Features, Mechanisms, Challenges, and Responses of the Spatial Jobs-Housing Relationship: A Network Perspective

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Abstract: Guiding the evolution of jobs-housing relations requires a clear account of how these relations form. Using mobile-phone signaling data for Shanghai, this study constructs a jobs-housing network and examines its nodes, edges, and overall organization. Employment and residential nodes show both convergence and divergence; network edges combine centripetal and dispersed patterns; and the network forms a one-core, multi-cluster structure. Statistical analysis indicates that edge formation follows a common power-law mechanism, while spatial distance and housing prices shape edge intensity. Shanghai's monocentric housing-price gradient and employment concentration jointly generate the observed network. The resulting challenges include spatial mismatch, transport bottlenecks, and socio-spatial inequity. Scenario simulations show how housing affordability and employment decentralization alter commuting patterns and support corresponding planning responses.

Keywords: jobs-housing relationship; complex network; commuting; housing affordability; Shanghai

Employment and residence are two fundamental urban functions. Their changing relationship affects system performance, daily life, economic efficiency, and environmental quality. Urban expansion in large cities has intensified separation and peak-hour congestion [1-3]. Scientific planning therefore requires knowledge of the mechanisms and drivers underlying jobs-housing change [4-5].

Most previous studies use static indicators within spatial units, including balance and self-containment [1,6]. These indicators understate cross-unit flows. Network science instead treats spatial units as nodes and commuting relations as directed edges, captures dynamic inter-area relationships [7-9], and provides quantitative measures for explaining network structure.

1 Literature Review

1.1 Defining the Spatial Jobs-Housing Relationship

Chinese scholarship approaches jobs-housing relations through morphology, emphasizing distributions of residents and workers [10-11], and through structure, emphasizing the organization and intensity of residential-employment connections [12-13]. This study defines the spatial jobs-housing relationship as the organizational intensity of residential-employment functional connections within and between areas with identifiable locations, attributes, and forms.

1.2 Research on Jobs-Housing Relations

Four strands dominate the literature. The first measures internal relations and spatial patterns using self-containment, commuting distance, standard-deviation ellipses, and related indices [14-17]. The second identifies individual and spatial determinants. Survey and transport data relate commuting to the built environment, socio-economic attributes, and institutions [18-23], while big-data studies examine how local environments affect balance [24-27]. Both approaches can obscure interactions among areas.

The third strand evaluates organizational efficiency through excess-commuting models and optimization [28-31]. These models identify theoretical potential but often minimize aggregate travel without fully representing personal housing and social costs. The fourth uses large-scale data to reconstruct local formation and change [13,32-34], although quantitative accounts of evolution remain limited. A network perspective can connect these strands and explain formation mechanisms.

2 Research Design and Data

2.1 Analytical Framework

The study first measures residential-employment connections between Shanghai grid cells and uses commuter counts as directed edge weights. It then examines nodes, edges, and the overall network. Ordinary least squares, power-law models, and community detection are used to explain edge formation and network organization. Challenges are identified from these results, after which simulations test alternative housing-price acceptance and employment-distribution scenarios.

2.2 Data Sources and Processing

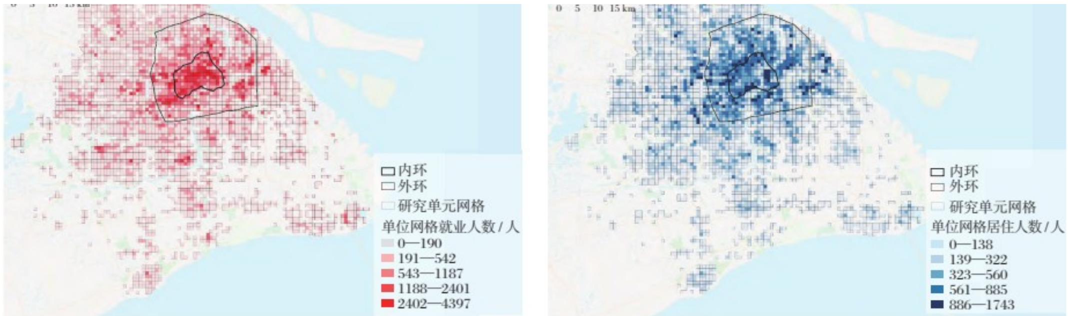
The study area excludes Chongming and Changxing islands because of their distinctive cross-water commuting. A 1 km by 1 km grid retains spatial precision and limits scale effects documented at larger units [35], yielding 7,708 cells. China Unicom signaling data for October 2023 identify home and work locations. Individuals completing at least 11 home-to-work trips are retained. Cells accounting for the first 95% of cumulative resident and worker counts form 3,698 nodes, covering 716,571 commuters.

