



# Evaluating Community Micro-Renewal via Visual Graph Analysis: A Space Syntax-Based Comparative Study in Shanghai

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**Abstract.** Community micro-renewal has become a dominant urban regeneration strategy in China, yet existing evaluations remain largely qualitative, leaving the role of spatial configuration underexplored. This study employs Visual Graph Analysis within the framework of Space Syntax to compare two Shanghai communities representing contrasting renewal models. Results reveal a statistically significant divergence in visual intelligibility between the two sites. Dongming Road exhibits a Transparent Logic, where local visual cues reliably predict global accessibility. Conversely, Xinhua Road displays a Cryptic Logic, where visual openness and functional importance are decoupled. This typological distinction suggests that renewal strategies must be morphology-adapted. Fabrics with high intelligibility benefit from Network Proliferation through distributed interventions, while fabrics with low intelligibility require Nodal Acupuncture, concentrating resources at algorithmically identified integration cores. These findings demonstrate the utility of intelligibility analysis as a diagnostic tool for community regeneration, offering planners an evidence-based framework to move beyond intuition-driven site selection.

**Keywords:** Space Syntax; Community Micro-Renewal; Spatial Configuration

## 1 Introduction

China's urbanization has entered a phase of intensive stock renewal. Since 2015, Shanghai has shifted from large-scale demolition-and-reconstruction to incremental community micro-renewal (shequ weigengxin), a strategy that seeks to improve living environments through small-scale, participatory interventions in existing neighborhoods [1,2]. By 2023, the Shanghai Municipal Government had funded over 400 micro-renewal projects, embedded within the broader 15-Minute Community Life Circle policy framework [3]. This policy shift has generated significant scholarly attention, yet most evaluations remain qualitative, relying on resident satisfaction surveys or governance process descriptions rather than spatial analysis [4].

A critical gap exists in the quantitative assessment of how spatial configuration shapes the outcomes of micro-renewal. While planners routinely select intervention sites based on intuition, land availability, or political considerations, the underlying

spatial structure of a community—its connectivity patterns, integration hierarchies, and accessibility gradients—may fundamentally influence whether an intervention succeeds or fails. Space Syntax, a set of theories and techniques developed by Hillier and Hanson [5] for describing and analyzing spatial configurations, offers a rigorous quantitative toolkit for this purpose. However, existing Space Syntax studies in the Chinese context mostly focus on large-scale urban networks or historical conservation areas [6,7], while community-scale comparative applications remain rare.

While Space Syntax has been increasingly adopted in Chinese urban research, existing applications have largely remained at the city or district scale, with comparatively little attention to the fine-grained community level where micro-renewal actually takes place. Moreover, most studies continue to rely on axial analysis, which captures linear movement potential but overlooks the two-dimensional spatial experience that shapes everyday neighborhood life. These limitations point to the need for a community-scale, VGA-based approach that bridges spatial configuration and functional performance.

## 2 Literature Review

Space Syntax, originating from Hillier and Hanson's seminal work *The Social Logic of Space* [5], provides a mathematical framework for analyzing the relationship between spatial configuration and human movement. The theory's central proposition—the natural movement hypothesis—holds that a significant proportion of pedestrian flow can be predicted by spatial configuration alone, independent of land-use attractors [8]. Two core metrics operationalize this framework: connectivity (the number of spaces directly linked to a given space) and integration (a normalized measure of topological depth from a given space to all others in the system). When plotted against each other, the resulting  $R^2$  value yields what Hillier terms “intelligibility,” a measure of how well local spatial properties predict global structure [8]. A recent bibliometric analysis by Mohamed and Yamu [9] covering 1976–2023 confirms that Space Syntax remains one of the most widely adopted analytical frameworks in urban morphology research, with applications spanning transportation, heritage conservation, and neighborhood walkability.

In the Chinese context, Space Syntax has been applied at various scales. Liu et al. [6] combined axial analysis with multi-source data to evaluate pedestrian vitality in Yushan historical district. Lee et al. [10] demonstrated significant correlations between integration values and observed pedestrian volumes in East Asian neighborhoods. However, these studies predominantly operate at the district or city scale. At the community level, the literature on micro-renewal in China has expanded rapidly since the policy shift of 2015. Zhu [2] identified three mechanisms of spatial publicization in Shanghai micro-renewal projects, while Wang et al. [4] analyzed participatory governance in Beijing's Qinghe community. Yang and Qian [11] provided a comparative review of the “15-minute city” concept across Chinese and Western contexts, and Sun and Zhong [12] developed a diagnostic framework for 15-minute community life circles across four Chinese cities. Yet these contributions are largely

qualitative or policy-oriented; quantitative spatial analysis at the community micro-renewal scale remains scarce.

