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# Intelligent Development Research on Job-Housing Space in Chinese Metropolitan Area under the Background of Rapid Urbanization

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## 1 ABSTRACT

Under the impact of regional integration and rapid urbanization, Chinese metropolitan area is confronted with the pressure brought by further massiveness, high density and continuous development. The existing layout of job-housing space balance in cities has been further spread and aggravated, which leads to a series of problems including traffic jams and air pollution, etc. This thesis excavates, analyzes and integrates the city residents' action trajectory data in various heterogeneous cities through the intelligent transportation data platform of metropolitan area. Furthermore, the research also extracts the intelligent knowledge on the aspect of urban job-housing space, identifies and analyzes its characteristics effectively.

This thesis takes Beijing-Tianjin-Hebei metropolitan area as the research object to carry out intelligent analysis on working and residential space in main cities. We can identify residents' commuting behaviors with multi-source location perception data. Firstly, the GPS trajectory data of large-scale taxi will be utilized, and the transportation behaviors and characteristics of taxi will be assumed as the urban residents' trip behaviors. Then the research of urban space-time structure and residents' activities hot spots will be carried out from the macro perspective. Secondly, a residents' trip survey method combining mobile phone location and internet feedback will be put forward. Aiming at the location Microblog data, the characteristics of residents' workplaces and residences could be identified with fuzzy mathematical method. During the identification process, the individual behavior patterns obtained from the resident trip survey data will be used as the recognition feature.

Through the analysis, We discovered that the data mining method of the residents' action trajectory is feasible for the study of job-housing space. The study shows that the key factor influencing the job-housing balance in metropolitan area is the improvement of disperse urbanization life-style which takes family as a single unit. It also puts forwards the future ternary development mode of "employment-residence-public service" of job-housing balance in Chinese metropolitan area. The research also discovers a measurement method of excess commuting to develop the commuting efficiency in job-housing space. Furthermore, through the research on excess commuting degree of main cities in Beijing-Tianjin-Hebei metropolitan area by utilizing the commuting behaviors extraction result of Microsoft data, the correlation factor of characteristic attributes and job-housing separation phenomenon in urban community could be found. Finally, the intelligent development characteristics of job-housing space in metropolitan area will be discussed by combining the geographical visualization method and taxi trajectory mining result.

## 2 WISDOM DEVELOPMENT: A NEW CHALLENGE FOR JOB-HOUSING BALANCE IN METROPOLITAN AREAS OF CHINA

### 2.1 Rapid evolution of spatial form in metropolitan areas

China's urbanization is entering a period of rapid development, and it took only 30 years to increase the urbanization rate from 17.8% in 1978 to 56.1% in 2016. The significant increase of the population size in metropolitan areas has brought about rapid expansion of urban space. Figure 1 shows the increasing trend of urban built-up areas and the changed situation of population density in China. During the period from 2001 to 2011, the area of urban built-up area in China has increased year by year. However, the change of population density is opposite to the outward development tendency of urban form. More employed population are flocking to the core area of the metropolis, which reflects the gap of population job-housing balance between the peripheral city clusters and the core areas in the metropolis.

Continuous and rapid urbanization results in China's urban Agglomeration region, especailly Beijing-Tianjin-Hebei metropolitan area centered on Beijing and Tianjin, facing tremendous pressures of mega-development, high density and continuous development (Fig.2). With the horizontal or vertical division of labour focusing on different links between different industries or the same industry in various cities within

the area, the spatial agglomerations of the emerging functional areas have become the dominant form of the social and economic factors of spatial movements in the metropolitan areas. The second industry and the third industry are developing in the areas with superior location conditions, high level of productivity and resource conditions, which promote continuous generation of new urban areas, and attract a large number of workers to concentrate here. With the increase of employed population, employment and living spaces are rapidly expanded. However, the construction level of the regional transportation infrastructure is relatively backward, resulting in the increase of residents' job-housing commuting distance. They have to shorten the job-housing commuting time by relying on operation efficiency improvements of the regional traffic network. Energy consumption of a large number of commuting tools leads to the deterioration of the ecological quality of the environment in the metropolitan area, such as the high haze index, excessive water pollutant content and frequent traffic safety accidents. Therefore, the path choice of China's new urbanization must rely on solving the unbalanced relationship between job and housing, in terms of defining the spatial development priority of metropolitan areas and guiding the layout of urban functions.

