Research on Functional Interdependence Patterns of “Village-Urban” Spatial Structure of Shenzhen: A Living and Activity Space Perspective

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Abstract. The urban village is a special product of the rapid urbanization process in China. To accurately understand its functional embedding mode in the urban organism is an important decision-making prerequisite for optimizing the governance effectiveness of urban renewal. Taking residents' living and activity space as the breakthrough point, this paper analyzes the spatial functional patterns of villages in cities by measuring the "village-urban" interdependence relationship based on cellphone big data. It is founded that urban villages in Shenzhen are closely related to other parts of the city, and are not self-isolated communities. At the same time, due to the extensive construction and management mode, the function homogenization of urban village space is obvious, and its location is the main determinant of its participating way in urban activities. The research holds that from the perspective of providing citizens with low-cost opportunity to participate in urban public life and ensuring the resilient development capacity, it is necessary to coordinate and reserve a certain proportion of urban village residential land within the sub-community of residents’ living and activity space to promote the benign and healthy development of urban space organisms.

1. Introduction
As a special product of the rapid urbanization process in China, urban village plays an import role in urban socioeconomic system. Existing studies have built urban village space theory system from the perspectives of space formation mechanism, social space differentiation, and space renovation. In terms of formation mechanism, different disciplines discuss from multiple perspectives which includes urban sprawl, urban-rural dual management system, agricultural population urbanization, institutional transaction costs, etc.\cite{1-4}, pointing out that the rapid development of urban villages is the result of the spontaneous matching of the institutional arrangements of rural collective land management and the low-income migrants’ demand for low-cost housing in the process of urbanization, providing flexible development space for the stable operation of society to some certain extent\cite{5}. In terms of social spatial differentiation, based on the measurement of residential differentiation of floating population in urban villages, the social and economic causes are revealed and spatial governance strategies are proposed\cite{6}. In terms of space renovation, problem-orientated urban village renovation measures are proposed from the perspectives of physical landscape and building renewal, policy implementation process design, and marginal community governance\cite{7-9}. 

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For a long time, urban villages have been regarded as urban problems to be resolved. However, with the development of China's urbanization and the improvement of public governance, both the physical and social environment of urban villages has been greatly improved. The inclusive effect of urban villages on new urban immigrants and lower-income groups has been valued in practice. Under sustainable development and governance concept, theoretical and practical study of urban village meet each other in the point of human scale spatial creation. Therefore, to understand the complex relationship between human activities and urban environment based on individual and micro-processes, it is necessary to construct theoretical framework for spatial urban village analysis, providing effective explanation for the resilient development mechanism of urban villages for urban space system.

2. Literature Review
Living and activity space refers to the "spatial scope included in the various daily activities and movement between activities carried out by individuals in urban space to meet their own needs" [14]. With the scale shift of space research from macro to micro, individual activities have become an important perspective to examine the urban dynamic spatial structure, living and activity space is often used as a proxy for the socio-spatial composition of urban villages. Lan et al. based on analysis on migrants’ activity log data in 5 urban villages of Beijing, found the existence of different lifestyle groups such as work dominance, entertainment dominance, and home-activity dominance [10]. Lin et al. explained the social isolation of migrants in urban villages from the perspective of urban public space and facility utilization through questionnaire survey of more than 400 migrants in urban villages of Wenzhou [11]. Zhao et al. conducted an empirical study on the spatial differentiation of commuting activities in urban villages based on cellphone big data [12]. Zhou et al. investigated workplace segregation of migrants in urban villages using cellphone big data [13].

Based on human-oriented paradigm, urban village space research from the spatio-temporal behaviour perspective explores the deep dynamic mechanism of spatial functions.

The aforementioned studies mostly characterized the spatio-temporal laws of individual or group behaviours, instead of further revealing the "village-urban" structure. Hence systematic understanding of the spatial functional mechanism of urban village needs to be further explored.

3. Analytical Framework
To fill the gaps in the existing literature as discussed above, this article attempts to apply cellphone big data to investigate functional interdependence patterns of village-urban spatial structure of Shenzhen, focusing on the functional embedding mode of urban village in urban organism. The following sections will discuss the rationale and methodology for measuring functional interdependence using cellphone big data.

3.1. Rationale of using cellphone big data in measuring village-urban spatial structure
Urban villages in Shenzhen are large in scale, wide in scope, and diverse in land use types (Fig. 1). They have comprehensive functions for housing, consumption, employment, and leisure activities of citizens. While studies to date mostly pay attention to the living space attributes of urban village and neglect its activity space attributes. To investigate the bilateral dynamic village-urban spatial structure features, this article measures the dependence of residents living in village on urban activity places and the dependence of residents living in urban community on village activity place, respectively.

