Spatiotemporal Characteristics of "Urban-Suburban-Rural" Interaction in Shanghai Metropolis: A Perspective on Commuting Mobility

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Abstract

As urbanization progresses, the flow of population, capital, and other resources between urban and rural areas accelerates, leading to evolving urban-rural interactions. This study examines the spatiotemporal characteristics of the "urban-suburban-rural" interactions in the Shanghai metropolis from 2017 to 2020, focusing on commuting flows. The results indicate that interactions among urban, suburban, and rural areas in Shanghai metropolis have generally strengthened, characterized by increasingly distinct commuting structures and more pronounced strong connections. Urban commuting patterns predominantly rely on intra-urban flows, while suburban and rural areas demonstrate varying degrees of employment dependence on urban areas. Notably, rural areas exhibit stronger dependence on suburban areas than on urban centers. Despite these interactions, significant differences persist in the commuting structures among the three areas. The development of employment centers, such as the central city, urban peripheries, new towns, and industrial parks, has enhanced connections within urban areas, as well as between urban and suburban areas and between urban and rural areas. However, the commuting structures within rural areas and between rural and suburban areas have shown little change, reflecting lagging functional development in these areas. Shanghai metropolis should focus on unlocking the potential of suburban and rural areas by advancing functional development and establishing employment centers.

Keywords

Shanghai metropolis, urban-rural continuum, commuting mobility

1. Introduction

It is generally believed that after urbanization reaches a certain level, factors such as population and capital are reallocated between urban and rural areas. Populations and economic activities will exhibit characteristics that are significantly different from those of the rapid urbanization stage: from unidirectional agglomeration in the city to bidirectional mobility between urban and rural areas (Liu Shouying & Long Tingyu, 2022). During rapid urbanization, cities often serve as centers of production and exchange, leveraging their economic and cultural advantages to attract rural populations and resources to urban areas. This process leads to an increasing dependence of rural areas on urban markets, infrastructure, and public services. This stage is characterized by the unidirectional concentration of population and economic activities in cities (Davoudi, 2002). Since the latter half of the 20th century, some countries have gradually reached higher levels of urbanization. At the same time, cities began to face "urban problems" such as air pollution, skyrocketing housing prices, and traffic congestion, prompting many urban residents in the United States and European countries to migrate to suburbs and rural areas. This phenomenon of counter-urbanization has become a long-term trend and continues to this day (Li et al., 2024). As population and capital elements continue to flow between urban and rural areas, the urban-rural relationship is dynamically evolving, exhibiting increasingly complex patterns of interaction between the two. The interaction between urban and rural areas is also undergoing significant changes.

The study of urban-rural relationships has long been a key focus in academic research. During the development of this field, an important theoretical shift has occurred. As the urbanization process continues, the boundaries between urban and rural areas have become increasingly blurred. The traditional urban-rural "binary" division is no longer applicable, and it has been replaced by a society characterized by urban-rural integration and mutual interweaving. The theory of the urban-rural continuum is one of the key representations of this shift. This theory suggests that the relationship between urban and rural areas is not simply a binary division but rather a continuous hierarchical structure. Specifically, between completely rural and fully urbanized areas, there exists a continuum that is represented by a continuous gradient (Yuan, 1970). The introduction of this theory broke the binary opposition framework between urban and rural areas, incorporating both into a unified analytical perspective. It not only focuses on the internal differences between urban and rural areas but also emphasizes the connections and integration between the two (Lichter & Brown, 2011). Guided by this theory, many scholars have conducted extensive empirical research to explore the economic and social phenomena in different regions of the urban-rural continuum, such as the factors influencing the flow of elements within the continuum and the differences in asset poverty and residents' well-being across different areas (Braun, 2007; Fisher & Weber, 2004; Requena, 2016). Based on this, this paper attempts to move beyond the

traditional analysis of the urban-rural "binary" relationship in China, drawing on the theory of the urban-rural continuum, and uses the Shanghai metropolis as a case study to explore the interactive relationships between different levels of the urban-rural continuum in Shanghai metropolis.

With the development of big data technologies, particularly the proliferation of multi-source data such as POI data and mobile signaling data, the study of urban-rural relationships has gradually expanded to include the analysis of the mobility of various factors such as population flows and transportation (Xie Zhiming & Zhen Feng, 2023). Against this backdrop, this paper utilizes mobile data to analyze Shanghai's urban-rural interactive relationships from the perspective of population flow. Population movement can generally be classified into daily flows (e.g., shopping, healthcare), short-term flows (e.g., tourism, schooling), and long-term flows (e.g., employment). Among these, long-term flows have a particularly profound impact on urban-rural interactions (Du Guoming & Liu Mei, 2021). Therefore, this paper focuses on long-term commuting flows to explore the interactive relationships between different levels of the urban-rural continuum in Shanghai metropolis. Through this approach, the paper aims to provide insights into the urban-rural integration process in Shanghai and other metropolis.

