce, and rural tourism serve as the primary drivers of income growth, forming a diversified development model of “agriculture and fisheries + cultural tourism + e-commerce.” Surveys show that the labor force among individual farming households is primarily employed in nearby townships (44.2%) and in local traditional agriculture and fisheries (25.6%), while the share of the tertiary sector—such as agricultural tourism and homestays—has grown significantly in areas like Doumen Town and Lianzhou Town. Changes in household livelihoods inevitably lead to shifts in housing demand^[17].

2.2.3 Homestead Area. The 1962 “Draft Amendments to the Regulations on the Work of Rural People’s Communes” stipulated that residential land was collectively owned by production teams and that leasing or selling it was strictly prohibited^[18]; the 1982 “Regulations on the Management of Housing Construction Land in Townships and Villages” clarified the legal requirements and area restrictions for new residential land; and the 2004 State Council “Decision on Deepening Reforms and Strengthening Land Management” tightened policies on residential land^[19], with most new residential land in this region being approved during this period. Survey data show that the average residential plot area for homes built in this region before 1979 was 108.1 square meters, while the average area of new residential plots approved after policy liberalization was 141.1 square meters; in Zhuhai’s West District, the overall average residential plot area is 133.3 square meters, with an average street-facing width of 9.1 meters and an average depth of 13.9 meters.

2.2.4 Residential Floor Area. Research data indicates that the average floor area per household for rural dwellings constructed before 1979 was 119 square meters; between 1980 and 1989 it was 127 square meters; from 1990 to 1999 it reached 153 square meters; between 2000 and 2009 it increased to 201 square meters; and for dwellings built since 2010, the average floor area per household stands at 273 square meters. The overall average floor area per household for existing rural dwellings is 176 square meters.

2.2.5 Building Structure (Figure 2d). Houses built before 1979 were primarily constructed with masonry walls and tiled roofs; in the coastal villages of Sanzao and Nanshui Town, stone walls were common. From 1980 to 1989, brick-concrete structures dominated, though 40% still featured masonry walls and tiled roofs, with very few concrete-frame structures; From 1990 to 2009, reinforced concrete frame structures became the mainstream, with 12% being brick-concrete structures; since 2010, all buildings have been reinforced concrete frame structures.

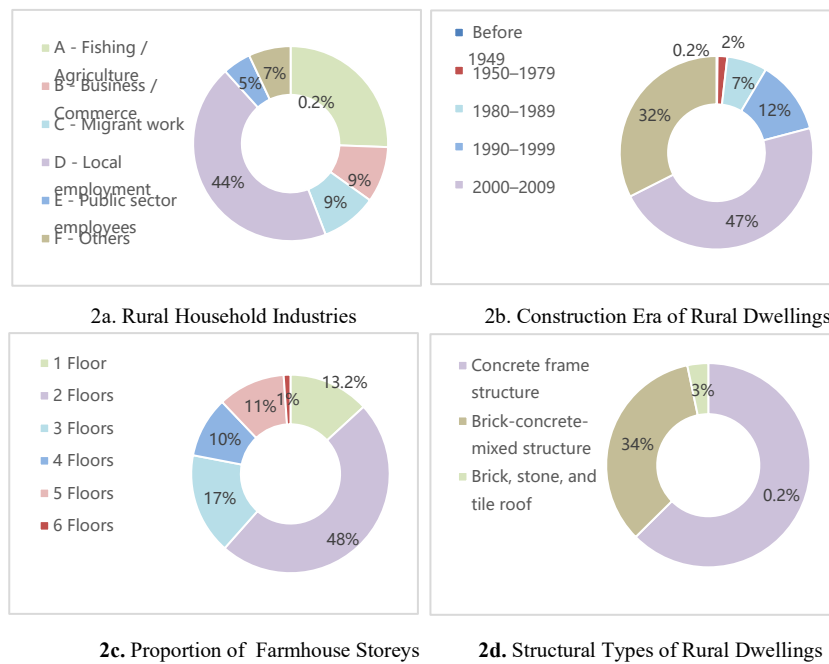


Fig.2. Basic Information on Rural Housing

2.2.6 Layout Patterns .

Traditional rural dwellings in Zhuhai's Western District include single-bay bamboo-tube houses, double-bay Ming-style houses, three-bay courtyard-style houses and four-bay courtyard-style houses with corresponding layouts^[20]. Before 1979, farmhouse designs followed traditional patterns. Between 1980 and 1999, new floor plans emerged while few residences still imitated traditional styles, and this period was unstable and transitional. Since 2000, floor plans have become stable and uniform, courtyard functions have gradually diminished or disappeared, and the living room has become significantly more central (Figure 3).