Despite these advances, the existing literature exhibits several notable limitations. First, the predominant focus on city-wide and district-level networks has left community-scale spatial dynamics largely unexamined, even though it is precisely at this scale that micro-renewal interventions are implemented and experienced. Second, comparative studies that employ spatial configurational metrics to contrast different renewal governance models—such as top-down versus bottom-up approaches—remain scarce, limiting our understanding of how institutional frameworks shape spatial outcomes. Third, while DepthmapX has proven effective as an analytical platform in various urban contexts, its practical utility as a pre-evaluation tool for renewal site selection has yet to be tested within China's emerging micro-renewal practice. Essawy et al. [13], who compared road networks in two Egyptian communities using Space Syntax, provide a partial methodological precedent, but their focus on vehicular networks differs from the pedestrian-oriented micro-renewal context of this study. The present study addresses these gaps by applying VGA at the community scale to compare two contrasting renewal models and to explore the potential of DepthmapX as a diagnostic instrument for micro-renewal planning.

### 3 Methodology

#### 3.1 Case Selection

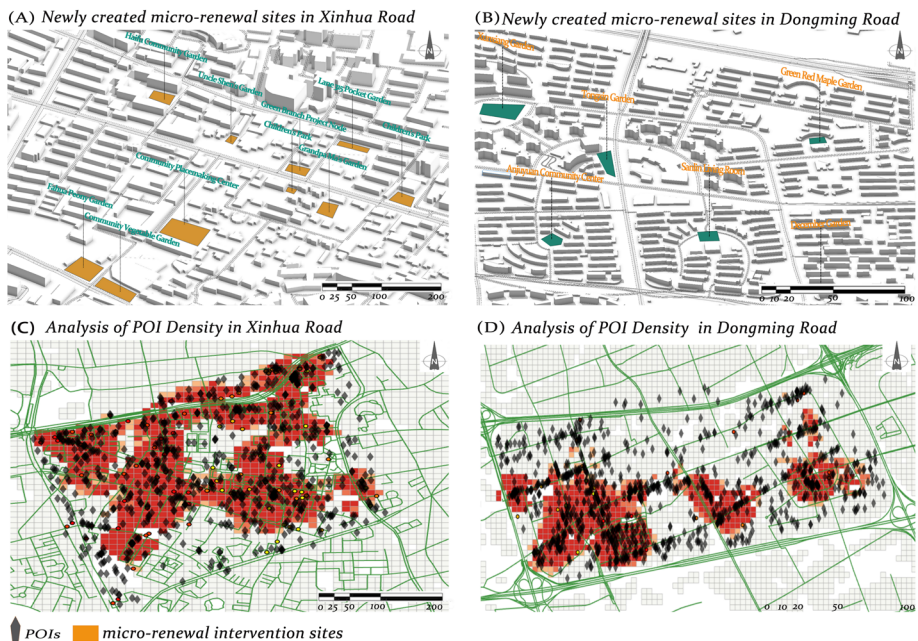
Two communities in Shanghai were selected to represent contrasting renewal models (Table 1). Xinhua Road Community, located in Changning District, covers approximately 2.2 km<sup>2</sup> and is characterized by a historically layered urban fabric, including lane houses, garden villas, and post-1949 workers' housing. Micro-renewal in Xinhua Road has involved multiple stakeholders including residents, commercial tenants, and heritage NGOs, representing a bottom-up governance model. Dongming Road Community, located in Pudong New District, covers approximately 5.95 km<sup>2</sup> and consists primarily of commercial housing estates built in the 1990s–2000s with a regular grid layout. Renewal here has been predominantly government-led (top-down model), focusing on infrastructure upgrading and pocket park installation.

**Table 1.** Case Study Comparison.

Attribute	Xinhua Road	Dongming Road
Location	Changning District	Pudong New District
Area	2.2 km <sup>2</sup>	5.95 km <sup>2</sup>
Urban Fabric	Historical layered (1920s)	Commercial housing (1990s)
Renewal Model	Bottom-up, multi-stakeholder	Top-down, government-led
Morphology	Irregular lanes + arterial roads	Regular grid + gated clusters

### 3.2 Data Collection and Analysis

The construction of the geospatial database followed a rigorous multi-step verification protocol to ensure topological integrity. The foundational pedestrian network data were extracted from OpenStreetMap and subsequently corrected using high-resolution satellite imagery (Google Earth, 0.5 m resolution) to rectify topological errors such as disconnected nodes or missing pathways. To guarantee the accuracy of the local street fabric, particularly within the gated xiaoku compounds of Dongming and the narrow lanes of Xinhua, on-site field verifications were conducted over a six-month period to manually validate the accessibility of all digitized segments. Complementing this morphological data, Point-of-Interest (POI) data representing functional urban amenities were acquired via the Gaode Map API and filtered into relevant categories (commercial, public service, and recreational) to serve as proxies for community activity. Additionally, the precise coordinates of the 41 micro-renewal intervention sites (14 in Xinhua, 27 in Dongming) were geo-referenced based on published project archives from the facilitating organizations and confirmed through physical site surveys (Fig. 1).