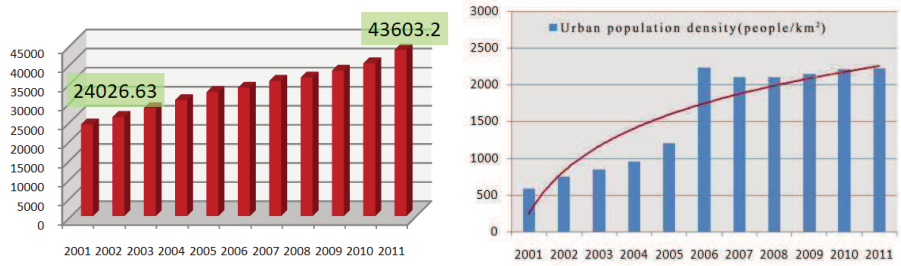


Fig. 1: China's urban area and the density of urban population growth (2001-2011).

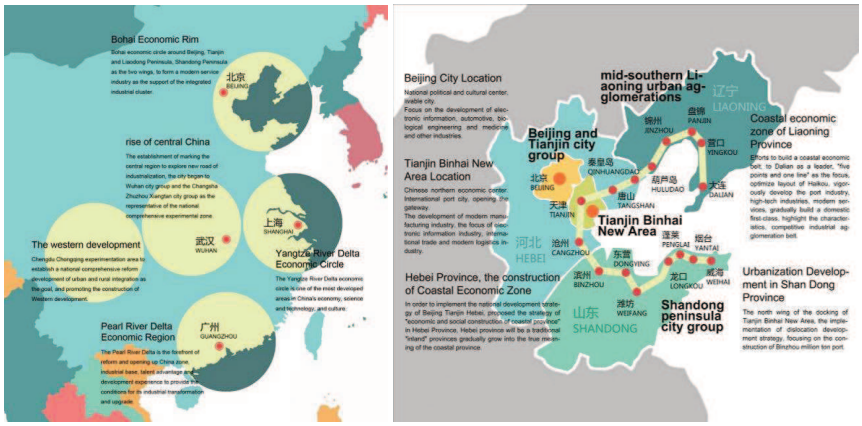


Fig. 2: China's high density city cluster distribution and link bohai sea three urban agglomerations.

## 2.2 New urbanization and job-housing imbalance

In 2014, the Chinese government issued the National New Urbanization Plan (2014 - 2020) to define and guide the path of new urbanization. In future, China will reduce the large-scale "population migration of migratory birds", and advocate "the nearest urbanization". However, considering Chinese society which emphasizes family ethics and clan etiquette, research of new urbanization is expressed more as a problem of job-housing imbalance based on the core unit of the Chinese family. In the process of urbanization of China's metropolitan areas, and taking into account the daily living activities in urban and rural areas of family members, unreasonable separation emerged between family members in urban and rural areas, city and city, or within the core areas of metropolis, with the result that they could only meet with each other once a week, a month, or even a year. Alternatively, although family members live together every day, the spatial locations of their employment, living and public service activity are highly scattered, which is leading to overlength commuting distances. Two types of dissociated families have arisen in the process of urbanization which could be classified from the perspective of spatial scale of the job-housing imbalance in the metropolitan area, as urban- rural dissociated and Inter-city dissociated. This spatial separation formed during the process of urbanization at the micro level led to imbalance between employment, living and public services. Serious job-housing imbalance resulting in multiple land source occupations, frequent travel consumption or the absence of family love, will affect the urbanization process and family quality of life.