2. Research Design

2.1 Research Methods

The research in this paper mainly covers two parts. The first part focuses on the spatial identification and division of different levels of areas within the urban-rural continuum of Shanghai metropolis. Currently, there is no unified standard for classifying urban-rural continuums. The Organization for Economic Co-operation and Development (OECD) primarily divides urban-rural continuums based on population density, while the European Union's statistical office proposes a relatively comprehensive classification method that combines population density and urbanization level. The United States Statistical Department, on the other hand, considers multiple factors such as population density and geographical location in its classification criteria. Considering the actual situation of the Shanghai metropolis, this paper mainly draws on the classification method of the European Union's statistical office, adjusting the relevant standards. Based on population density and urbanization level, Shanghai metropolis is divided into three categories: urban, suburban, and rural areas. This classification method can more accurately reflect the spatial characteristics of Shanghai's urban-rural continuum and lay the foundation for subsequent research.

The second part focuses on analyzing the interaction between different levels of areas. Based on the spatial division mentioned above, this paper delves into the interaction between urban, suburban, and rural areas of the Shanghai metropolis from a commuting flow perspective, mainly examining the spatiotemporal characteristics of commuting ratios and commuting structures.

2.2 Research Data

In the spatial division section, this study uses the 2023 LandScan Global grid population data provided by the Oak Ridge National Laboratory (ORNL). This dataset integrates geospatial science, remote sensing technology, and advanced machine learning algorithms, making it one of the highest-resolution global population distribution datasets currently available (Lebakula et al., 2024). The grid unit size of this data is 30 arc seconds, providing detailed population distribution information worldwide. Based on this data, the paper calculates the population density of each grid unit as the foundation for subsequent spatial division analysis.

The commuting flow data comes from location-based service (LBS) travel data, collected throughout October 2017 and October 2020, aimed at comparing commuting characteristics between two different years. Using this data, the paper identifies users' residential and employment locations. The identification rule is as follows: during non-working hours (9:00 PM to 7:00 AM) on weekdays and weekends, the coordinate point with the highest frequency of user presence is defined as the residential location; during working hours (10:00 AM to 5:00 PM) on weekdays, the coordinate point with the highest frequency is defined as the employment location. Based on this rule, the paper filters the commuting origin and destination coordinates along with the corresponding number of people for subsequent statistics and analysis. It is important to note that there is a certain discrepancy in the total amount of travel data between 2017 and 2020. Therefore, this study only analyzes the proportional changes and structural characteristics of commuting data between the two years, without conducting an in-depth comparison or interpretation of the specific data volume.

3. Spatial Identification of "Urban-Suburban-Rural" in Shanghai Metropolis

The spatial identification method used in this study consists of two key steps. The first step is to identify different density clusters based on population density and scale, specifically dividing them into high-density clusters, medium-density clusters, and low-density grid cells (see Figure 1, left). The specific methods for this step include the following: ① Areas with a population density of ≥5000 people per square kilometer and a total population of ≥40,000 people in adjacent grid cells are classified as high-density clusters. These clusters are further expanded by filling in gaps. Specifically, if 5 or more of the 8 neighboring grid units of a particular unit belong to a high-density cluster, the unit is also classified as part of the high-density cluster. This process continues iteratively until no new units are added to the cluster. ② Areas with a population density of ≥2000 people per square kilometer and a total population of ≥20,000 people in adjacent grid cells are classified as medium-density clusters, applying a similar gap-filling strategy. ③ The remaining grid units are classified as low-density grid units.