The following section discusses how to use cell-phone big data to achieve our research purpose and the indices we build to measure village-urban spatial structure.
3.2. Methodology of measuring functional interdependence

3.2.1. Data processing.

Data source
Cell-phone big data has become an important data source for studying residents' spatiotemporal behavior patterns due to its advantages such as wide coverage, good real-time performance, long sampling period, and low acquisition cost. The cellphone big data used in current research generally includes two types: communication data and continuous sampling data. The former is a kind of irregular sparse sampling data based on random events such as mobile phone calls and text messages. It has strong randomness and has a large error in reflecting individual spatiotemporal characteristics. The latter is based on mobile phone tracking and positioning data at fixed time intervals, which can reflect the time and space characteristics of individuals more completely, and is an ideal data source for studying residents' activities and travel patterns.

This article uses the regular sampling location data of about 10 million mobile phone users of an operator in Shenzhen from December 1st to December 31st, 2019. The original record includes the user's anonymous ID, timestamp, and the latitude and longitude coordinates of the mobile phone base station. The sampling interval for each user is approximately 0.5 hour.

Travel purpose identification
Mobile phone location data is a kind of passively acquired data, which only has a location record, lacking travel purpose information. Therefore, it is necessary to adopt technical means to identify the purpose of travel activities. With reference to related research [15], we identify user's activity place by selecting the base stations whose accumulative stay time of the user exceeds a specified threshold in a specific period of time based on the 24-hour activity sequence of each user. More detailed identification rules are as follows:

The base station a user continuously stays from 0:00 a.m. to 5:00 a.m. for more than 15 days in a month is marked as the residence place of the user; the base station a user accumulatively stays more than 6 hours from 9:00 a.m. to 6:00 p.m. for more than 10 days in a month is marked as the work place of the user; the base station a user accumulatively stays more than 1 hours from 6:00 p.m. to 10:00 p.m. on weekdays is marked as the consuming place of the user; the base station a user accumulatively stays more than 2 hours from 10:00 a.m. to 8:00 p.m. on weekends or holidays is marked as the leisure
place of the user. The employment, consuming, leisure place that is same with the user’s residence place is excluded from sampling.

**Urban village space identification**

Mobile phone big data research usually uses Voronoi polygon to divide the service range of base stations. However, the service area unit generated in this way is too large to distinguish urban village space from urban space. Therefore, we use a 250m*250m spatial grid to generate the base station service unit, which scale is basically the area of a block, and is appropriate to recognize urban village block. By superimposing the urban village land patch with the base station service unit, we are able to calculate the proportion of urban village land in each base-station service unit, and the ones with more than 60% urban village land are identified as urban village service unit. This recognition method has a 90% recognition rate for the number of natural urban villages in total, and an 80% recognition rate for the size of urban village land, which is technically feasible. By this way, the village and urban attributes of the places where activities such as residence, employment, consumption, and leisure occur is distinguished.

**Measuring unit**

The 250m*250m base station service unit has the dual attribute between village and city, and it is difficult to simultaneously reflect the bilateral dependence between village and city within homogeneous units. Therefore, we set the 1km*1km spatial environment unit as the measurement unit for "village-urban" interdependency investigation, which is considered to appear good spatial environment homogeneity according to related study[16].

3.2.2. **Interdependence measurement index.**

**City to village dependence index**

The article uses city to village dependence index (short for C-v Di) to measure the degree of dependence of non-urban village residents on urban village activity places. The higher the C-v Di, the more non-urban village residents go to urban village places for employment, consumption, and leisure activities. The calculation formula of C-v Di is as follows:

\[
P_w = \frac{N_{w}}{N_{a}} \\
P_c = \frac{N_{c}}{N_{a}} \\
P_e = \frac{N_{e}}{N_{a}}
\]

Where \(P_w\) is employment C-v Di, \(P_c\) is consuming C-v Di, \(P_e\) is leisure C-v Di, \(N_{a}^{w}\) is the total employment activity intensity of non-urban village residents living within the unit, \(N_{a}^{c}\) is the total consuming activity intensity of non-urban village residents living within the unit, \(N_{a}^{e}\) is the total leisure activity intensity of non-urban village residents living within the unit, \(N_{a}^{w}\) is the employment activity intensity occurring on village place of non-urban village residents living within the unit, \(N_{a}^{c}\) is the consuming activity intensity occurring on village place of non-urban village residents living within the unit, \(N_{a}^{e}\) is the leisure activity intensity occurring on village place of non-urban village residents living within the unit.

