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IMPACTS OF SPATIAL MISMATCH ON COMMUTING TIME OF URBAN RESIDENTS IN CHINA

ABSTRACT

In many studies on spatial mismatch between residential and employment locations, job accessibility has been measured. However, the apparent disadvantages of the traditional measurement methods on the studies of Chinese cities have been noted. This paper proposes an optimized method for job accessibility measurement by introducing the weight coefficient of job opportunity, which quantifies the degree of uneven distribution of job opportunity in the Chinese cities. Taking Nanjing city for example, this new method was used to measure the spatial distribution of job opportunity, investigate the spatial patterns and analyze the influences of job accessibility on commuting behaviour. The results show that the distribution of job accessibility in Nanjing exhibits the different spatial patterns and mechanisms compared with US cases.

KEY WORDS

spatial mismatch; job accessibility; commuting time; MNL model

1. INTRODUCTION

The spatial mismatch hypothesis was first proposed by American scholars in 1960s [1]. The theory relates the vulnerable population groups, such as low income earners, females and racial minorities to the spatial constraints of residence and employment opportunities [2, 3, 4]. Although there is no racial difference in large cities of China, the spatial mismatch has occurred in the majority of Chinese cities since 1990s when work/residence separation became more obvious due to the emergence of urbanization and suburbanization [5]. The residents' commuting problem caused by spatial mismatch has been noticed in China and the related factors such as commuting space and time have been widely discussed. Meng Bin et al. analyzed the commuting time, commuting direction and other microscopic features on the basis of large-scale investigation, and found that spatial mismatch of residence and employment in Beijing was very serious [6]. Li Qiang found that migration had widened the degree of separation between residence and employment for commuters who lived in large-scale residence communities such as Huilongguan and Tiantongyuan and increased the reserve time for travel [7]. Wang Donggen et al. investigated the influence of unit system on residents' commuting behaviour using the structural equation model [8]. Liu Zhilin et al. analyzed the differences on the separation of residence and employment among different housing property rights and communities on the basis of the indicator of commuting distance [9]. Wang Maojun analyzed the factors of residents' commuting distance and investigated the influences of space variables, such as street employment density, number of bus stops and subway stations using the decision tree method [10]. In recent years, it has been pointed out that commuting time, commuting distance and other indicators for commuting features cannot fully reflect the degree of spatial mismatch, and empirical studies based on only commuting features failed to get unified conclusion and cannot directly prove the existence of spatial mismatch [11, 12, 13]. Ong, Blumenberg and Shen proposed to adopt the job accessibility as the direct measurement indicator for spatial mismatch and provided different methods [14, 15] which have been widely applied in the studies on spatial mismatch in the American cities. Job accessibility is an important indicator in reflecting the matching degree between potential employed population and job opportunity around different districts in the city and the spatial heterogeneity degree between residence and employment.

In this paper, we proposed an improved job accessibility measurement method applicable to the Chinese cities, and measured the job accessibility level in each district of Nanjing City to discuss the characteristics of spatial mismatch in big cities of China. Moreover, we verified the influences of job accessibility and other various factors on residents' commuting behaviour by taking job accessibility as the measurement indicator for spatial mismatch. The purpose of this study is to grasp the change characteristics of commuting behaviour and provide the scientific basis for improving residents' commuting conditions and enhancing commuting quality.

2. DATA AND METHODS

2.1 Job accessibility measurement

2.1.1 Traditional measurement method and its limitation

Most existing job accessibility measurement methods are based on the method established by Hansen in 1959. The job accessibility can be expressed as Eq. (1) [16]:

$$A_i = \sum_j^n O_j F(C_{ij}) \tag{1}$$

where A_i represents job accessibility of zone *i*; O_j represents the number of job opportunities in zone *j* and $F(C_{ij})$ represents impedance functions travelling from zone *i* to zone *j*.