The second step is to classify local administrative units based on the level of urbanization, which includes urban, suburban, and rural ar-

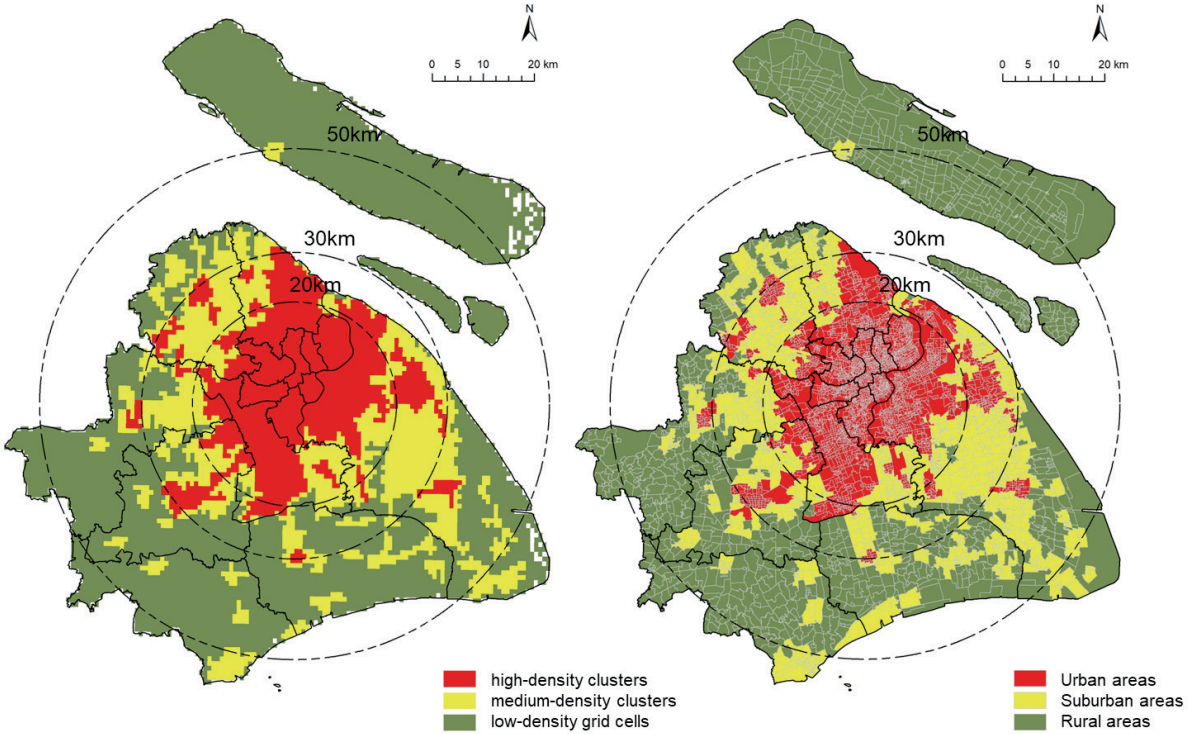

Figure 1. “High-Medium-Low” density grid cells (left) and “Urban-Suburban-Rural” classification in Shanghai metropolis. Source: drawn by author

eas (see Figure 1, right). This step uses communities as the smallest administrative unit, and the specific classification rules are as follows: ① If at least 50% of the population resides in high-density clusters within a community, the community is classified as part of the urban area; ② If fewer than 50% of the population resides in high-density clusters but at least 50% reside in medium-density clusters within a community, the community is classified as part of the suburban area; ③ If more than 50% of the population resides in low-density grid units within a community, the community is classified as part of the rural area. During the classification process, if a community unit spans multiple density clusters, the classification is weighted based on the area of each cluster to ensure accuracy and fairness in the results.

The spatial division results show that Shanghai's urban, suburban, and rural areas exhibit distinct concentric ring distribution characteristics. The urban area is mainly concentrated within 20 km of the city center, with some localized clusters appearing around the 30 km mark. The suburban area is primarily distributed within 30 km

of the city center, with small clusters in some peripheral regions.

4. Spatiotemporal characteristics of "urban-suburban-rural" interaction in Shanghai metropolis

4.1 Commuting ratio

Commuting proportion refers to the ratio of commuting flows from one area to another compared to the total commuting flow of the area in question. By measuring the commuting proportion between different areas, we can effectively assess the dynamic connectivity between those areas. Specifically, the higher the commuting proportion, the closer the interaction and connection between two areas; conversely, a lower proportion indicates weaker connectivity between the regions.