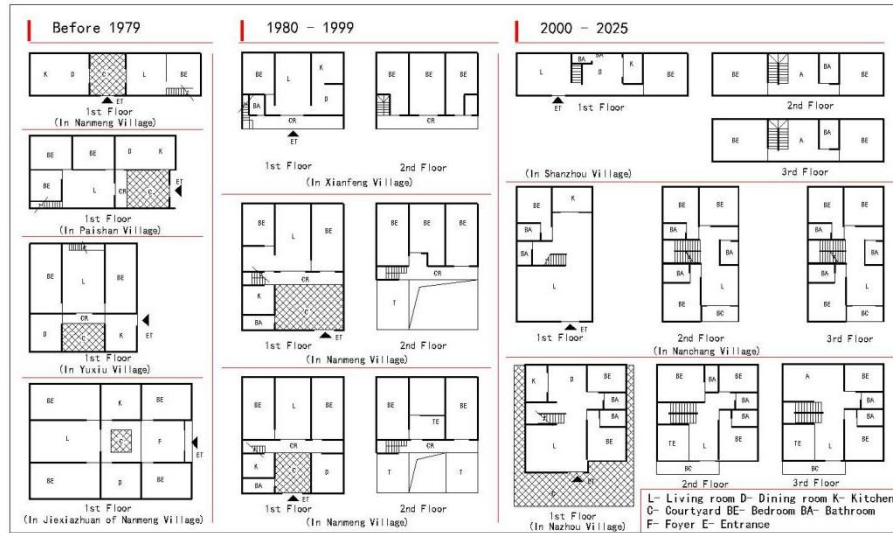


Fig.3. Typical Floor Plan Types of Different Stage

3 Evolutionary Patterns of Rural Dwellings

Based on survey data, the following section analyzes the evolutionary patterns of rural dwellings in this region through phased changes in spatial scale, functional layout, and spatial combination patterns:

3.1 Quantitative Changes in Spatial Scale

3.1.1 Changes in Number of Floors.

The average number of stories in rural dwellings shows a clear upward trend (Figure 4a). Before 1979, the average was only 1.5 stories, while from 2010 to 2023, it reached 3.14 stories. Economic development has increased farmers' incomes, enabling them to construct more stories. Simultaneously, population growth has driven housing demand, prompting farmers to build multi-story structures to meet residential needs. However, influenced by local self-built housing regulations and population growth factors, the upward trend in story count has flattened.

3.1.2 Changes in Floor Height.

The height of residential buildings has also shown a clear upward trend, with the increase in floor-to-floor height being particularly notable (Figure 4b), which is consistent with the trend of an increase in the average number of stories. Greater floor-to-floor heights provide better natural lighting, ventilation, and a sense of space, reflecting improvements in rural housing conditions.

3.1.3 Changes in Window-to-Floor Area Ratio.

The window-to-floor-area ratio reflects the emphasis placed on natural lighting and ventilation in architectural design, which aligns with people's growing demand for residential comfort, energy efficiency, and healthy living. Over the past 45 years, the window-to-floor-area ratio in rural residences has increased from 0.06 to 0.23—a roughly threefold increase (Figure 4c).

3.1.4 Changes in Courtyard Area (Figure 4d).

Courtyard area continued to increase between 1980 and 1989, reaching a peak, and then gradually decreased after 1990. The proportion of courtyard area relative to total land area also followed a similar trend. The upward phase reflects changes in the size of newly allocated residential land plots after the 1990s (research data shows that the average residential land plot size before 1979 was 108.1 square meters, while the average size after 1980 was 141.1 square meters, with no significant changes thereafter), as well as the needs of household units during that period in terms of agricultural production and processing [21]. The decline phase (during which the average courtyard area was reduced by more than half) reflects the gradual weakening of the courtyard's functions and the growing demand for indoor functional spaces.