### 2.3 Smart city: the interpretation of job-housing balance

Urban traffic congestion in Chinese metropolitan areas has increased average commuting distance and time of residents. An intelligent method must be developed to study the structure and characteristics of the job-housing space. For example, the average commuting distance of the personnel who work in the centre of Beijing has been lengthened from 9.7km/time in 2004, to 17.1km/time in 2015, and the average commuting time has been extended from 36.5 minutes in 20014 to 58.2 minutes in 2015. With the improvement of China's urban information infrastructure, it is possible to collect and process the data of urban residents' behaviour on a large scale. Internet of things, GPS terminals, smart phones, municipal information and other urban data collection facilities are gradually applied to the study of smart city. On the basis of obtaining abundant spatial data of urban job-housing space, the overall information contained in the city perceived big data is utilised to interpret the spatial structural characteristics of the city, which is conductive to quickly grasping the inner mechanism between residents' commuting behaviours and urban job-housing spatial characteristics, so as to optimize the urban and rural spatial planning layout within the metropolitan area.

Therefore, this paper utilizes the intelligent data technology to obtain the multi-source perceived data of residents in metropolitan area on the basis of semantic trajectory data model, such as the typical passive group perceived data including taxi vehicle-mounted GPS data as well as the spatial and temporal social media data. The activity behaviour and the characteristics of the taxis will be assumed as the residents' travel behaviour to carry out the studies on urban job-housing spatial and temporal structures and residents' travelling spatial and temporal hot spots from the macro perspective.

## 3 MULTI-SOURCE TRAJECTORY DATA ACQUISITION AND PROCESSING OF RESIDENTS' COMMUTING BEHAVIOURS

Data acquisition path of residents' commuting behaviour

#### 3.1.1 Taxi-mounted GPS data

There are two types of significant information in the taxi GPS data: One is the origin destination (0D) information extracted from the boarding and alighting record of extraction, the other is the movement trajectory information of taxi in road network. 0D information only records the starting point and end point of passengers' travel, while ignoring the path information in the travel process. From the perspective of the study on passengers' behaviour, 0D information represents the relation between people's behaviour and its location. Conversely, the movement trajectory records the continuous positions of the moving vehicle. It includes the places of both departure and destination, and also objectively reflects the road traffic conditions, such as distance and congestion. This paper studies the Beijing-Tianjin metropolitan area (Fig. 3), which mainly contains the two major cities of Beijing and Tianjin. The permanent resident population size in this metropolitan area is 41,205,900, among which 21,516,000 in Beijing and 15,168,100 in Tianjin. There are 83,917 taxis in Beijing and Tianjin, and the average daily passenger trips are 2,730,000. At present, the taxis in this area are generally equipped with GPS and taximeter, which will transfer the data including the vehicle number, time, latitude and longitude and operational status to the dispatching centre to form massive data sources. The data formats are shown in Table 1.

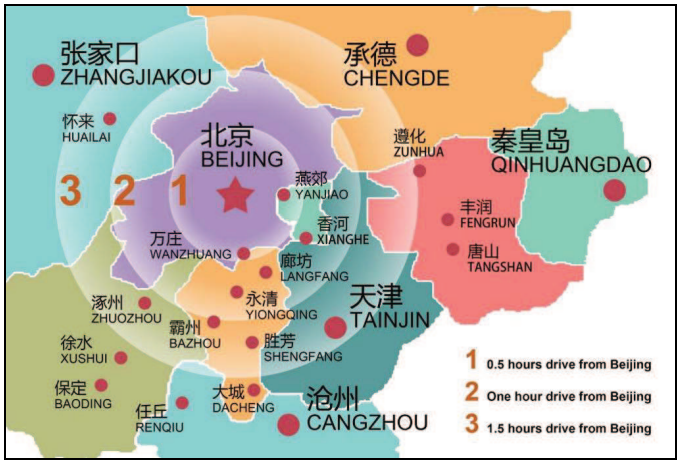


Fig. 3: The composition of beijing-tianjin-hebei metropolitan area.