Based on the analysis results (see Table 1), the following main findings can be drawn: ① In both 2017 and 2020, whether in urban, suburban, or rural areas, there is a tendency for commuting within the same region to dominate. However, the proportion of local commuting is notably higher in urban areas, indicating that employment opportunities and living demands within the urban areas have a stronger attraction for local residents. In contrast, suburban and rural areas exhibit relatively lower local commuting proportions, reflecting a tendency for commuting flows from these areas to other regions. ② A further analysis of the temporal changes from 2017 to 2020 reveals a general downward trend in the proportion of local commuting across urban, suburban, and rural areas. This change indicates a gradual increase in cross-regional connections. ③ Regarding cross-regional commuting, suburban areas mainly have their commuting flows directed toward urban areas, suggesting a high reliance on employment opportunities in the urban areas. In contrast, rural areas show a significantly lower commuting proportion to the urban areas, with their primary destination for cross-regional commuting being suburban areas. This phenomenon reflects a stronger dependence of suburban areas on urban areas for employment, while rural areas rely more on suburban areas than on urban areas.

Employment / Residence	urban areas（%）		suburban areas（%）		rural areas（%）	
	2017	2020	2017	2020	2017	2020
urban areas	94.65%	94.03%	4.48%	4.92%	0.88%	1.05%
suburban areas	21.52%	23.25%	74.47%	71.86%	4.01%	4.90%
rural areas	9.35%	10.31%	15.03%	15.97%	75.62%	73.72%

Table 1. Matrix of "urban-suburban-rural" commuting ratios in Shanghai metropolis, 2017-2020. Source: drawn by author

4.2 Commuting structure

Visualizing the daily commuting connections of residents can provide a comprehensive view of the overall commuting structure and its dynamic changes. The specific method involves the following steps: First, using communities as the basic statistical unit, data is aggregated based on the origin and destination of commuting, obtaining one-way population flow between units, which represents the total number of commuters

from the origin unit to the destination unit (Tian Lin et al., 2023). Then, based on the spatial classification of these statistical units, nine types of commuting connection patterns are identified: "urban-to-urban," "urban-to-suburban," "urban-to-rural," "suburban-to-urban," "suburban-to-suburban," "suburban-to-rural," "rural-to-urban," "rural-to-suburban," and "rural-to-rural." Corresponding commuting connection data tables are constructed, followed by spatial visualization analysis, ultimately generating nine commuting structure matrix maps. This calculation only retains connections between different statistical units, excluding intra-unit commuting connections. The larger the commuting flow between units, the closer the connection (Fan Jiahui et al., 2019).

The research results (see Figures 2 and 3) show that from 2017 to 2020, the structure of commuting flow became increasingly clear, the networked nature deepened, and some strong connections became particularly evident. A detailed analysis is as follows. In terms of Intra-regional commuting, ① The "urban-to-urban" commuting structure remained highly networked. By 2020, some complete "center-periphery" substructures had formed, especially between areas such as Zhangjiang Town, Jinqiao Town, and Gao Dong Town in Pudong New Area, as well as between Xinhong Subdistrict in Minhang District and the surrounding areas, highlighting high-density commuting within the urban area. ② The "suburban-to-suburban" commuting links showed some degree of network development, mainly consisting of short-distance strong connections. By 2020, some strong connection areas had formed a "diamond-shaped" substructure, primarily distributed in areas such as Tinglin Town and Shihua Subdistrict in Jinshan District. ③ The "rural-to-rural" commuting structure was less networked, but some strong nearby connections existed, concentrated in towns like Shanyang Town in Jinshan District, Ye Xie Town in Songjiang District, Ni Cheng Town in Lin-gang Special Area, and Changxing Town in Chongming District. Particularly between 2017 and 2020, the strength of these connections and their networked influence increased significantly, showing a growing trend of internal commuting links in rural areas.

In terms of inter-regional commuting, ① Urban-to-suburban commuting: From 2017 to 2020, commuting between urban and suburban areas became more distinct, especially at the urban periphery, where several strong connection structures formed. For example, strong "suburban-to-urban" links were formed in areas such as Zhangjiang Town, Jinqiao Town, Gao Dong Town in Pudong New Area, Songjiang Industrial Zone, and Pujiang Town in Minhang District, while "urban-to-suburban" strong links were formed in areas such as Tang Town in Pudong New Area, Songjiang Industrial Zone, and Xujing Town in Qingpu District. This indicates tighter connections between employment centers at the urban edge and surrounding areas, emphasizing the dependence of suburban areas on the urban area for employment. ② Urban-to-rural commuting: The commuting connection between urban and rural areas remained less networked. However, by 2020, some long-distance strong connections appeared, such as