Validation against the Seventh National Population Census produces street-level Pearson correlations of 0.85 with total population and 0.88 with working-age population, both significant at 99%. Housing prices come from Lianjia second-hand transactions. Kriging converts community-level prices into a raster, and area-weighted means are calculated for each grid.

3 Features: Spatial Characteristics of the Jobs-Housing Network

3.1 Convergence and Divergence: Spatial Characteristics of Nodes

Employment and residential populations both exhibit a core-periphery structure, although employment is more concentrated. Jobs cluster in the Nanjing West Road-Nanjing East Road-Lujiazui corridor, Greater Xujiahui, Wujiaochang, Caohejing, Zhangjiang, and several new-town centers. Residential population is more dispersed around the Inner Ring and suburban towns such as Huacao, Qibao, Jiuting, and Caolu. The historic commercial core contains fewer residents than workers.



（a）居住人口　　（b）与就业人口

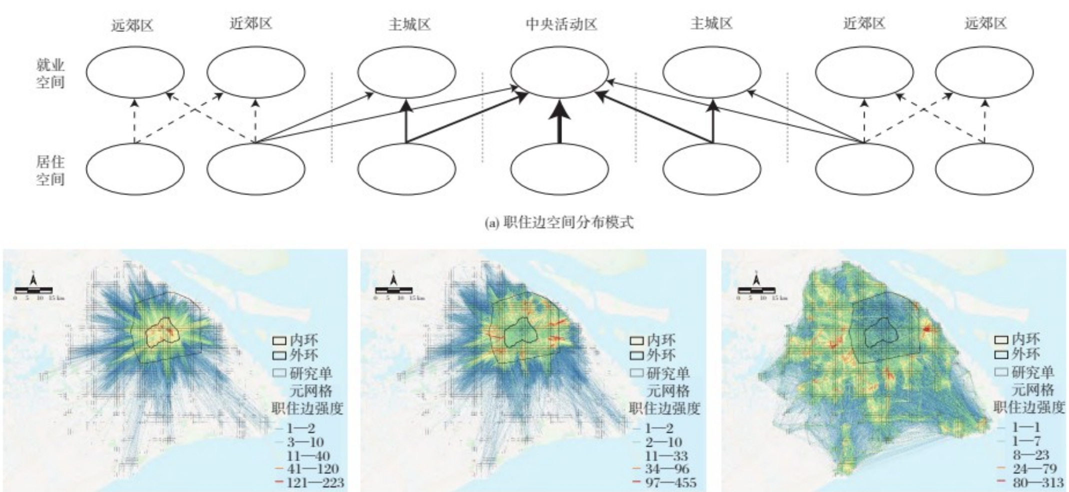
图1　居住人口与就业人口的分布特征

Fig. 1 Spatial distribution of residential and employment populations

3.2 Centripetal and Dispersed Patterns: Spatial Heterogeneity of Edges

Edges terminating inside the Inner Ring are strongly centripetal and extend from the central city to near-suburban towns. Edges terminating between the Inner and Outer rings also draw residents from the main city and its immediate periphery. In contrast, edges terminating outside the Outer Ring connect closer nodes and form more dispersed local patterns. Shanghai therefore combines a powerful central commuting field with localized suburban connections.

3.3　一主与多团：职住网络的空间组织　　随着r值从1降低到0.1，组团数量　　形成逻辑。



(b) 职住边强度（就业在内环）　(c) 职住边强度（就业在内环—外环）　(d) 职住边强度（就业在郊区）

图2　上海市职住边空间分布模式及强度分布特征

Fig. 2 Spatial patterns and intensity of jobs-housing edges in Shanghai

3.3 One Core and Multiple Clusters: Spatial Organization

The whole network forms one core and multiple clusters. The central activity zone, main city, and near suburbs constitute a strongly centripetal core, while relatively self-contained employment-residential clusters occur in the outer suburbs. Near-suburban towns have a dual role: they extend the central network and connect it to outer clusters. Louvain community detection [36] confirms this pattern. As resolution decreases from 1.0 to 0.1, communities in the central area merge into large sectors, while many outer-suburban communities remain independent.