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| | | |
|---|---|---|
| Space scale | Urban- rural discrete | Inter-city discrete |
| Taxi-id | Character varying(10) | The vehicle's only logo |
| GPS time | Timestamp | The quantitative data set time |
| Location | Geometry(Point, 4326) | Data point location |
| Flag | Integer | With the direction of the geographic North Pole Angle, which is divided into eight direction |
| State | Integer | 0 means no load, 1 means passenger, 2 means status is unknown |

Table 1: The taxi data table structure.

| Field name | Type | Note | Sample |
|---|---|---|---|
| Id | Serial | The only number of record | 1 |
| Taxi_id | Character varying(10) | The only number of vehicle | 523938 |
| Trajectory | Geometry (LineString,4326) | Vehicle trajectory | LINESTRING(121.51215 31.2304,⋯) |
| Time_o | Timestamp | Zero hour | 2015-12-09 01:11:03 |
| Location_o | Geometry (Point,4326) | Zero point location | POINT(121.51215 31.2304) |
| Time_d | Timestamp | D some moment | 2015-12-23 01:18:59 |
| Location_d | Geometry (Point,4326) | D point location | POINT(121.48077 31.2217) |

Table 2: OD table structure.

The data acquisition time periods utilised in this study are the whole days of two operation weeks from December, 9th, 2015 to December 23rd 2015. The original GPS data is generated and provided by 32,258 taxis. The taxi-mounted GPS collects the current location every 20 seconds to generate 84,896,382 location records. After the preprocessing of the problem data that can be used, the taxi samples available for the analysis are 14,839, and 48,758,408 records in total. Then the taxi OD is extracted by combining PostgreSQL/PostGI database environment and the Net. programming environment to form the travel OD Table (Table 2). Finally, the visual matching will be carried out between the taxi trajectory data and the figure of road vector data, township boundary data and the current land application situation in the metropolitan area. After a preliminary statistical analysis on the OD point data of taxis in the villages, towns and districts, OD quantitative classification statistical diagram (Fig. 4) is obtained, which could intuitively understand the spatial distribution of passengers' boarding/alighting.

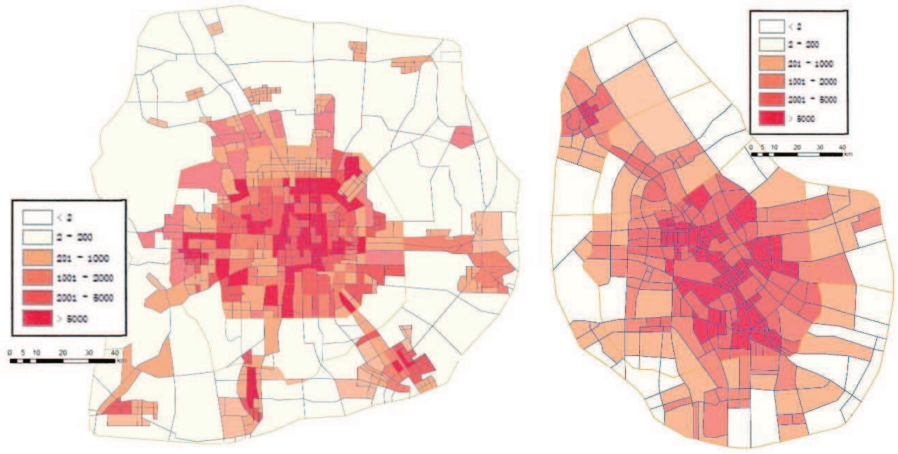

Fig. 4: The OD quantitative classification statistical diagram (Beijing and Tianjin).

### 3.1.2 Space-time social media data

There are 6,320,000,000 netizens in China in 2014, and the coverage rate of Micro-blog among the netizens has reached 43.6%. Many micro-blogs are posted from the users' intelligent terminals. The locations of an individual or a good could be obtained by means of built-in GPS and other location awareness support equipment of mobile devices, which allows the micro-blog data with the location awareness function. This provides an excellent opportunity for researchers to extract the information for micro-blog social data. This study takes the API interface provided by the Sina Micro-blog open platform as the core means of data crawling and utilizes the location service interface and the users' reading interface to write the crawling program. The program flow is shown as Fig. 5. Through the above-mentioned micro-blog crawling program, the data collection space is set as Beijing-Tianjin-Hebei metropolitan area, and the time horizon is set as the period from August 1st, 2015 to January 1st, 2016. 4,174,518 Micro-blog data from 104,715 Micro-blog

