Research on an Evaluation Method for the Job-Housing Spaces of Megacities Using Different Scales Based on Multisource Data Integration: A Case Study from Shenzhen

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Abstract: Urbanization is proceeding rapidly in several developing countries, such as China. The accelerating urbanization causes not only the expansion of the city scale and space but also creates changes to the internal spatial structure, especially the separation of job-housing spaces and increased commuting time. Reasonable urban space organization is necessary because it can both optimize the structure of urban multicenter groups and reduce residents’ need to drive, which lessens traffic congestion, improves the accessibility of public facilities, reduces environmental pollution and promotes the sustainable development of the city. Based on the spatial complexity and development uncertainty of megacities, this paper establishes an evaluation method for the job-housing spaces of megacities on different scales by using traditional statistical data, survey data and big data from multisource data integration to guide urban development and formulate urban policy on the macro level and to understand the relationship of urban space and the relationship between humans and land on the micro level, which may provide the basis for intelligent and refined management of the city. The comparison of multisource data integration and evaluation results from different scales provide a more comprehensive and reasonable reference for the management of megacities.

1. Introduction
With the acceleration of urbanization in China, the equilibrium between human activities and the function of spatial structure is decreasing [1, 2]. The feature of the spatial relation between the places of residence and the places of employment in cities is evolving more noticeably from the “integration of job-housing space” to the “separation of job-housing space” [3]. The space allocation of residences, employment, facilities of residential areas and public facilities determines urban residents’ total travel time and distance, which have a certain impact on urban traffic and the effectiveness of social resources allocation. Thus, the spatial relation between working and living spaces greatly affects the space distribution of infrastructures and eventually will influence the basic pattern of urban spaces [4]. Therefore, it is necessary to study the rationality of the urban job-housing space.

The urbanization of a city not only affects the urban space but also leads to the continuous growth of the city scale. According to The Notice of the State Council on Adjusting the Standard of Dividing Urban Scale (2014), a city with more than 10 million residents is called a megacity. There were almost 10 megacities in 2016, represented by Beijing, Shanghai, Guangzhou and Shenzhen. The urban space structure of megacities is complicated because of the large, built-up urban area and the population.
The large amount of capital and material, as well as the high-speed flow of information technology from the population and employment of megacities, lead to the increasing uncertainty of urban development and complex urban problems [5]. Megacity diseases, such as separated job-housing spaces, spatial dislocation, traffic congestion, and imbalanced accessibility of public resources, are growing increasingly serious in megacities in China. Therefore, constructing reasonable urban job-housing spaces should not only evaluate and hold the development direction on the macroscale of the whole city but also study the dynamic change and interactive relationship between the residence and employment sites on the micro scale to achieve more refined urban management. In summary, establishing an evaluation method for job-housing spaces on different scales is of great practical significance for policy formulation and the intelligent and refined management of megacities.

Based on research involving western urban job-housing spaces, modern scholars have launched many empirical and theoretical studies on the relationship between job and housing areas [6, 7]. These studies are focused on the macroscale of the city and region and on the microscale of urban interior aspects, such as traffic area [8] and employment centre [9], using an assessment scale. In terms of research methods, the evaluation is performed mainly through the ratios of employment and residence [10] and accessibility and urban efficiency [11, 12]. The study on the macro scale mainly uses government statistical data from censuses and economic censuses to analyze the distribution of job-housing spaces in the region [7], while the study on the micro scale uses questionnaires to conduct empirical research [13,14]. The use of signaling data from mobile phone and smart card data to study urban working and residential areas is becoming increasingly prevalent due to the popularization and application of big data in recent years [9, 15].

Previous studies often assessed job-housing spaces on a single scale and seldom evaluated whether the relationship between the occupation and residential areas of a city is reasonable on multiple scales. Moreover, regarding the use of research data on different scales, census and economic census data are more reliable and comprehensive because they are official statistical data. However, research data are also restricted by the same rationale, because the research range is wide and the data are easily outdated. The sample data of surveys has many advantages, such as strong pertinence, high efficiency and high quality, but it is difficult to thoroughly determine the characteristics of urban working and living space due to the restrictions of the sample selection method. Although the large data method made popular in recent years has merits of high accuracy, real-time updates and wide coverage [16], it is limited by many factors, such user groups that cause the relatively low reliability of the evaluation results. On the basis of previous research, this paper tries to establish an evaluation method for job-housing spaces, which is based on the need for assessing job-housing spaces of megacities on different scales. This evaluation method combines the urban-district scale from the macro view with the unit-kilometer-grid scale from the micro view and integrates traditional statistical data, space survey data and big data to provide a more comprehensive and accurate reference.