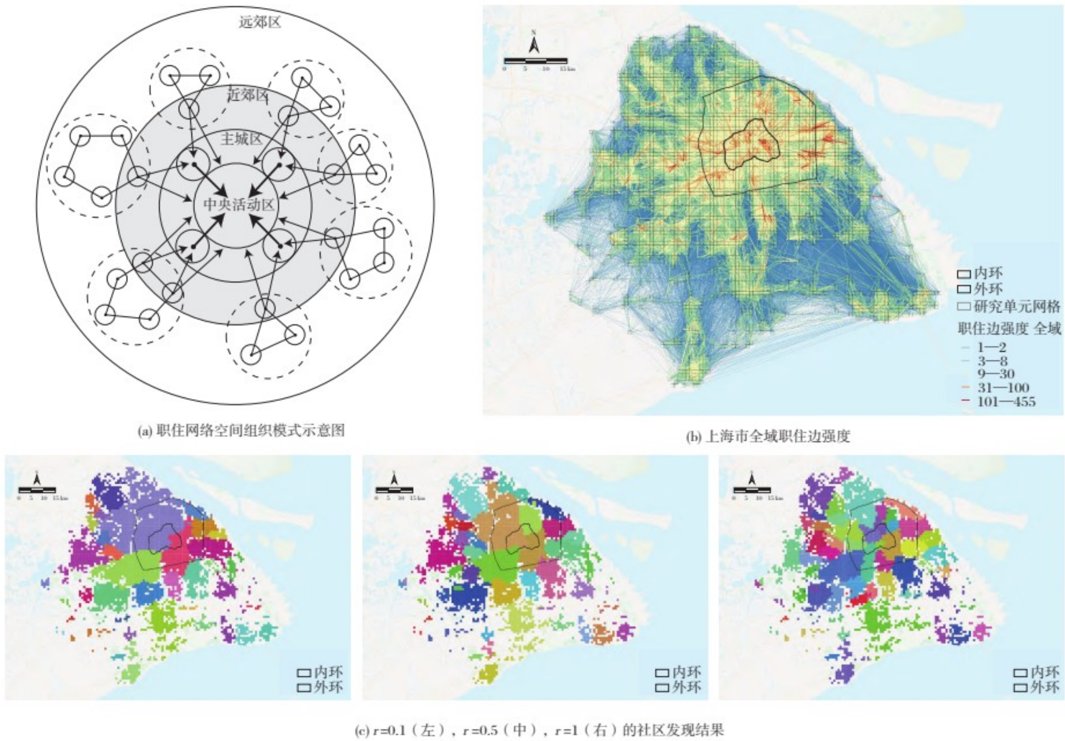


Fig. 3 Network organization, edge intensity, and community-detection results

4 Mechanisms: Formation Principles and Structural Logic

4.1 Edges: Common Mechanism and Housing-price Heterogeneity

Kolmogorov-Smirnov tests assess the edge-weight distribution for each employment node [37-38]. Among 1,689 nodes with more than 100 workers, only one fails the power-law test. Most employment nodes thus connect strongly to a small set of residential nodes, suggesting stable commuting corridors.

Following the first law of geography and classical location theory [39], edge intensity P is modeled from a combined utility X: P = X^-alpha and X = alpha1D + alpha2R + beta, where D is spatial distance and R is the housing price at the employment node. Mean goodness of fit is approximately 0.58 for employment nodes with more than 100 workers. Greater distance and housing cost reduce edge intensity. The monocentric, exponentially declining housing-price surface explains the contrast between long, centripetal central-city links and shorter, localized suburban links.