users is grasped. Then the statistics on the number of individual users to publish the location micro-blog is carried out to discover the characteristic conforming to power-law distribution. Conduct the data with visualization technology to obtain the spatial and temporal distribution characteristics of micro-blog location data. The classic density clustering algorithm DBSCAN is utilized to cluster the position micro-blog, so as to study the commuting travel and job-housing spatial pattern contained in the data.

### 3.2 Commuting behaviour information mining based on multisource trajectory data

#### 3.2.1 The job-housing space analysis based on the taxi movement pattern

Taxi trajectory has natural temporal and spatial attributes. The analysis could be carried out from the spatial and temporal patterns for the clustering results obtained from the clustering method. Firstly, some statistical indicators could be utilized to mine the spatial and temporal patterns related to the taxi traffic in each cluster. And then conduct the related features with spatial and temporal visualization so as to evaluate the residents' travel characteristics in relevant regional and urban areas. Secondly, the movement trajectories of taxis of each cluster are utilized to evaluate the connectivity and connection degree of the regions. This study takes the commuting behaviour as an example to mine the related temporal and spatial patterns. The characteristics of the taxi origin destination are utilised to describe the job-housing situation in an area so as to put forward the concept of job-housing factor, which is as follow:

$$JRF = \frac{\mathrm{inflow_m} \times \mathrm{outflow_e} - \mathrm{inflow_e} \times \mathrm{outflow_m}}{\mathrm{totalflow_m} \times \mathrm{totalflow_e}}$$

In the formula,

$$\mathrm{totalflow_m} = \mathrm{inflow_m} + \mathrm{outflow_m}$$

$$\mathrm{totalflow_e} - \mathrm{inflow_e} + \mathrm{outflow_e}$$

Where, inflowm represents the flow of the taxis entering into this area in the morning, inflowe represents the flow of the taxis entering into this area in the evening, outflowm represents the flow of the taxis driving out from this area in the morning, outflowe represents the flow of the taxis driving out from this area in the evening. When the taxis driving out from this area dominate in the morning, whereas driving into this area dominates in the evening the job-housing factor in the interval of [-1,0), which indicates that this area has the characteristics of residential area. When the factor is closer to -1, its characteristics of residential area is more obvious. On the contrary, if the taxis driving in this area dominates in the morning, whereas driving out from this area dominates in the evening, the job-housing factor(JRF) in the interval of (0,1], which indicates that this area has the characteristics of job area. When the factor is closer to 1, its characteristics of job area is more obvious.

According to the trip survey data of residents' in Beijing-Tianjin-Hebei metropolitan area by statistics department, the single commuting time by taxi is about 30 minutes. The on duty period of this survey is from 5:30 to 9:30, and the off duty period is from 15:30 to 19:30. Taxi trajectories in the two periods accounte for 43% of the total number of the whole day. Then the inflow, outflow, and totalflow of each cluster are calculated, based on which job-housing factor of each cluster could be obtained. According to the statistical histogram of the calculated results, concluded that the job-housing factors in the study area present a significant normal distribution. Its mean=0.05, and standard deviation SD=0.2. If the area of which the job-housing factor is bigger than 0.2 is set as the job area, smaller than 0.2 is set as residential area, in the interval of [0.1,0.2] as job area to be, in the interval of [-0.2,0.1] as residential area to be, in the interval of (-0.1,0.1) as balance area, the job-housing area distribution figure could be obtained. (Fig. 6)

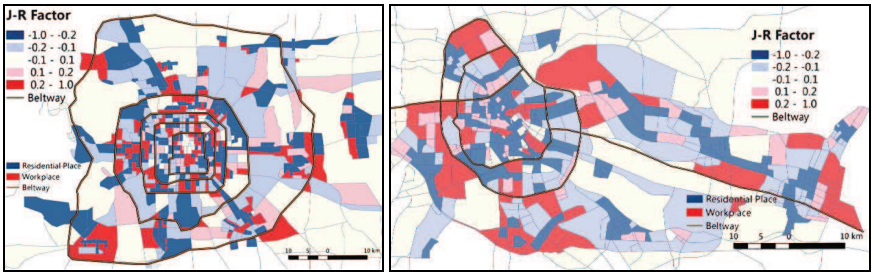


Fig. 6: Job-housing factor classification statistics and regional distribution.