Hansen proposed that Eq. (1) could be applicable only when at least one of the following two conditions is met: opportunity demand is equally distributed in space or there is no restriction on the quantity of opportunities. However, the different employment facilities presented the dislocation distribution due to the significance of difference between old and new urban zones during the development process of the Chinese cities. For example, financial and service industries are usually distributed in old urban zones, while electronics technology and other high-tech industries are generally distributed in new urban zones and traditional and manufacturing industry is moved to the periphery of the city, resulting in obvious uneven distribution characteristic of job opportunity and limitation of the overall scale of job opportunity. This method will lead to inaccurate results applied to the Chinese cities without satisfying the two conditions in Eq. (1)

2.1.2 Improved measurement method

The selection probability of different job opportunities has to be taken into account due to uneven distributions in the Chinese cities. The measurement method of job accessibility was improved by introducing the job opportunity weight coefficient (γ_{ij}), which is the probability of job opportunity in zone j being selected by job hunters in zone i. The improved measurement is described as follows:

$$A_i = \sum_j^n \gamma_{ij} O_j F(C_{ij}) \tag{2}$$

where A_i, O_j and $F(C_{ij})$ are the same as Eq. (1) and γ_{ij} represents the weight coefficient of job opportunities in zone *j* by traveller in zone *i*.

γ_{ij} can be calculated using an average of the probability of all individuals in zone *i* as follows:

$$\gamma_{ij} = \frac{1}{N_q} \sum_q^{N_q} P_{ijq} \tag{3}$$

where N_q represents the set of individuals *q* in zone *i* and P_{ijq} represents the selection probability of job opportunity in zone *j* by individual *q* in zone *i*.

Assuming that the selection set of employment destinations for individual traveller *q* in zone *i* is Ω_q and that the utility of employment destination zone *j* in Ω_q is V_{ijq}, the selection probability of individual traveller *q* in zone *i* of reaching zone *j* can be expressed as Eq. (4):

$$P_{ijq} = \frac{e^{V_{ijq}}}{\sum_{j \in \Omega_q} e^{V_{ijq}}} = \frac{e^{-\theta X_{ijq}}}{\sum_{j \in \Omega_q} e^{-\theta X_{ijq}}} \tag{4}$$

where: V_{ijq} represents the utility of traveller *q* reaching zone *j* from zone *i*; X_{ijq} represents effect variable of utility; V_{ijq} is mainly composed of three parts: influencing factor of land utilization, influencing factor of transportation system and individual characteristic factor, and θ represents the influencing degree of parameter values on each variable and can be calculated through regression analysis.

Substituting Eq. (3) to Eq. (2), the measurement method of job accessibility consideration of non-uniformity of opportunity distribution can be expressed as follows:

$$A_i = \sum_j^n \gamma_{ij} O_j F(C_{ij}) = \sum_j^n \frac{1}{N_q} \sum_q^{N_q} P_{ijq} * O_j \left(e^{-\beta d_{ij}}\right) \tag{5}$$

where d_{ij} represents travelling distance between zones *i* to *j* and β represents regression coefficient.