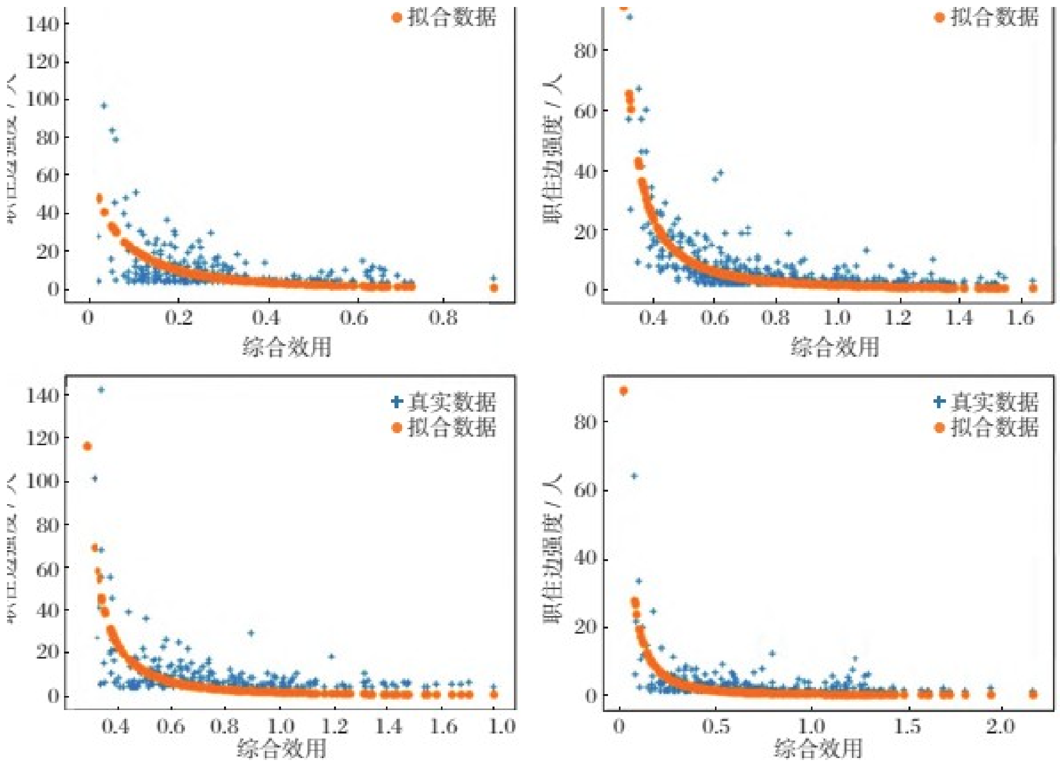


Fig. 4 Model fits for the six largest employment nodes

4.2 Network Formation: Superposition of Subnetworks and Employment Concentration

Each employment node forms a subnetwork as workers choose residences according to commuting distance and housing cost. Superposition of these subnetworks produces the citywide network. Shanghai's one-core, multi-cluster structure is rooted in monocentric employment. Dense central employment sustains strong links from nearby suburbs despite distance, while suburban industrialization creates local employment groups whose workers can reside nearby. The former generates the main core; the latter produces multiple outer clusters.

5 Challenges

5.1 Spatial Jobs-Housing Imbalance: Uneven Average Commuting Distance

Employment-node commuting distance declines from the center outward, whereas residential-node distance has a hump-shaped distribution that peaks near the Outer Ring. Near-suburban areas are simultaneously linked to the central activity zone and outer towns, making them the most pronounced zone of spatial separation.