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### 3.2.2 Identification of job-housing space based on social network data

According to the residents' space-time social micro-blog data obtained in 3.1.2, the job and housing sites in this area could be calculated. Take the centre of gravity of each site as the midpoint, which is taken as the centere of a circle. Take 500 meters as the radius to make a buffer to record the land-use type and area in each buffer. Match each resident's residence and job to the street scale so as to form a commuting network (Fig. 7). Each vertex in the network represents the street scale of each resident's housing and job areas, and each edge represents the connection of each resident's housing and job areas. V represents the vertex, and E represents the edge to regard the commuting network as the concept of Figure (G) in a mathematical sense, which could be expressed as G(V,E) with mathematical symbols. There are 417 vertexes and 9211 edges, and the figure density is 0.473 in Network G. This shows that the commuting behaviors don't exist in all areas between two streets. In fact, most commuting behaviors occur in the area of several streets and form internal commuting subsystem (the node of the same color in Fig. 7). The commuting flow between the nodes is different. How the important commuting nodes in the network can be found in the network is through the control of flow, so as to further identify the the job-housing space characteristics of the area.

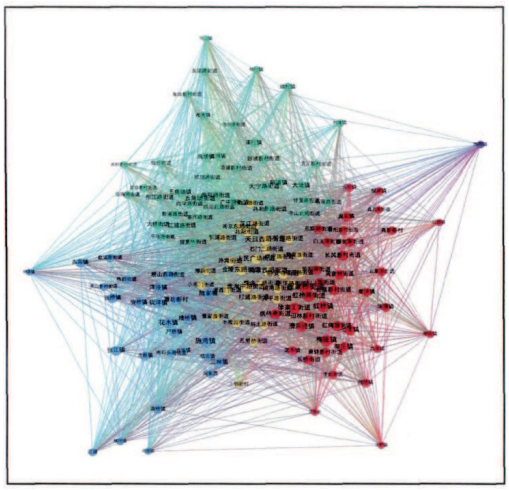

Fig. 7: Commuting and main node distribution network.

## 4 A STUDY ON THE CHARACTERISTICS OF THE JOB-HOUSING SPACE IN BEIJING-TIANJIN-HEBEI METROPOLITAN AREA BASED ON COMMUTING BEHAVIOUR

### 4.1 Study on commuting efficiency of Beijing-Tianjin-Hebei metropolitan area

Since the data acquisition process of Chinese commuting efficiency study is seriously affected by the administrative units and organizations, the survey scale always adopts the administrative division of villages, towns, streets, districts and counties. The areas are mostly above 10km2, and the scale is large. This paper adopts two spatial analysis units of the real estate plate (REP) and traffic zone (TZ). The scale of the real estate plate size is relatively large, and the area is usually in the interval of 10 and 100km2. Traffic zone is the results obtained through the taxi OD cluster. The scales of each area could be controlled by changing the parameter of the clustering algorithm, which are usually in the interval of 1 and 10 km2. In this paper, the real estate plates are 297, and the traffic zones are 1649.