**Village to city dependence index**

The article uses village to city dependence index (short for V-c Di) to measure the degree of dependence of urban village residents on non-urban village activity places. The higher the V-c Di, the more urban village residents go to non-urban village places for employment, consumption, and leisure activities. The calculation formula of V-c Di is as follows:

\[
\bar{P}_w = \frac{M_{a}^{w}}{M_{a}^{w}} \\
\bar{P}_c = \frac{M_{a}^{c}}{M_{a}^{c}} \\
\bar{P}_e = \frac{M_{a}^{e}}{M_{a}^{e}}
\]

Where \(\bar{P}_w\) is employment V-c Di, \(\bar{P}_c\) is consuming V-c Di, \(\bar{P}_e\) is leisure V-c Di, \(M_{a}^{w}\) is the total employment activity intensity occurring on village place of non-urban village residents living within the unit, \(M_{a}^{c}\) is the total consuming activity intensity occurring on village place of non-urban village residents living within the unit, \(M_{a}^{e}\) is the total leisure activity intensity occurring on village place of non-urban village residents living within the unit.
Where $P_{vth}$ is employment V-c Di, $P_{c}$ is consuming V-c Di, $P_{l}$ is leisure V-c Di, $M_{a}^{w}$ is the total employment activity intensity of urban village residents living within the unit, $M_{a}^{s}$ is the total consuming activity intensity of urban village residents living within the unit, $M_{a}^{l}$ is the total leisure activity intensity of urban village residents living within the unit, $M_{a}^{w}$ is the employment activity intensity occurring on non-village place of urban village residents living within the unit, $M_{a}^{c}$ is the consuming activity intensity occurring on non-village place of urban village residents living within the unit, $M_{a}^{l}$ is the leisure activity intensity occurring on non-village place of urban village residents living within the unit.

4. Results and Discussion

4.1. Results

4.1.1. Employment interdependence patterns. The average value of employment C-v Di is 0.17, and the average value of employment V-c Di is 0.43. The dependence of the village on the city is significantly higher than that of the city on the village. Spatial distribution of employment C-v Di and employment V-c Di (Figure 2) shows that the spatial employment interdependence pattern of the city center area and suburban area appears to be a strong one-way dependence trend from the village to the city, and the peripheral area is an asymmetric two-way dependence between the village and the city. That is, the proportion of non-urban village residents employed in the urban village space is generally low, and most of them are concentrated in the peripheral areas of the city; the proportion of urban village residents employed in the non-urban village space is high in all of the urban areas and the degree of dependence on city gradually increase from peripheral area to center area.

![Fig 2. Spatial distribution employment C-v Di and V-c Di](image)

4.1.2. Consuming interdependence patterns. The average value of consuming C-v Di is 0.38, and the average value of consuming V-c Di is 0.43. The dependence of the village on the city is slightly higher than that of the city on the village. Spatial distribution of consuming C-v Di and V-c Di (Figure 3) shows that except for the strong one-way dependence from village to city in city center area and the medium one-way dependence from city to village in some northern part of peripheral area, all of the other area is weak two-way dependence between the village and the city.

![Fig 3. Spatial distribution of consuming C-v Di and V-c Di](image)
4.1.3. Leisure interdependence patterns. The average value of leisure C-v Di is 0.38, and the average value of consuming V-c Di is 0.44. The dependence of the village on the city is slightly higher than that of the city on the village. Spatial distribution of leisure C-v Di and V-c Di (Figure 4) shows similar laws with that of consuming C-v Di and V-c Di, thus we don’t repeat here.

![Spatial distribution of leisure C-v Di and V-c Di](image)

4.2. Discussion

Study results above indicate that Shenzhen’s urban villages are closely linked to other parts of the city, and are not isolated communities in self-isolation. At the same time, due to the extensive construction and management method, the homogenization of the function of the urban village space is obvious, and the location is the main determinant of its participation in urban activities. As a result, the distribution pattern of the circle-layered "village-city" function dependent mode based on the city center, suburban area, and peripheral area is presented.