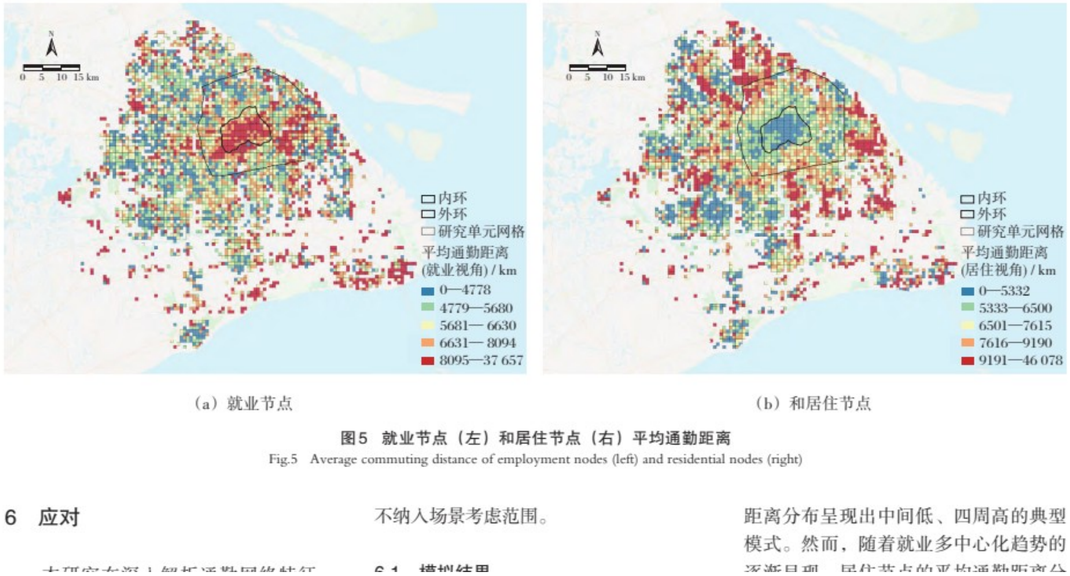


Fig. 5 Average commuting distance of employment and residential nodes

5.2 Transport Bottlenecks: Pressure from Centripetal Commuting Flows

Large peak-hour flows from the urban periphery to the central city place sustained pressure on expressways and rail corridors. Recurrent congestion on these links reduces system reliability and residents' accessibility [40].

5.3 Social Inequity: Intensified "Time Poverty" among Low-income Groups

Workers in the central city face high housing prices. When affordable housing is unavailable, lower-income groups exchange housing costs for longer travel and live farther from work. Extended commuting deepens time poverty and reduces time for personal development, family life, and rest [41].

6 Responses

A 50 by 50 grid with 1 km cells is used to simulate one million workers. Baseline employment and housing prices decline exponentially from the center, and residential choice follows a power-law process driven by distance and price. Nine scenarios combine low, medium, and high housing-price weights with monocentric, one-main-plus-secondary-center, and homogeneous polycentric employment.

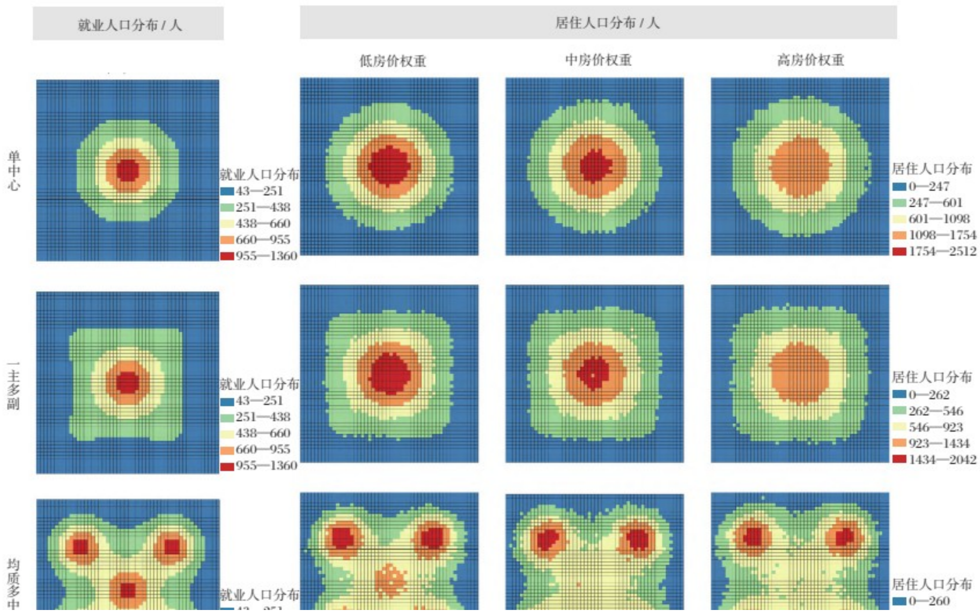


Fig. 6 Simulated employment and residential population under alternative scenarios

6.1 Simulation Results

Residential distribution responds strongly to employment configuration, and higher price weights push households toward the periphery. Employment-node commuting distance declines from the center in all nine scenarios. Housing-price acceptance significantly changes its magnitude, confirming the influence of market conditions. Residential-node distances are low in the center and high at the edge under monocentric employment, but become increasingly polycentric as jobs decentralize.

Employment distribution determines overall network organization. Monocentric employment produces strongly centripetal edges. A main center with secondary centers resembles Shanghai's one-core, multi-cluster pattern. Homogeneous polycentric employment strengthens outer clusters and weakens central centripetal dominance. Greater housing-price acceptance shortens commuting and further weakens the centripetal tendency.