Set two conditions: (1)Residents' jobs and housing units are homogeneous and same. (2)Residents can freely exchange job and housing locations. For all the residents of this city or area, there should be a minimum required commute (MRC) in theory, which is an optimal value in job-housing balance. The value of MRC is generally smaller than minimum required commute (MRC). At the same time, there should be a difference value between the maximum required commute (MaxRC) and MRC under the established spatial distribution, which is called excess commute (EC) to represent the job-housing imbalance degree in a city. After confirmation of the minimum spatial analysis unit on the basis of the two concepts of ARC and MRC, The following formulas are utilized to measure the commuting efficiency and job-housing balance condition:

$$E = \left(\frac{ARC - MRC}{ARC}\right) \times 100\%$$

$$C_u = \left(\frac{ARC - MRC}{MaxRC - ARC}\right) \times 100\%$$

Where E is the excess commuting efficiency, which is used to represents the proportion of excess commuting in actual commuting of the metropolitan areas. It shows the theoretical minimum required commute provided by the job-housing imbalance degree relative to the existing job-housing distribution. Cu is the commuting capacity usage rate, which reflects the commuting proportion of excess commuting and job-housing separation in the worst case of the metropolitan area. The smaller the value of Cu, the higher commuting efficiency will be, and the job-housing balance will be better. In the unified evaluation standard, the balance situation of various cities in the metropolitan area could be evaluated and compared. This paper establishes a OD spatial distribution matrix and a shortest spatial commuting matrix on the basis of actual data in two scales of REP and TZ respectively. The former identifies the commuting population in arbitrary two areas, and the latter identifies the shortest commuting distance in arbitrary two areas.

| $REP_h$ | $REP_j$ | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | … | 297 |
| 1 | 272 | 0 | 73 | | | 0 |
| 2 | 26 | 221 | 0 | 0 | | 0 |
| 3 | 0 | 1 | 50 | 0 | | 0 |
| 4 | 5 | 0 | 0 | 32 | | 0 |
| … | … | … | … | … | … | … |
| 297 | 0 | 0 | 0 | 5 | | 12 |

Table 3: The start-end point spatial distribution matrix in REP scale.

| $TZ_h$ | $TZ_j$ | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | … | 1649 |
| 1 | 11 | 0 | 27 | 7 | | 0 |
| 2 | 0 | 8 | 0 | 1 | | 5 |
| 3 | 6 | 13 | 7 | 3 | | 0 |
| 4 | 3 | 0 | 4 | 6 | | 8 |
| … | … | … | … | … | … | … |
| 1649 | 0 | 9 | 0 | 0 | | 5 |

Table 4: The start-end point spatial distribution matrix in TZ scale.

| $REP_h$ | $REP_j$ | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | … | 297 |
| 1 | 2.7 | 4.95 | 7.11 | 8.81 | | 17.81 |
| 2 | 3.66 | 1.73 | 0.69 | 4.96 | | 13.51 |
| 3 | 7.18 | 0.96 | 3.31 | 6.65 | | 9.92 |
| 4 | 6.48 | 12.81 | 2.73 | 1.77 | | 6.53 |
| … | … | … | … | … | … | … |
| 297 | 16.31 | 17.47 | 10.11 | 5.38 | | 13 |

Table 5: The shortest commuting matrix in REP scale.

| $TZ_h$ | $TZ_j$ | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | … | 1649 |
| 1 | 0.68 | 1.15 | 1.37 | 1.49 | | 0.94 |
| 2 | 1.17 | 0.93 | 1.19 | 2.07 | | 2.77 |
| 3 | 1.44 | 1.86 | 0.71 | 1.91 | | 3.61 |
| 4 | 2.15 | 2.32 | 1.58 | 0.81 | | 1.79 |
| … | … | … | … | … | … | … |
| 1649 | 1.98 | 2.77 | 3.32 | 1.87 | | 1.36 |

Table 6: The shortest commuting matrix in TZ scale.

| Objects | Samples | ARC | | MRC | | MaxRC | | E | | Cu | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | REP | TZ | REP | TZ | REP | TZ | REP | TZ | REP | TZ |
| Beijing | 216884 | 7.4 | 8.5 | 4.2 | 2.8 | 22.8 | 33.2 | 43.2 | 67.1 | 17.2 | 18.1 |
| Shanghai | 115731 | 8.1 | | 3.0 | | 37.3 | | 64 | | 17 | |
| Tianjin | 91680 | 7.5 | | 3.0 | | 10.5 | | 71 | | 18.9 | |
| Xian | 59967 | 5.1 | | 4.0 | | 14.6 | | 21 | | 11 | |
| Guangzhou | 15000 | 5.0 | | 2.7 | | 13.5 | | 44 | | 23 | |

Table 7: Commuting efficiency compared with other cities.