2. Study Objects and Data Sources

2.1 Study Objects
Shenzhen has developed from a small town with 3.8 km² of construction land in the early 1990s to a megacity with a 968 km² built-up area, 1.01 billion square meters of building volume and more than 20 million people (Figure 1). Shenzhen displays an unconventional urban development process within the dominant socialist market economy in China. High-density agglomeration leads to the diversity of population demands and the complexity of industry type and urban space organization, which brings much uncertainty to urban planning and management. Shenzhen has established an industry structure within the restrictions of its own development factors. The core of this structure is a headquarters economy and innovative industry in the central area of the original special zone, and its basic industry is traditional manufacturing outside of the original special zone. However, residential space mainly is located at the intersection of the inner and outer original special zone, forming a multicenter and
grouped urban space organization. Therefore, it is essential to explore an intelligent and refined mode for urban space management.

![Figure 1. Location of Researching Area](image1)

### 2.2 Data Sources

The research data used in this context mainly include the following three types: The first is statistical data, mainly from the Statistical Yearbook of Shenzhen (2015), which selects the number of permanent residents and employments in each district at the end of the year from the partial population and employees. The second is big data, which focuses on the POI data of Amap and describes the space and attribute information of urban geographical entities. The attribute fields mainly include name, type, address, longitude and latitude. The third type of data is urban space survey data, which contains population grid data (Figure 2) and building census data (Figure 3). Population grid data is the data generated from 100 m x 100 m grid population distribution data under the support of the population data spatialization method. Each pixel is given an identification and attribute value, reflecting the population distribution in the administrative unit. Targeting the survey data from the main buildings inside the city, building census survey data is collected by Shenzhen city managers every year, including their functions, numbers of layers, and information from the subjects who hold property rights.

![Figure 2. Population Grid Data of Researching Area](image2)
3. Evaluation Model of Job-housing Spaces on Different Scales

3.1 Macro Scale
For the whole city and each district, urban statistical data and the deviation index method are used [17] to count the total number of residents and employees of each unit and to calculate the job-housing deviation index $Z_{ij}$ (see Formula 1).

$$Z_{ij} = \frac{P_{ij}/P_i}{Q_{ij}/Q_i}$$

In the above formula, $Z_{ij}$ is the job-housing deviation index of the $i$th year in $j$ district, $P_{ij}$ is the number of employees of the $i$th year in $j$ district, $P_i$ is the number of employees of the $i$th year in the whole city, $Q_{ij}$ is the number of inhabitants of the $i$th year in $j$ district, and $Q_i$ is the number of inhabitants of the $i$th year for the whole city. A deviation index of a district equaling 1 shows that the function of employment and residence in the district relatively is matched. A deviation index larger or smaller than 1 means that the employment of the district does not match up with the residence of the district. An index greater than 1 implies that the proportion of employees is higher than the proportion of residents, which signifies that the employment function of this district is stronger than the housing function. In contrast, housing function may be the dominant function.

To facilitate subsequent statistical tests, the job-housing deviation index $Z_{ij}$ will be processed by the reciprocal if it is smaller than 1. All processed data then will be larger than 1. The job-housing space is more balanced when the data are smaller.