**Fig. 1.** Spatial distribution of micro-renewal sites and urban functional intensity in case areas

The analytical workflow integrated configurational analysis with geocomputational assessment through three distinct phases. Initially, the spatial boundaries of the public realm were imported into DepthmapX to perform Visual Graph Analysis (VGA). Unlike segment angular analysis which processes linear road centerlines, VGA discretizes the open space into a 0.5m grid to calculate two primary syntactic metrics:

Visual Connectivity, measuring the immediate visual field size from a specific location, and Visual Integration [HH], quantifying the topological shallowness of each grid cell relative to the entire system. Subsequently, to evaluate the physical service efficiency of the renewal interventions, QGIS Network Analysis was employed to generate 5-minute and 10-minute isochrone walksheds originating from each intervention site. This step allowed for the assessment of service coverage overlap and the identification of blind spots in the pedestrian network. Finally, to diagnose the underlying spatial logic of each community, a Visual Intelligibility analysis was performed by performing a regression analysis between local Visual Connectivity and global Visual Integration. The resulting correlation coefficient serves as a quantitative indicator of the spatial legibility, distinguishing between highly intelligible, centralized structures and fragmented, distributed configurations. Given the large sample sizes ( $n > 29,000$ ), a Fisher's z-test was employed to assess the statistical significance of the difference in correlation coefficients between the two communities.

## 4 Results

The VGA results reveal distinct spatial profiles for the two communities (Table 2). In terms of connectivity, Dongming Road recorded a mean of 2,851.34 (SD = 2,477.26), approximately eight times higher than Xinhua Road's mean of 348.08 (SD = 337.79). This reflects the fundamental morphological contrast: Dongming Road's wide courtyards create expansive visual fields, whereas Xinhua Road's narrow lanes restrict visibility. Similarly, Visual Integration [HH] was substantially higher in Dongming Road (mean = 8.03, SD = 1.70) compared to Xinhua Road (mean = 4.03, SD = 0.60), indicating that Dongming Road functions as a more globally connected spatial system.

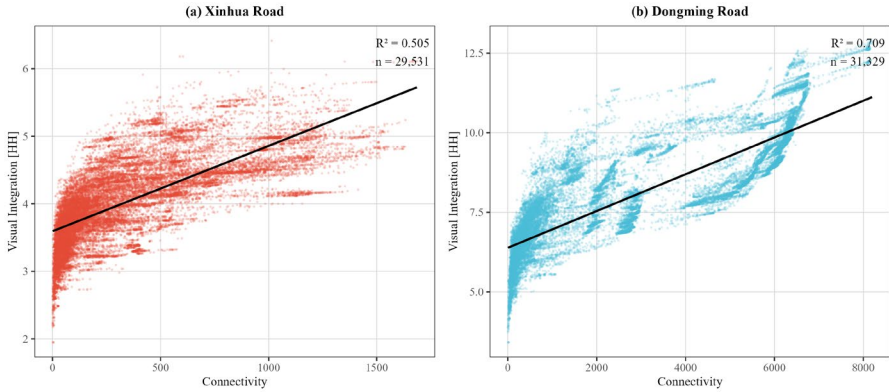
The key finding concerns intelligibility—the correlation between local connectivity and global integration (Fig. 2). Dongming Road exhibited higher intelligibility ( $R^2 = 0.709$ ,  $p < 0.001$ ) with regression equation  $y = 0.000577x + 6.38$ . Xinhua Road showed moderate intelligibility ( $R^2 = 0.505$ ,  $p < 0.001$ ) with equation  $y = 0.001264x + 3.59$ . A Fisher's z-test confirmed this difference was statistically significant ( $z = -41.89$ ,  $p < 0.001$ ).

**Table 2.** Comparative VGA metrics and intelligibility statistics for cases.

Metric	Xinhua Road	Dongming Road
Mean Connectivity	348.08	2,851.34
SD Connectivity	337.79	2,477.26
Mean Integration [HH]	4.03	8.03
SD Integration [HH]	0.60	1.70
Intelligibility ( $R^2$ )	0.505	0.709
Regression Slope ( $\beta$ )	0.001264	0.000577
Regression Intercept	3.59	6.38

The higher  $R^2$  in Dongming Road indicates that its spatial logic is more legible: highly connected spaces tend to be highly integrated. Users can rely on local visual

cues to infer global accessibility. In Xinhua Road, the weaker correlation suggests spatial complexity—some locally enclosed spaces may be globally strategic, while some visually open spaces may be peripheral dead-ends. This pattern is characteristic of organic, incrementally developed urban fabrics.