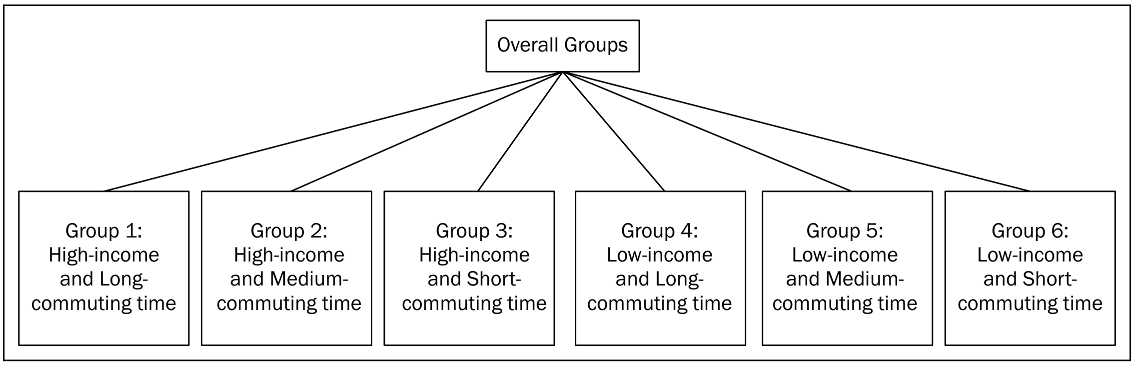

Figure 1 - Six dependent variable groups in the MNL model

2.2 Regression analysis method

Multiple regression analysis was used to determine whether the job accessibility indicator has significant influences on the residents' commuting time. There are two income groups: high-income (annual household income >100,000 yuan) and low-income (annual household income <50,000 yuan), and three commuting groups: long commuting time (>35 minutes), medium commuting time (25-35 minutes) and short commuting time (<25 minutes). The six combinations are shown in *Figure 1*.

The Multinomial Logit model (MNL) was used for the analysis where the probability of different individual alternatives can be obtained through calculating the determining items of utility function. Through model calibration, stochastic term influencing factors of the utility have already been expressed in parameters.

2.3 Survey method

The study area is the main urban area of Nanjing City, which covers an area of 280 km^2 and has a total population of about three million. The study area is divided into five districts based on each function division of the city, as shown in *Figure 2*. Population and employment data were collected from National Bureau of Statistics of China in 2010.

Transportation data were collected from travel surveys of citizens in Nanjing City in 2010. The questionnaire was made by means of stratified sampling with the survey sampling rate of 2%. There were 50,000 questionnaires distributed and 49,137 questionnaires were retrieved, including 43,450 valid questionnaires (86.9% of valid rate). The survey data included the population and employment in each traffic zone, the gender, age, job, income and personal basic attributes as well as travel conditions throughout a working day for each resident. The information of travel conditions includes trip destinations, duration and purpose, and modes of transportation. A total of 21,689 samples with commuting to and from work were collected for this analysis.

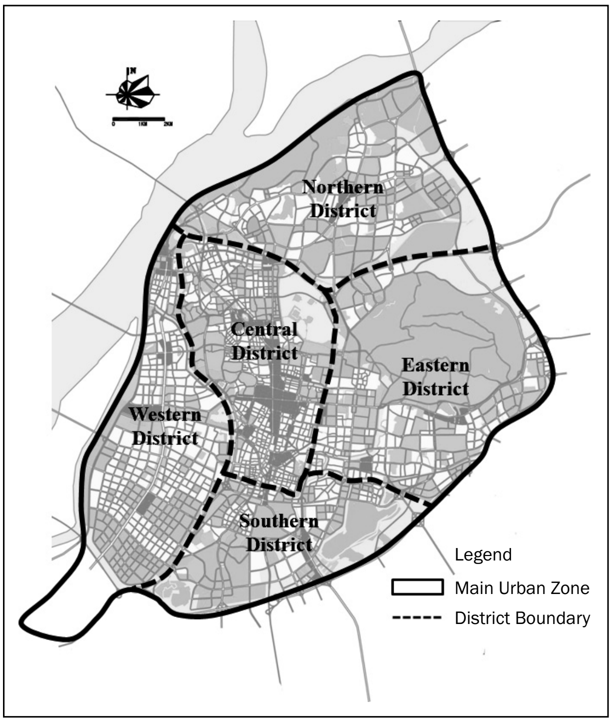

Figure 2 - Study area

2.4 Software

The calculation of job accessibility was completed by C language program, and the results were stored and displayed with the aid of Arcgis software. SPSS software was used to collect and sort each type of variables and generate regression analysis results.