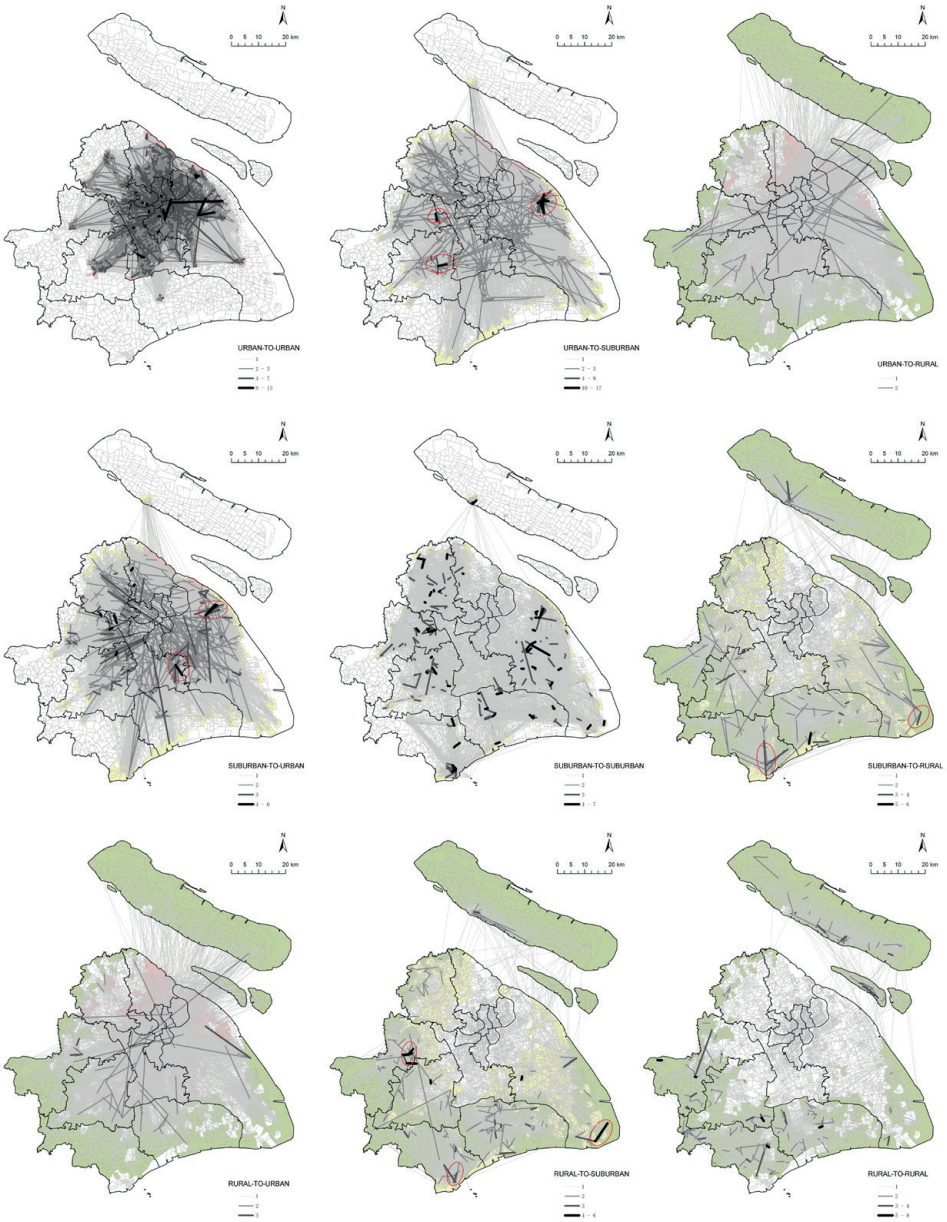

Figure 2. “Urban-Suburban-Rural” commuting structure in Shanghai metropolis, 2017.
Source: drawn by author