In city center area, urbanization is at a mature stage. Urban villages mainly provide residents with residential functions. Most of the needs of urban village residents for employment, consumption, leisure and other daily life activities do not rely on urban village places. In the suburbs, urbanization is still in the development stage. In addition to housing, urban villages still retain certain functions of employment, consumption, and leisure. Village and city places together support the needs of urban village residents for life activities, but non-urban village residents rarely regard urban villages as destinations in their daily lives. In peripheral area, urbanization is still relatively imperfect, and the employment, consumption, and leisure functions of urban villages are relatively strong. In addition to serving the residents of urban villages, it is also an important destination for the life activities of non-urban village residents.

5. Conclusion

In areas where urbanization development and construction are more imperfect, urban villages provide citizens with more comprehensive functions of housing, employment, consumption, and leisure; in areas where urban public facilities are more mature, urban villages provide citizens with opportunities to enjoy high-quality urban public services at low living cost. It is foreseeable that with the continuous advancement of Shenzhen’s urban development and construction to the suburbs and periphery, most of the non-residential functions of urban villages will be replaced by corresponding urban public service facilities, and the importance of low-cost residential functions will become prominent. From the perspective of providing citizens with low-cost opportunities participating in urban public life and ensuring the flexibility of urban development, it is necessary to coordinate and reserve a certain proportion of residential land of urban villages based on residents’ activity space, and build a multi-level and diversified housing system to promote the benign and healthy development of urban spatial organisms.

References

[1] Yan X, Wei L, Zhou R, (2004) Research on the Coordination of Urban-Rural Relations in Rapidly Urbanized Areas—Taking the Transformation of "Villages in the City" in Guangzhou as an Example, City Plan Re, 28, 30-38.

[2] Han D, (2004) The theoretical Framework and Case Study of "Village in City" Reconstruction, Planners, 20:13-15.
[3] Li P, (2002) The end of the village-a study of the village in the city, Social Science in China, 1:168-179.

[4] Yang S, Zhou X, (2006), Analyze the urbanization of "Village in City" from the perspective of institutional economics, China Economist, 10: 84-85.

[5] Zhang B, Wang F, Wu Z etc., (2018) Recognition of the value of urban villages based on the concept of flexible cities: taking Shenzhen urban villages as an example. In: Proceedings of China Urban Planning Annual Conference, Hangzhou.

[6] Zhou C, Yang G, Wang S. (2016) The evolutionary characteristics and influence mechanism of the gathering space of migrant workers in Shenzhen, SCIENTIA GEOGRAPHICA SINICA,36: 1643-1653.

[7] Li W, Zhang K etc., (2019) Research on the Renewal of Urban Villages Based on the Theory of Complex Adaptive Systems: Taking the Ancient City of Nantou, Nanshan District, Shenzhen as an Example. In: Proceedings of China Urban Planning Annual Conference, Chongqing.

[8] Zou B, (2017) Practice, effectiveness and challenges of the stock development model—Evaluation and extended thinking of Shenzhen's urban renewal, City Plan Re, 1:89-94.

[9] Son H, (2017) The Form Evolution and Structural Attributes of Urban Fringe Communities: Taking Chongqing as an Example, Urban Problems, 10: 38-44.

[10] Lan Z, Feng J, (2012) Temporal and Spatial Structure of Urban Floating Population's Daily Activities——Based on the Survey of Some Typical Urban Villages in Beijing, SCIENTIA GEOGRAPHICA SINICA,4: 409-417.

[11] Lin S, P Gaubatz, (2017) Social-spatial segregation in China and migrants’ everyday life experiences: the case of Wenzhou, Urban Geography, 2017,7:1019-1038.

[12] Zhao M, Jiao H, Sun Z, (2018) Analysis of Temporal and Spatial Activity Characteristics of Residents in Urban Villages Based on Multi-source Data—Taking Wuhan City as an Example, In: Proceedings of China Urban Planning Annual Conference, Hangzhou.

[13] ZHOU X, CHEN Z etc., (2019) Workplace Segregation of Rural Migrants in Urban China: A Case Study of Shenzhen using cellphone big data Urban Analytics and City Science, 0:1-18.

[14] Shen Y, Ta N, Chai Y, (2017) Research Framework of Suburban Space Based on the Perspective of Living Space and Activity Space Human Geography, 4:1-6.

[15] Xu N, Yin L, Hu J, (2014) Identify residents' occupation and residence from mobile phone location data sampled by large-scale short-term rules Journal of Wuhan University, 39:750-756.

[16] LIU X, GONG L, GONG Y etc. (2015) Revealing Travel Patterns and City Structure with Taxi Trip Data Journal of Transport Geography, 43:78-79.