3.2 Micro Scale
The evaluation method for the job-housing deviation index on the macro scale is convenient for policy research and macro control, areas where there is potential to reach an absolute balance of job-housing space. However, that method is inadequate in determining the corresponding relationship between jobs and residents of every district inside the city. Therefore, it is necessary to establish an evaluation model of job-housing spaces on the micro scale. A unit-kilometer grid is used to estimate the job-housing balance on the micro scale in this paper. We establish 2182 unit-kilometer grids in Shenzhen and assess the deviation of the job-housing balance based on the Amap POI data on the micro scale. The main modeling method is as follows:
First, identify the characteristics of employment and residence from the Amap POI data, among which employment includes industry employment, service employment and retail employment and residence includes ordinary residence and commercial residence (Figure 4). According to the information type of each grid, the Amap POI data of each grid are reclassified by the Naive Bayesian Model (see Formula 2).

\[
P(C|\mathbf{X}) = P(C) \cdot \frac{P(\mathbf{X}|C)}{P(\mathbf{X})}
\]  

(2)

Figure 4. Characteristics of Employment and Residence of Researching Area

Second, in light of the different types of working and living spaces, use an analytic hierarchy process to check the impact and give a corresponding weight (Table 1). For example, the impact values and given weights of newsstands, small shops and other retail employment space are smaller when compared to industrial parks and centralized office areas. The weight value of objects with a larger area and higher public cognition, such as supermarkets, large companies, factories, business offices and so on, is always higher.

Table 1. Weight Determination of Various Types of Jobs and Housing by an Analytic Hierarchy Process
Finally, count the weighted POI data for the employments and residences of every analyzed unit (Formula 3).

\[ N_i = n_i \times \rho_i \]  

(3)

In the above formula, \( N_i \) is the point of POI after redefinition, \( n_i \) is the total of the POI of the ith types of the analyzed unit, and \( \rho_i \) is the weight value of the POI of the sample type. For example, the weight value of a point of interest of an architecture which is a residential building is 0.6. Thus, the point of the residential building is 0.6. Count the weighted values of the POI of employments and residences, and then calculate the job-housing deviation index \( Z_{ij} \) of every analyzed unit according to Formula 1.

4. Results

4.1 Job-housing Evaluation Results on the Macro Scale

According to statistics, there are approximately 11.3 million people living in Shenzhen and approximately 9 million jobs. The main population is concentrated in the Bao’an District and Longgang District, followed by the Futian District, Nanshan District, Luohu District and Yantian District. The largest population density of Shenzhen is in the Futian District, followed by the Luohu District, Nanshan District, Bao’an District, and Longgang District, and the smallest population density is in the Yantian District (Figure 5a). Regarding the number of jobs, most are available in the Bao’an District and Futian District, while some are available in the Longgang District, Nanshan District, Yantian District and Luohu District. Among them, the largest work density is in the Futian District, followed by Luohu District, Nanshan District, Bao’an District, Longgang District and the Yantian District (Figure 5b).

Figure 5a. Population Density of Researching Area
On the basis of the population distribution and employment of the Statistical Yearbook of Shenzhen (2015), the calculation result of the total job-housing balance of Shenzhen is 0.796. The job-housing proportion of each district is evaluated by the ratio of jobs to workers. As the result, the job-housing balance of the Futian District, Nanshan District, Luohu District, Yantian District, Longgang District, Bao’an District, Dapeng New District, Longhua District and Pingshan District is 1.711, 1.294, 1.401, 0.701, 0.782, 0.742, 0.914, 0.985 and 1.119, respectively. However, the reciprocal of numbers that are larger than 1 must be considered. Thus, the job-housing balance of the Dapeng New District, Longhua District and Longgang District is 1.095, 1.182 and 1.280, respectively, while that of the Bao’an District and Yantian District is 1.348 and 1.389, respectively. The reciprocal of the calculated job-housing balance is divided into 5 grades, and the results are shown in Figure 6. The Futian and Nanshan districts mainly have business and administrative functions as their main function, hence the amount of employment is much larger than the number of people living there. The job-housing separation is obvious in these two districts because they have been developed for a long time, and the residential facilities are improved. However, some residential areas have formed gradually with industrial migration and renewal. The Yantian District and the eastern region are dominated by a living function with a high degree of job-housing separation and low degree of job-housing balance. Mixed job-housing areas are primarily in the Luohu District and the western region, where there is a good balance of job-housing space.
4.2 Evaluation of Job-housing Balance on the Micro Scale