**Fig. 2.** Visual Intelligibility analysis. (a) Xinhua Road:  $R^2 = 0.505$ ,  $n = 29,531$ ; (b) Dongming Road:  $R^2 = 0.709$ ,  $n = 31,329$ .

In summary, the quantitative evidence categorizes the two sites into distinct spatial typologies. The statistical divergence in intelligibility serves as a definitive indicator: Dongming Road represents a Transparent Logic where visual hierarchies are explicit and predictable, whereas Xinhua Road represents a Cryptic Logic where visual and functional hierarchies are decoupled. This typological distinction, detailed in Table 2, suggests that relying on visual intuition works for the former but fails for the latter, necessitating fundamentally different intervention strategies.

## 5 Discussion

The regression results reveal a fundamental typological divergence between the two communities, pointing to distinct mechanisms of spatial perception. Dongming Road characterizes what can be termed a Transparent Logic. Despite the physical enclosure of gated boundaries, the internal modernist grid maintains a high degree of visual predictability, where local openness reliably signals global accessibility. This finding challenges the common stereotype that gated communities are spatially chaotic. Internally, they often possess a rational, coherent visual structure. In sharp contrast, Xinhua Road reflects a Cryptic Logic, akin to what Hillier [8] describes as a complex organic system. Here, the historical accumulation of irregular laneways creates a labyrinthine effect where visual cues are frequently decoupled from functional hierarchies. A visually secluded alleyway might be a critical shortcut, while a wide intersection might be topologically segregated, forcing users to rely on familiarity rather than visual intuition for wayfinding.

These morphological diagnostics dictate that renewal interventions must be tailored to the underlying visual structure rather than applied uniformly. For high-intelligibility fabrics like Dongming Road, a Network Proliferation strategy is most effective. Since the spatial system is inherently legible and uniform, interventions can be distributed across multiple smaller nodes—such as fitness corners or seating pockets—without the need for a singular monumental center. The predictability of the grid ensures that these dispersed points remain discoverable and accessible, maximizing service coverage. Conversely, low-intelligibility fabrics like Xinhua Road require a Nodal Acupuncture strategy. In such a cryptic environment, resources dispersed randomly risk being lost in visual dead zones. Interventions must therefore be concentrated at algorithmically identified Integration Cores—locations that act as structural anchors. By strengthening these specific nodes, the renewal can artificially enhance the legibility of the complex historical fabric.

While previous studies have established the link between spatial centrality and land-use distribution [14] and called for embedding configurational analysis into design practice [15], the morphology-adapted strategies proposed here demonstrate how such integration can be operationalized differently depending on whether the underlying fabric is legible or cryptic. This study establishes a methodological framework for quantitative pre-evaluation, it is important to recognize that the identified spatial potential does not automatically equate to social vitality. The current model focuses on visual possibility; future research should integrate behavioral data—such as pedestrian counts, stationary activity mapping, and resident surveys—to validate whether the Transparent and Cryptic logics identified here translate into actual usage patterns. This step would bridge the gap between configurational potential and realized community life.

## 6 Conclusion

This study establishes that visual spatial structure acts as a fundamental constraint on the distribution of community spatial potential. By utilizing Visual Graph Analysis, we quantitatively contrasted the Cryptic Logic of Xinhua Road with the Transparent Logic of Dongming Road, providing empirical evidence that optimal micro-renewal strategies are contingent upon the underlying urban morphology. Specifically, the findings advocate for a Morphology-Adapted Strategy: complex historical fabrics with low intelligibility benefit most from Nodal Acupuncture interventions that intensify algorithmically identified visual cores, whereas legible modernist grids require Network Proliferation strategies that maximize coverage through distributed interventions. This distinction offers planners a robust diagnostic reference to move beyond intuition-based site selection toward evidence-based spatial interventions.

Methodologically, this research demonstrates the specific utility of VGA-based Intelligibility Analysis as a pre-evaluation tool within the broader context of neighborhood regeneration frameworks. Unlike traditional axial analysis which focuses on movement efficiency, VGA effectively captures the human-scale visual field, revealing structural blind spots where visual intuition contradicts spatial reality. The signif-

icant divergence in determination coefficients between the two community types proves that Visual Intelligibility is a sensitive and robust indicator for classifying spatial typologies. Consequently, configurational analysis should be integrated into the standard micro-renewal workflow as a critical diagnostic step that complements qualitative resident engagement.

To fully operationalize this approach, future research must address the limitations identified in this exploratory study. First, the gap between simulated visual potential and realized social vitality needs to be bridged by integrating behavioral data, such as on-site pedestrian dwelling counts or mobile signaling data. Second, while this study focused on static physical form, future inquiries should employ longitudinal approaches to assess how specific renewal interventions dynamically alter the visual configuration over time. Expanding this comparative framework to a broader range of Asian high-density cities will further validate the generalizability of the proposed typology in urban regeneration practice.

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