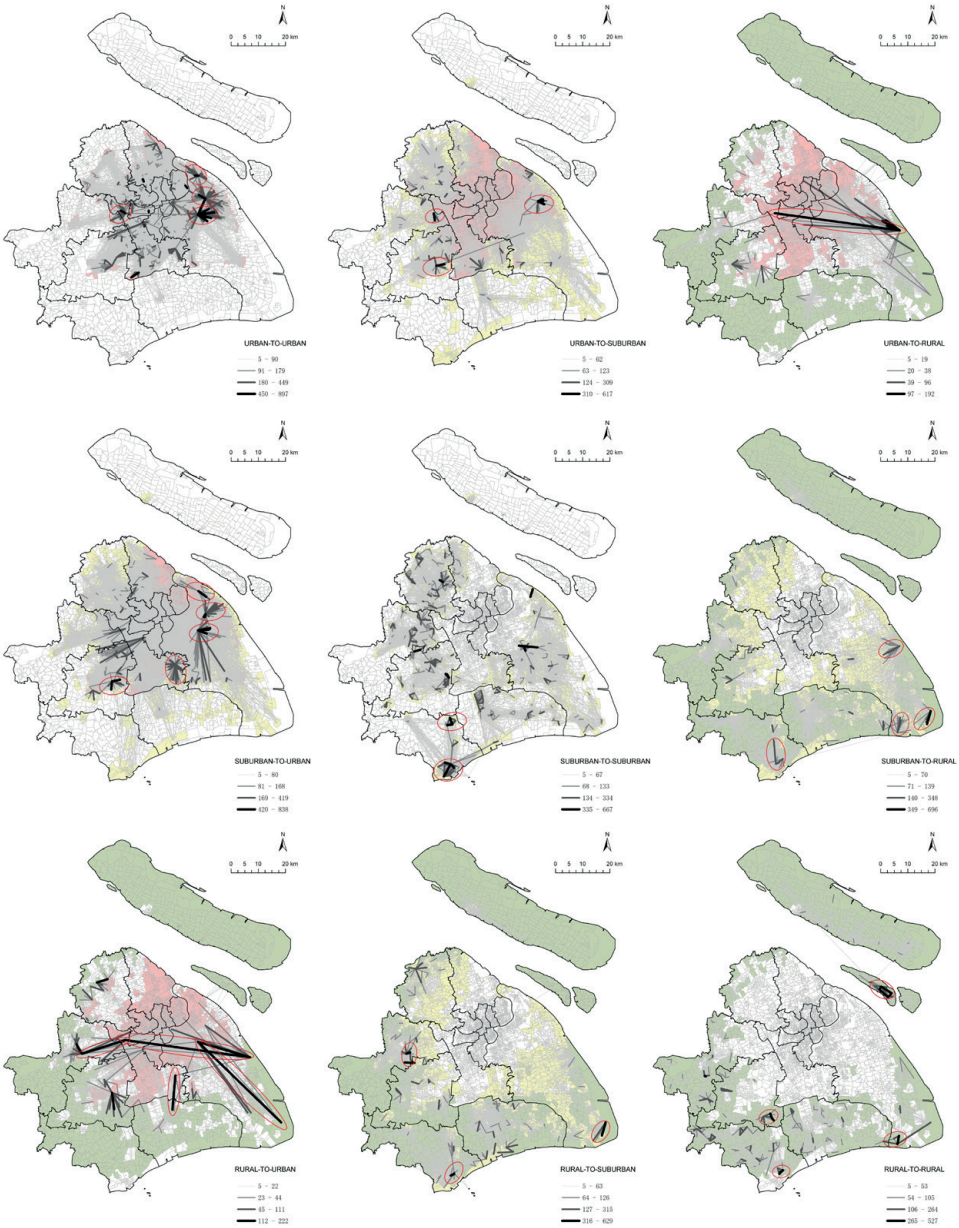

Figure 3. “Urban-Suburban-Rural” commuting structure in Shanghai metropolis, 2020.
Source: drawn by author

those between Zhuqiao Town in Pudong New Area and Xinhong Subdistrict in Minhang District, Xinhong Subdistrict and Zhaoxiang Town in Qingpu District, as well as Zhangjiang Town in Pudong New Area and Nanhui New Town. These long-distance connections primarily occurred in the five new towns and airport areas in Shanghai metropolis, indicating that the construction of new urban areas and functional zones provided employment opportunities, strengthening the interaction and connection between urban and rural areas. ③ Suburban-to-rural commuting: Commuting between suburban and rural areas remained weakly networked, with little change from 2017 to 2020. This connection primarily consisted of a few nearby strong links, mainly distributed in areas such as Zhuqiao Town in Pudong New Area, Nanhui New Town, Sanyang Town in Jinshan District, and Zhaoxiang Town in Qingpu District, indicating that these areas are somewhat reliant on neighboring regions for employment opportunities.

5. Conclusions and Discussions

5.1 Findings

The study delves into the spatiotemporal characteristics of the "urban-suburban-rural" interactive relationships within the urban-rural continuum of Shanghai metropolis from the perspective of commuting flows. The main findings are as follows:

(1) With the acceleration of urbanization, the interactions between urban, suburban, and rural areas in Shanghai metropolis have gradually intensified. Specifically, from 2017 to 2020, the proportion of local commuting within these areas decreased, while the proportion of cross-regional commuting increased across the board.