图6　不同场景下的就业人口、居住人口分布

Fig.6　Distributional patterns of working and residential population under different scenarios

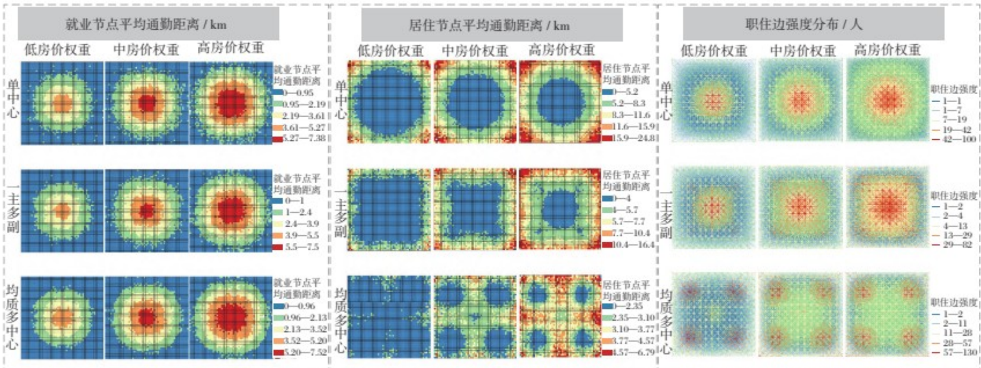


图7　不同场景下的就业节点平均通勤距离、居住节点平均通勤距离及职住边强度

Fig.7　Average commuting distances of employment nodes, residential nodes, and job-housing edge intensity under different scenarios

“一主多副”结构下那样突出。

住房价格可接受程度的变化对职住网络的结构特征亦具有一定的影响。尽管这一变化不会直接导致职住网络边的结构特征发生显著改变，但其向心趋势减弱。

6.2　应对策略

6.2.1　住房价格接受程度提升：多维度策略组合

接受程度提升能直接促进居民就近居住，减少空间平均通勤距离和减弱向心流强度。一是持续强化保障性住房体系建设。针对上海市当前情况，应进一步加大保障性住房的投资与建设力度，确保住房

Fig. 7 Average commuting distances and edge intensity under different scenarios

表1　不同场景下节点平均通勤距离的均值

Tab.1　Mean commuting distance of nodes across scenarios

场景	低房价权重		中房价权重		高房价权重	
	就业节点	居住节点	就业节点	居住节点	就业节点	居住节点
单中心	1.06	5.50	1.68	7.16	2.26	8.26

Table 1 Mean node commuting distance across simulation scenarios

6.2 Response Strategies

6.2.1 Improving Housing Affordability through Coordinated Measures

Improved housing affordability enables residence closer to employment and reduces average commuting distance. Shanghai should expand a stable and diverse affordable-housing supply. Differentiated subsidies can reflect housing prices around employment locations and compensate lower-income workers for the time costs created by spatial separation.

6.2.2 Optimizing Employment Distribution through Industrial Decentralization

Employment distribution substantially changes network organization. Shanghai has entered a stage in which suburban enterprise growth exceeds that of the center [42]. The five new cities should therefore be strengthened as comprehensive nodes, and market-compatible incentives should guide suitable industries outward. Transport planning must proceed with industrial decentralization [43], because dense commuting flows may shift toward peripheral employment centers as polycentricity develops.

7 Conclusions and Discussion

7.1 Conclusions

Shanghai's employment and residential nodes share a broad core-periphery form, although employment is more concentrated. Central-city edges are centripetal, suburban edges are dispersed, and the whole network is organized as one core with multiple clusters. Edge weights follow a common power-law mechanism; distance and housing prices shape their intensity. The monocentric housing-price gradient and employment distribution jointly generate the observed structure. Simulations show that housing affordability and employment decentralization can reduce mismatch, congestion, and inequity.

7.2 Discussion

Three limitations define future research. The edge-formation mechanism is estimated from employment nodes and should be tested from residential nodes. The model currently focuses on housing prices and distance; public services and transport facilities should be added. Finally, simulations assume a monocentric housing-price field. The persistence of this pattern under increasingly polycentric employment requires further examination.

Notes

1. The ring-based zones are the central activity area inside the Inner Ring, the main city between the Inner and Outer rings, and suburbs outside the Outer Ring. 2. The terms central activity area, main city, and new city follow the Shanghai Master Plan (2017-2035). 3. Comprehensive node city follows the same plan.

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AI-assisted translation