Fig.4.The Evolution of Spatial Dimensions in Rural Housing

3.2 Evolution of Housing Layout Functions

Over the past half-century, the floor plans of rural dwellings in this region have been characterized by a diversification of room types, a specialization of functions, and a diminishing or evolving role of the courtyard:

1) Before 1979: Traditional layouts predominated, with living spaces centered around a main hall that served multiple functions (such as ancestral worship, entertaining guests, and processing agricultural products). Auxiliary spaces (kitchen, dining area, storage room) were arranged around the courtyard, while toilets had not yet appeared (which were added later).

2) 1980 – 1989: Functional zoning began to emerge in floor plans; dining rooms and bedrooms gradually became separate, and private bathrooms became commonplace. The front porch of the living room reinforced its role as a functional hub, while auxiliary spaces became more integrated with the living room. There was a surge in multi-story construction, and new housing became the dominant trend.

3) 1990 – 1999: Functional zoning was further reinforced. The living room expanded significantly in size, and living spaces became closely integrated with auxiliary spaces. The courtyard's roles as a passageway and for production gradually diminished. Bathrooms became ubiquitous, and the need for motorcycle parking increased significantly.

4) 2000 – 2009: New functional needs emerged, including entertainment, family gatherings, and vehicle parking. The living room solidified its position as the functional core of the interior space. The front porch evolved into an internal passageway, while the courtyard's productive and circulation functions diminished or disappeared entirely.

5) 2010 – Present: The floor plans of rural residences have matured and stabilized, particularly after 2020, with new homes exhibiting several common characteristics. First, there is a trend toward floor-by-floor modularization. Each floor has become more independent, exhibiting a layered, modular structure. Today, most floors feature not only bedrooms but also self-contained functional areas such as family activity rooms, kitchens, and bathrooms. Second, a leisure-oriented design trend has emerged. Non-traditional functional spaces such as study rooms, tea rooms, entertainment rooms, and home gyms have become widespread, reflecting the improvement in rural living standards and shifts in lifestyle. Research by Tang Sainan^[22] (2025), Zhong Yu^[23] (2025), and others provides evidence of the functional transformation of courtyards from the perspectives of spatial behavior and the plant landscape. Although a small number of courtyards are still used for production, processing, or the storage of agricultural supplies, the primary functions of most courtyards have shifted toward leisure, landscaping, and parking.

3.3 Evolution of Spatial Combination Patterns

An analysis of the floor plan survey sample reveals that rural dwellings constructed during different periods exhibit a relatively clear pattern of evolution in terms of their

functional spatial configurations. These evolutions can be divided into three representative phases, each with distinct characteristics (Figure5):

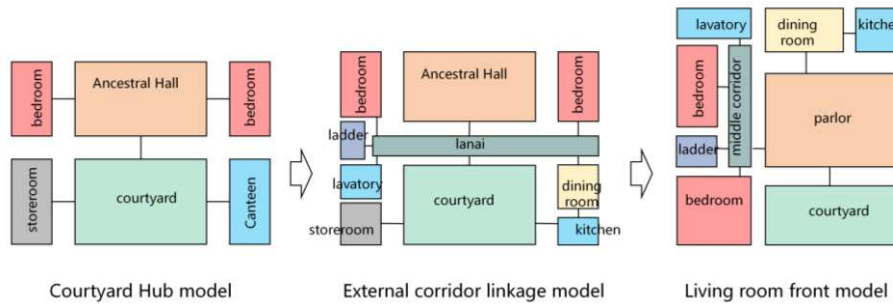


Fig. 5. Ground-floor spatial configuration patterns of rural dwellings across different stages

3.3.1 Courtyard Hub Model Phase

Traditional residences often emphasize the orderliness of the main hall while neglecting spatial connectivity ^[11]. Whether in bamboo-tube houses, Ming-style residences, or the “three rooms and two corridors” layout, the spatial arrangement of traditional residences in western Zhuhai revolves around a central courtyard. Due to a lack of exterior windows, the courtyard plays a crucial role in providing natural light and ventilation. Functional rooms are primarily arranged in a radial pattern with the courtyard as the circulation hub, demonstrating both functional diversity and flexibility (which enhances spatial efficiency within the constraints of limited floor area). The courtyard is closely linked to traditional lifestyles and production patterns, serving as a space for processing agricultural products, daily cooking, and food preparation. Functions such as drying grain, storing farm tools, and tilling the land or raising livestock are carried out in the outer courtyard. However, fewer than 20% of rural residences have private outer courtyards, so they must rely on shared village spaces to meet these needs. Although the main hall serves important functions—including receiving guests, leisure, dining, and the fine processing of some agricultural products and handicrafts—its spatial flow still depends on the central courtyard ^[24].