(2) In terms of commuting proportions, urban commuting largely depends on local areas, whereas suburban and rural areas still exhibit strong dependence on urban employment. However, rural areas show a higher dependency on suburban areas than on urban areas.

(3) Over time, the commuting structure in each region has become increasingly clear, with strong connections becoming more prominent. This indicates that the coordination between various regions within Shanghai metropolis has improved, and the interactive relationships are becoming more refined.

(4) In local commuting structures, the "urban-to-urban" commuting network is highly developed, and by 2020, some complete "center-periphery" substructures had formed. The "suburban-to-suburban" commuting network also showed some degree of development, primarily with short-distance strong connections, and in some areas, a "diamond-shaped" substructure emerged. In contrast, the "rural-to-rural" commuting network was less developed, with only a few strong connections in nearby areas.

(5) In cross-regional commuting, strong connections formed between urban and suburban areas, particularly at the urban periphery, reflecting a stronger dependence of suburban areas on employment centers at the urban edge. The

commuting link between urban and rural areas showed a lower level of network development, but some long-distance strong connections appeared in the five new towns and airport areas, indicating that the construction of new urban zones and functional areas has enhanced the interaction between urban and rural areas. The commuting connections between suburban and rural areas were weakly networked and showed little change, reflecting the relatively delayed development of functions in suburban and rural areas.

5.2 Discussions

In recent years, the Shanghai government has significantly increased its investment in urban-rural integration and rural revitalization, aiming to enhance financial support for rural areas, improve basic public services, and bolster infrastructure construction. While rural living standards have seen improvements over the past few years, challenges persist. The urban-rural income disparity remains high, with the urban-rural income ratio exceeding 2, indicating a significant gap in wealth and economic development between urban and rural areas. Moreover, rural development continues to lag behind the rapid pace of urbanization, exacerbating the disparity. Additionally, the level of rural governance and management, particularly in terms of detailed administrative functions, remains less developed compared to urban areas, which has become a critical bottleneck in achieving true urban-rural integration (Gu Shoubai & Shen Gaojie, 2023; Liu Xuhui et al., 2023).

This paper examines the dynamics of "urban-suburban-rural" interactions, offering insights that could inform the further development of urban-rural integration in Shanghai metropolis. From the analysis of the available data, it is evident that the interaction and coordination between urban, suburban, and rural areas in Shanghai metropolis are gradually intensifying. However, a closer examination of the commuting patterns between these areas reveals substantial differences. The development of employment centers—such as those in central urban areas, urban fringe zones, new towns, and industrial parks—has played a pivotal role in strengthening the connectivity between urban and suburban areas, as well as between urban and rural areas. These centers rely heavily on an advanced and integrated infrastructure network, which has facilitated more fluid exchanges across regions. Nevertheless, the commuting structure between rural and suburban areas remains relatively unchanged, which can be attributed to the functional underdevelopment of these rural regions. For Shanghai to truly realize urban-rural integration, it is crucial to unlock the potential of suburban and rural areas by fostering the development of key economic functions and creating employment opportunities. Only when urban, suburban, and rural areas possess core economic functions, provide stable employment, and are supported by a robust network of basic services, can the integration of urban and rural areas be achieved in a balanced and sustainable manner. This integration should not only focus on economic and functional connections but also preserve the unique characteristics of each area, thereby

ensuring a state of "division of labor, preservation of characteristics, and interdependence" (Fan, Jiahui & Paola Vigano, 2024).

The changing "urban-suburban-rural" interaction in Shanghai provides valuable insights for cities both domestically and internationally. In the Shanghai metropolis, the growing interaction between urban, suburban, and rural areas demonstrates the potential to optimize urban-rural relationships through rational planning and infrastructure development. Centered on employment hubs and industrial parks, and supported by a well-developed transportation and infrastructure network, Shanghai has broken away from the traditional monocentric agglomeration model, fostering the development of a polycentric structure. By enhancing the functions of suburban towns and rural areas, particularly in terms of job creation and public service improvements, Shanghai has gradually explored a practical path to promote balanced resource allocation and coordinated regional development. For other cities undergoing urbanization transitions, Shanghai's experience highlights that counter-urbanization can not only alleviate resource and environmental pressures in central urban areas but also offer new opportunities for balanced regional development. By guiding policies and investing in infrastructure, the redistribution of regional resources and functional coordination can facilitate a healthier transition in urbanization processes. However, due to differences in land ownership systems and institutional mechanisms, the path and characteristics of counter-urbanization in China differ from those studied in mainstream Western research. Examining the phenomenon of counter-urbanization in China not only deepens the understanding of local practices but also makes significant contributions to enriching and expanding global theories of counter-urbanization (Li et al., 2024).