3. RESULTS

3.1 Distribution of job accessibility in main urban area

The distribution of job accessibility in each traffic zone is shown in *Figure 3*a and the distribution in each district is shown in *Figure 3*b and *Table 1*. In the main urban area, job accessibility decreases gradually from central urban area to outer urban area. The declining

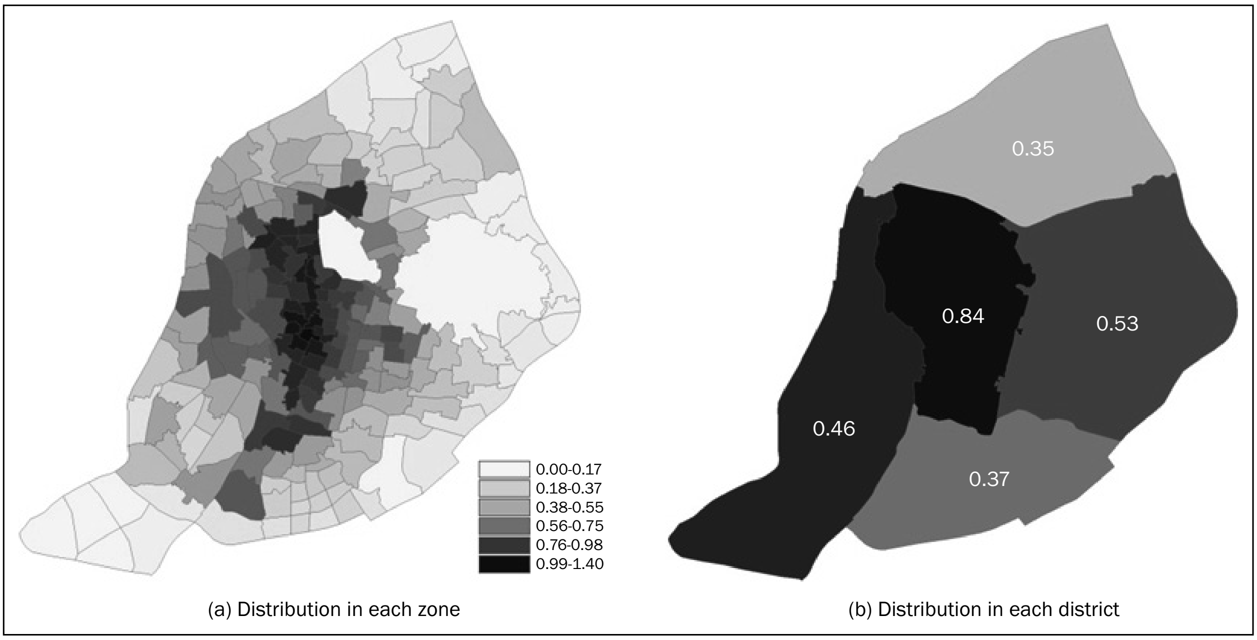

Figure 3 - Distribution of Job accessibility in main urban area of Nanjing

trend becomes more significant with the increase in distance away from the central urban area. The central district has the highest job accessibility of 0.84, which is nearly 88% higher than that of other districts. Southern and Northern District have the lowest job accessibility less than 0.4.

Table 1 - Job accessibility in different districts

Districts	Mean	Max.	Min.	Std. Dev.
Central	0.84	1.39	0.52	0.17
Northern	0.35	0.52	0.08	0.18
Southern	0.37	1.21	0.09	0.15
Western	0.46	0.95	0.11	0.25
Eastern	0.53	0.72	0.11	0.28

3.2 Influencing factors on commuting time

Taking low-income and long-commuting time group as reference, five MNL models were used to calculate the parameters in the regression model for other groups. The results showed that job accessibility, car ownership ratio of household, education level and career have significant effects on commuting time; however, the gender and household number have less effects on commuting time (*Table 2*). The sensitivity of the commuting time of different groups was calculated by taking long commuting time as reference and the results are shown in *Table 3*. Data β in the table refers to the change degree of the probability of dependent variables when the attributed value of independent variable is changed by 1%. If absolute value of t-test is greater than 1.96, it means that the calculated results are reliable.