3.3.2 External Corridor Linkage Model Phase

Beginning around 1985, the functional layout of rural residences began to evolve. Single-story buildings (some with attics) were gradually replaced by multi-story structures (typically two stories). To address the issue of circulation between rooms on upper floors, external corridors were widely adopted to prevent the crossing of pedestrian paths. The eaves-level corridor on the ground floor connected the main hall to auxiliary functional areas, allowing direct access from the auxiliary spaces to the main hall while minimizing reliance on traversing the courtyard. During this period, the courtyard/inner courtyard continued to play a key role in agricultural and domestic

functions. Living rooms gained greater independence, and bathrooms emerged, typically located on the periphery of the courtyard (rather than integrated into the interior). Prompted by the transformation of social relations, this renovation compels traditional architecture to accommodate modern demands, thereby giving rise to an "unorthodox" hybrid morphology^[25]. This layout reflects a transitional phase in rural society and the economy, where the overall design, while moving away from traditional residential forms, also partially adapted to the demands brought about by rising living standards.

3.3.3 Living Room-Front Model Phase.

After 2000, the layout of newly constructed residences underwent a shift: the living room was situated at the front of the house, while auxiliary functional areas (dining room, kitchen, storage room, and bathroom) were located at the rear. The living room thus became the central hub of traffic flow. This layout resembled that of mature urban apartment complexes from that period. Courtyards disappeared or merged with the outer courtyard, and the traditional courtyard-centered interior layout transformed into a centralized layout centered on the living room. Similar phenomena also occur in Japan^[26]. The frequency of productive activities in the living room decreased. In addition to its role as a reception area, the living room became an important venue for community gatherings, watching television, playing cards, and similar shared activities. Whether residents or visitors, the first interior space they typically entered was the living room or its adjacent circulation areas (such as the foyer, porch, or entrance), from which they accessed other spaces via hallways or staircases within the living room. The separation of different generations across floors was quite pronounced, with the elders' bedrooms typically located on the ground floor. The upper floors are clearly divided, with each bedroom equipped with a private bathroom. Some residences also feature separate family lounges, kitchens, and dining areas. Livestock-rearing areas in the outer courtyards have been reduced or eliminated, indicating the increasing specialization of animal husbandry. The developmental stages of rural residential floor plan configurations in this region reflect the combined effects of local rural industrial growth, changes in family structure, and rising living standards since the Reform and Opening-Up. Farmhouse design has shifted from compact, functionally concentrated layouts to spatial arrangements that emphasize privacy, independence, and comfort.

This rapid evolution of spatial patterns—from an inward-looking “Courtyard Hub” model to an outward-looking “Living Room-Front” model in just a few decades—is a tangible manifestation of “spatio-temporal compression” in the built environment. Accelerated socioeconomic change has forced rural dwellings to condense the evolution of lengthy living spaces into a brief timeframe, resulting in a hybrid architectural form that fails to reconcile traditional collectivist values with modern demands for privacy and efficiency.

3.4 Quantitative Analysis of Spatial-Temporal Correlation

The diachronic analysis in the preceding sections qualitatively outlines the evolutionary trajectory of rural dwellings. To move beyond descriptive observation and statistically verify and quantify the intrinsic relationship between the construction period (as a proxy for the time factor) and key spatial performance metrics, this section employs Pearson's product-moment correlation coefficient for analysis. This is consistent with the approach taken by Gökçen et al. (2024) ^[27] in their study of the evolution of rural housing in Turkey, where they employed quantitative methods such as spatial syntax and system dynamics to understand morphological changes. Although the methods differ, both aim to objectively depict the evolutionary trajectories of housing morphology through data models. The goal is to reveal the deterministic patterns of evolution through the lens of data.