Furthermore, this paper adopts the theory of the urban-rural continuum and introduces an innovative approach to classifying the Shanghai metropolis based on population density and the degree of urbanization, which contrasts with the traditional urban-rural dichotomy. This classification method not only offers a more nuanced analysis of the interactions between various levels of areas within Shanghai metropolis but also provides a valuable framework that could be applied to other metropolitan regions facing similar challenges in urban-rural integration. This approach allows for a more comprehensive understanding of the complex spatial and functional relationships that shape the development of large cities and their surrounding areas, contributing to more informed and effective policy-making.

References

[1] Braun, J. v. (2007). Rural-Urban Linkages for Growth , Employment , and Poverty Reduction.

[2] Davoudi, S. (2002). Urban-rural relationships: an introduction and brief history. Built Environment.

[3] Fisher, M., & Weber, B. A. (2004). DOES ECONOMIC VULNERABILITY DEPEND ON PLACE OF RESIDENCE? ASSET POVERTY ACROSS THE RURAL-URBAN CONTINUUM.

[4] Lebakula, V., Epting, J., Moehl, J., Stipek, C., Adams, D., Reith, A., Kaufman, J., Gonzales, J., Reynolds, B., Basford, S., Martin, A., Buck, W.. Faxon, A., Cunningham, A., Roy, A., Barbose, Z., Massaro, J., Walters, S., Woody, C.,... Urban, M. (2024). LandScan Silver Edition (Version tion) [raster digital data]. Oak Ridge National Laboratory. https://doi.org/https://doi.org/10.48690/1531770

[5] Li, Y., Yiran, W., & Mo, L. (2024). The emergence of counter-urbanisation in China: Can it be a pathway for rural revitalisation? Habitat International, 144, 102998. https://doi.org/https://doi.org/10.1016/j.habitatint.2023.102998

[6] Lichter, D. T., & Brown, D. L. (2011). Rural America in an Urban Society: Changing Spatial and Social Boundaries. annual Review of Sociology, 37, 565-592. https://doi.org/https://doi.org /10.1146/annurev-soc-081309-150208

[7] Requena, F. (2016). Rural-Urban Living and Level of Economic Development as Factors in Subjective Well-Being. social Indicators Research, 128(2), 693-708. https://doi.org/10.1007/s11205-015-1051-1

[8] Yuan, D. D.-Y. (1970). The rural-urban continuum : a demographic case study of Taiwan. Ann Arbor (Mich.) : Xerox university microfilms international. http://lib.ugent.be/catalog/rug01:000165612

[9] Du, Guoming, & Liu, Mei. (2021). A factor-based theoretical analysis of urban-rural relationship change. Progress in Geography, 40(08), 1298-1309.

[10] Fan, Jiahui, & Paola Vigano. (2024). Rural Planning from the Perspective of Urban-Rural Integration: The Experience of Switzerland. Urban Planning International, 39(04), 24-32.

[11] Fan, Jiahui, Zhang, Yishuai, Zhao, Min, & Zhang, Jie. (2019). On the Spatial Structure and Performance of Guangzhou: A Perspective of Job-housing Space. Urban Planning Forum, (06), 33-42.

[12] Gu, Shoubai, & Shen, Gaojie. (2023). Practice and Reflection on the Construction of Territorial Spatial Planning System in Rural Areas in Shanghai. Development of Small Cities & Towns, 41(09), 15-21.

[13] Liu, Shouying, & Long, Tingyu. (2022). The Theory of Urban-rural Integration: Stages, Characteristics and Enlightenment. Economic Perspectives, (03), 21-34.

[14] Liu, Xuhui, Li, Lulu, & Zhang, Yu. (2023). Current Situation Analysis and Countermeasure Suggestions for Urban-Rural Integration Devel-

opment in Shanghai International Metropolis. Shanghai Rural Economy, (08), 23-27.

[15] Tian, Lin, Cheng, Yao, & Niu, Xinyi. (2023). Spatial Organization of Town and Village Areas in the Network Perspective: An Analysis of Resident Cross-village Travel Links in Lin'an District, Hangzhou. Urban Planning Forum, (01), 104-110.

[16] Xie, Zhimin,& Zhen, Feng. (2023). Measuring urban-rural integration level in Nanjing based on multi-source data. Scientia Geographica Sinica, 43(01), 1-10.