3.2.1 Influences of job accessibility on commuting time

Compared with other influencing factors, the job accessibility is the most significant factor in commuting time with high absolute values of β (*Table 3*). Job accessibility has relatively small effect on the commuting time for the high-income group compared with the low-income group. If the job accessibility is increased by 1%, the probability that commuting time is reduced from above 35 minutes to below 25 minutes is only increased by 6%, which is 80% lower than the increase of low-income group (11%).

3.2.2 Influence of car ownership ratio on commuting time

The influence of car ownership ratio on commuting time is mainly embodied in low-income group. The commuting time has less effect on the high-income group who have their own cars or tend to select the more flexible transportation means such as taxi or company cars. In contrast, the low-income group depends more on public transportation or non-motor vehicles than the high-income group due to the limitation of travel budgets.

3.2.3 Influence of education level on commuting time

The influence of education level on commuting time is also mainly embodied in low-income group. The probability of commuting time below 25 minutes is increased by 2% with 1% increase of commuters with high education level in low-income group. This commuting time reduction is not significant for high-income group.

3.2.4 Influence of career on commuting time

It was found that the career has significant effect on commuting time in both high-income and low-income group. Compared with freelancers, the probabilities of other career persons with shorter commuting times are negative values (*Table 3*). For example, with respect to low-income group, every 1% increase in the ratio of civil servants and workers allows 9% and 11% reduction in the probability that commuting time is reduced to below 25 minutes. The reduction is more significant than that of high-income group, indicating that the influence of occupation on commuting time of low-income group is more striking for low-income group of civil servants, attendants and workers and has relatively fewer employment opportunities.

4. CONCLUSION

This paper proposed an improved job accessibility measurement method by introducing the weight coefficient of job opportunity. This approach overcomes the limitations of traditional accessibility measurement method and quantifies the degree of uneven distribution of employment opportunities. This improvement is more consistent with the distinctive characteristics of heterogeneity in land utilization pattern of Chinese metropolis.

The case analysis in this paper is based on the survey data regarding population census and resident travelling in main urban area of Nanjing City in 2010. The results showed that the differences among districts of the city in job accessibility are significant, and job accessibility displays an approximately concentric structure, in which job accessibility is reduced with the increase in the distance away from the city centre (*Figure 1* and *Table 1*). Central district is the old urban area with sufficient infrastructure and employment opportunities, which allows a high degree of job accessibility. Eastern and western districts are new residential and cultural districts where transportation facilities were gradually improved in recent years resulting in the travelling convenience of residents for employment and high job accessibility. Spatial mismatch is more serious in the southern and northern districts. The traffic inconvenience results in the low job accessibility in these areas.

In addition, this paper provided in-depth analyses on the impacts of job accessibility on commuting time.

Table 2 - Estimation results [coefficient estimate (ß) and t-statistic (t)] for multinomial logit models