3.4.1 Methodology and Data. Three representative indicators were selected to capture distinct dimensions of functional evolution: Building Area (spatial scale), Window-to-Floor Ratio (living comfort), and Courtyard Area Ratio (production-to-living transition). Other metrics such as floor count were excluded due to high collinearity with building area / regulatory constraints limiting variance. Pearson's correlation coefficient (r) measures the strength and direction of a linear relationship between two continuous variables, with values ranging from -1 to +1. The calculation formula is as follows equation (1):

$$r_{XY} = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2 \sum_{i=1}^n (Y_i - \bar{Y})^2}} \quad (1)$$

X represents the construction period (converted to a chronological sequence value), and Y represents the Building Area, Window - to - Floor Ratio (WFR), and Courtyard Area Ratio (CAR) respectively. $\bar{X}$ and $\bar{Y}$ are the means of the variables, and n is the number of valid samples. A significance level (p - value) of 0.05 is set to determine if the observed correlation is statistically significant and not by random chance.

3.4.2 Results and Discussion. The analysis results (Table 1) show that construction era is highly and statistically significantly correlated ($p < 0.001$) with all three key spatial indicators:

The year of construction is strongly positively correlated with floor area ($r = 0.62$). This indicates that, over time, the floor area of rural dwellings has shown a clear and significant trend of increase, providing quantitative support for the description of spatial expansion in Section 3.1.

There is a very strong positive correlation between construction era and the window-to-floor area ratio (WFR) ($r = 0.73$). This result empirically confirms that farmers' demand for comfort in the physical living environment (natural lighting and ventilation) has risen sharply over time, serving as one of the most direct quantitative manifestations of functional modernization.

There is a moderately strong negative correlation between construction era and courtyard area ratio (CAR) ($r = -0.58$). This clearly quantifies the shrinking proportion of courtyard space within the residential plot, statistically validating the argument in Section 3.2 regarding the weakening of the courtyard's productive and living functions and its declining spatial significance.

Table 1. Correlation Analysis Results between Construction Period and Spatial Indicators

Spatial Indicator (Y)	Pearson Correlation Coefficient (r)	Significance (p-value)	Interpretation of Strength and Direction
Building Area	0.62	$p < 0.001$	Strong Positive Correlation
Window-to-Floor Ratio (WFR)	0.73	$p < 0.001$	Very Strong Positive Correlation
Courtyard Area Ratio (CAR)	-0.58	$p < 0.001$	Moderately Strong Negative Correlation

(Note: $|r| \geq 0.5$ may be considered a strong correlation; $p < 0.05$ indicates statistical significance of the correlation.)

3.4.3 Section Conclusion

The correlation analysis employs a rigorous mathematical model to transform the qualitative observations from Sections 3.1 to 3.3 into verifiable quantitative conclusions. The evolutionary trajectory summarized as "increasing area, emphasizing lighting, and shrinking courtyard" is thus not merely a descriptive trend but a pathway with demonstrable statistical significance. This quantitative verification establishes a more solid and objective data foundation for the subsequent diagnosis of functional adaptability issues across different evolutionary patterns (as outlined in Section 3.3) and for the formulation of targeted renewal strategies (presented in Chapter 4).

4 Conclusion

Through a diachronic analysis and statistical modeling of 105 rural dwellings in the western district of Zhuhai, this study reveals the inherent laws governing the functional evolution of rural housing under the backdrop of rapid urbanization. Driven by the effect of "time-space compression," local rural dwellings have undergone a three-stage evolution within merely half a century: transitioning from a "Courtyard Hub" model to a "External Corridor Linkage" model, and ultimately to a "Living Room-Front" model. Furthermore, Pearson correlation analysis statistically validates this evolutionary trajectory: over time, there is a significant increase in dwelling floor area and lighting demands, accompanied by a continuous decline in both the area and function of courtyards.

This evolutionary process represents not only an architectural morphological shift but also a profound socio-spatial transformation. It marks the transition of rural life from a collectivist model centered on production to a modern nuclear family model oriented towards privacy and comfort. Notably, the "hybrid morphology" observed during the transitional phase served as an adaptive strategy that effectively responded to the emerging demands brought about by socio-economic changes at the time, thereby laying a solid foundation for the eventual mature model centered on family life.

The significance of this study lies in redirecting the discourse on rural housing renewal from macro-level policies and aesthetic facades to the core of micro-level functional adaptability. Against the policy backdrop of 100-1,000-10,000 Project, future rural construction should transcend superficial facade renovations and pivot towards adaptability-oriented renewal guided by functional resilience. This is not only crucial for improving the living standards of rural residents but also an essential pathway for stimulating the endogenous development momentum of rural areas and achieving high-quality urban-rural integrated development.

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