According to the evaluation result of the unit-kilometer grid (Figure 7), the older urban area of Shenzhen (Futian District and Luohu District) has a good base of economy and society due to its early development. There are ideal residential facilities and sufficient job opportunities available in these districts, so the job-housing balance of this area is strong. Although there are a few grid plots with an index higher than 4, the overall job-housing balance index is approximately 1.5. The degree of job-housing separation is high in the Nanshan and Yantian districts, where the job-housing balance index of some areas is greater than 4. However, the central areas of the Bao’an, Longgang and Longhua districts are new areas for the vigorous development of Shenzhen. New industries and factories are concentrated in these areas because of their preferential economic policies and implementation of social welfare, forming many labor-intensive industrial areas with a large number of jobs and urban villages with a low cost of living. The mixed distribution of industrial areas and urban villages has met the demand of many migrant workers’ choice for nearby employment and residence. The job-housing balance indexes are mainly approximately 1.7, so there is relative balance in these areas.
land prices are lower in these regions, so there are some general industrial parks. Most employees in this area choose their residence at an appropriate distance, but far away from the industrial area. The people’s commuting methods considers the balance between commuting time and living environment.

The southwest region of the Dapeng New District has pleasant scenery with a natural landscape, which is suitable for leisure and health. Therefore, it has become a place that arouses interest from merchants, and it has formed into a leisure vacation place and a typical employment area. The job-housing balance indexes of most areas in this district are greater than 2.7, so the degree of job-housing separation is very high. The landforms of north Guangming New District and the outer area of southwest Dapeng New District are mainly hills, which are not suitable for establishing factories or residences. Thus, the POI data is blank for these regions and we cannot judge the job-housing balance in them.

4.3 Comparison of Job-housing Evaluation Results on Different Scales

Considering the Futian District of Shenzhen as an example for analyzing the job-housing results of different scales, the findings are as follows:

From the view of the macro scale, the average value of the job-housing balance of the Futian District is approximately 1.7. This is higher than the level of job-housing balance, meaning that job-housing separation is severe in this area. As the Futian District is located in the older urban area of Shenzhen, the prime area of prior development in Shenzhen, it has developed from industrial land with residential villages and areas in the early stage of reform and is open to more financial commerce and service areas because of the rapid expansion of industrial land in 1990s. The Futian District has now become typical commercial land in Shenzhen where many high-level companies and opening ports are gathered. The development process of the Futian District is affected by both policy and the geographical environment, so it cannot continue without support from either side. Even though its development has been through various stages, employment is still its main function, which has not changed greatly.

From the view of the micro scale, the Futian District is characterized by job-housing separation (deep red, orange, yellow and light blue), but there are also some areas with job-housing balance. The Meilin area includes both typical living areas, such as "Hongan Garden", "Meixing Yuan" and "Zhongkang living area," and typical employment areas dominated by service industries, such as "Meisi industrial area", "The Branch Campus of Shenzhen Shanglu School" and other hotels and primary schools. These two areas fuse and exist together, forming a region with a relative job-housing balance.

To summarize, different scales have a non-negligible impact on evaluating job-housing balance, so a reasonable study scale is significant for studying urban job-housing balance.

5. Conclusions

Reasonable job-housing organization is an important factor in shortening the distance between residents’ working and living places and other daily travel distances and to improving commuting efficiency. It is also a significant way to promote the sustainable development of the city by reducing not only the probability of motor vehicle use but also energy consumption and environmental pollution. According to the evaluation results, the aspect of job-housing separation in Shenzhen is obvious on the scale of the whole city because some districts have different functions. Thus, housing security should be strengthened to optimize industrial structures on the macro scale. However, there are still some areas that are relatively balanced in their job-housing space, such as the Meilin area of the Futian District and the Bai Shizhou area of the Nanshan District. It is recommended that space organization should be improved inside the administrative districts in the near future. Public-welfare housing such as housing for talents and security housing should also be provided, and the infrastructure should be improved to alleviate traffic pressure caused by job-housing separation.

Based on the integration of the multidata, an evaluation method for megacities’ job-housing space on different scales is proposed in this paper. Evaluating job-housing spaces by using traditional data
on the middle- and macro scales can reflect the situation of the whole city more accurately and provide references for policy research and the direction of urban development. Regarding the micro scale, where traditional data cannot meet the evaluation demand, the POI data of Amap is mainly used for estimations, along with survey data. This is more appropriate for the refined management mode of future cities and also we can randomly choose analyzed units based on the research. Compared with other methods, this evaluation method can determine the distribution of the job-housing space more thoroughly.

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