Variable	High-income and Long-commuting time		High-income and Medium-commuting time		High-income and Short-commuting time		Low-income and Medium-commuting time		Low-income and Short-commuting time	
	β	t	β	t	β	t	β	t	β	t
Constant	4.365+++	12.34	3.224+++	11.78	3.107+++	11.09	1.822+++	3.74	0.442++	2.58
Job Accessibility	0.565	1.21	1.286	1.46	0.813++	2.86	2.846+++	6.09	3.486+++	7.75
Gender (Reference to Female)										
Male	-1.156	-0.87	0.068	0.35	0.377	1.11	0.066	0.32	0.837++	2.88
Age	0.465	1.18	0.678	1.23	0.033	0.27	-1.481	-0.98	-0.975	-0.75
Household Number	0.234	0.52	0.520	1.20	-0.495	-0.39	0.157	0.28	0.398	0.66
Car ownership rate of household (Reference to 0)										
1	1.286+++	4.46	1.873+++	4.82	0.678++	2.31	1.523++	2.76	2.353+++	7.55
2 and above	3.433+++	8.02	2.068++	2.83	2.197+++	6.85	1.388	1.13	4.192	1.53
Education Level (Reference to Junior high level)										
Senior high	0.722	1.36	0.436	0.92	-0.857	-0.41	0.278+	1.97	0.326+	1.99
Undergraduate	-0.557	-0.31	0.675	1.18	0.298	0.34	-0.463	-0.26	0.867++	2.76
Graduate and above	1.145+	2.01	0.267	0.47	0.633+	1.98	0.558++	2.82	-1.277	-0.69
Career (Reference to Freelance)										
Staff	2.235+++	4.12	1.391+++	3.05	1.592	1.74	-0.668++	-2.67	-1.172++	-2.85
Service	0.834	1.54	1.239	1.76	0.605	1.47	-1.562+	-1.98	-1.933++	-2.28
Worker	-0.237	-1.25	0.078	0.14	0.068	0.12	-0.553	-1.64	-2.252++	-2.69
R^2	0.477		0.423		0.405		0.424		0.401	

Note: +++ Significant at the 0.01 level; ++ Significant at the 0.05 level.; + Significant at the 0.1 level.

Table 3 - Variation sensitivity of short commuting time of different groups

Variable	Variation sensitivity of short commuting time			
	High-income		Low-income	
	β	t	β	t
Job Accessibility	0.06+	2.01	0.11+++	6.25
Gender (reference to female)				
Male	0.12	1.42	0.01+	1.97
Age	-0.02	-0.59	0.03	0.23
Household number	0.06	0.48	-0.05	-1.01
Car ownership rate of household (Reference to 0)				
1	0.03+	2.15	0.07+++	3.47
2 and above	0.04	0.84	0.11+	1.29
Education level (Reference to Junior high level)				
Senior high	0.07	1.06	0.02++	2.57
Undergraduate	0.06	1.02	0.03++	2.70
Graduate and above	0.06	0.92	0.08	1.14
Career (Reference to freelance)				
Staff	-0.04+++	-3.46	-0.09+++	-9.73
Service	-0.05++	-3.15	0.01	0.47
Worker	-0.08++	-5.23	-0.11+	-2.17

Note: +++ Significant at the 0.01 level; ++ Significant at the 0.05 level.; + Significant at the 0.1 level.

It found that the influence is particularly significant on low-income group and every 1% increase in the accessibility allows 11% rise in the probability that commuting time is reduced from more than 35 minutes to 25 minutes, which is 80% higher than that of high-income group. Urban public transportation system in China plays an important role in commuting. Low-income group relies more on public transportation and the improvement in job accessibility can effectively reduce commuting time of this group. However, higher job accessibility has no effect on expanding commuting range of low-income residents. High-income residents prefer to search job opportunities nearby their living locations. The effective measures to reduce employment hurdle is to optimize configuration of public traffic facilities and employment locations.

The above study conclusions are not completely consistent with those obtained from the residents in Los Angeles, America. According to the conclusions by Ong and Blumenberg, in American metropolitan areas, when job accessibility exceeds certain limits, low-income residents are motivated for longer-distance commuting, thus leading to further increase in commuting time. Unlike America, the Chinese cities have relatively higher developed public transportation, which is still the primary commuting means for Chinese citizens. Districts with more favourable job accessibility are also the areas with the higher public transport accessibility, which helps the low-income residents to search the appropriate job opportunities within limited space.

The measurement in this paper was focused on the spatial mismatch between employment position and residence in Nanjing City. The influence of the spatial mismatch on residents' commuting behaviours was analyzed, but without the in-depth analysis on the mechanism of the spatial mismatch phenomenon. In the following studies, it is necessary to consider the comprehensive system factors or policy factors that hinder low-income group and other social vulnerable groups, in order to grasp the influence of space inequality trend in Chinese cities during rapid urbanization progress on different social groups' commuting behaviours.

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