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Table 7 compares the commuting efficiency in Beijing and Tianjin with other cities. It is found that the job-housing balance and commuting in Beijing-Tianjin-Hebei metropolitan area possess the following characteristics: (1) On the perspective of the actual required commute, the job-housing balance under TZ scale in Beijing is the worst, which is higher than Tianjin, however it is lower than Guangzhou and flats within Shanghai. (2) As for the commuting efficiency index E, the job-housing balance under the scale of TZ in Beijing is similar to Beijing and Tianjin, and higher than Xi'an and Guangzhou. It shows that the excess commuting rate is higher in the metropolitan area, and the job-housing space represents the imbalance status. And the excess commuting rate under the scale of TZ is the same with Guangzhou. The commuting capacity usage rates of both Beijng and Tianjin are between 17 and 18 under each scale. This proves that there is still deterioration space on the aspect of job-housing balance.

## 4.2 The regional space characteristics and the job-housing separation

### 4.2.1 Housing estate characteristics and job-housing separation

The paper summarizes and compares the differences of the four community types on the aspect of residents' job-housing commuting distance (Table 8). It is found that the job-housing balance degrees in old public housing community and high-end community are much better than that of economically affordable housing community, residents' commuting distance of which are all shorter than 6km. However, the residents in economically affordable housing community need to bear the maximum commuting cost. The mean value of 17.3km of commuting distance is much higher than other community type. This proves that the government pays more attention to the construction amount, coverage and the construction cost, rather than the integrality of job-housing space distribution. Due to the increase in the employment population and housing prices rising pressure as well as the trend of suburban areas development, Beijing-Tianjin-Hebei metropolitan area will face more severe phenomenon of job-housing spatial mismatch.

| Community types | Average house prices (10000￥) | Samples | Commuting distance(km) | | | S | P |
|---|---|---|---|---|---|---|---|
| | | | mean value | median | standard deviation | | |
| Old government house | 4.4 | 248 | 5.8 | 6.2 | 6.4 | 6.3 | 18 |
| High-end community | 8.5 | 42 | 5.1 | 5.2 | 3.1 | 5.0 | 19 |
| General house | 3.3 | 1232 | 10.8 | 9.3 | 8.4 | 8.2 | 25 |
| Low-cost housing | 1.5 | 96 | 18.3 | 15.2 | 9.1 | 17.3 | 38 |

Table 8: Commuter comparison of different types of community.

### 4.2.2 The relation of professional industry characteristics and job-housing balance

This paper summarizes the employee proportion of the second and the third industry in Beijing-Tianjin-Hebei metropolitan area respectively, and compares it will the job-housing separation characteristics. (Fig. 8) It is found that the employee proportion of the second industry presents significant positive correlation property with the job-housing balance (the correlation coefficient is 0.72 under the confidence level of 0.01.) However, the employee proportion of the third industry presents significant negative correlation property with the job-housing balance (the correlation coefficient is -0.57 under the confidence level of 0.05.). The data shows that most employees in the second industry live in the suburbs and need to work in the downtown, whereas the residents working in the third industry could choose to live nearby. This indicates that development of the third industry is conducive to improving regional commuting balance to a certain extent.

### 4.2.3 The relation between regional housing price and job-housing balance

This paper summarizes the average house price in the core cities of Beijing-Tianjin-Hebei metropolitan area, and compares it will the job-housing separation characteristics. (Fig. 9) It is found that the regional house price presents significant negative correlation property with the job-housing balance (the correlation coefficient is -0.59 under the confidence level of 0.05.). Real estate developers consider the job-housing balance when they price the house. The traffic is more developed in the areas closer to the downtown. And there are more employment posts in the area where the house price is more expensive. This indicates that residents are willing to pay a higher price for housing in favorable job-housing balance areas.

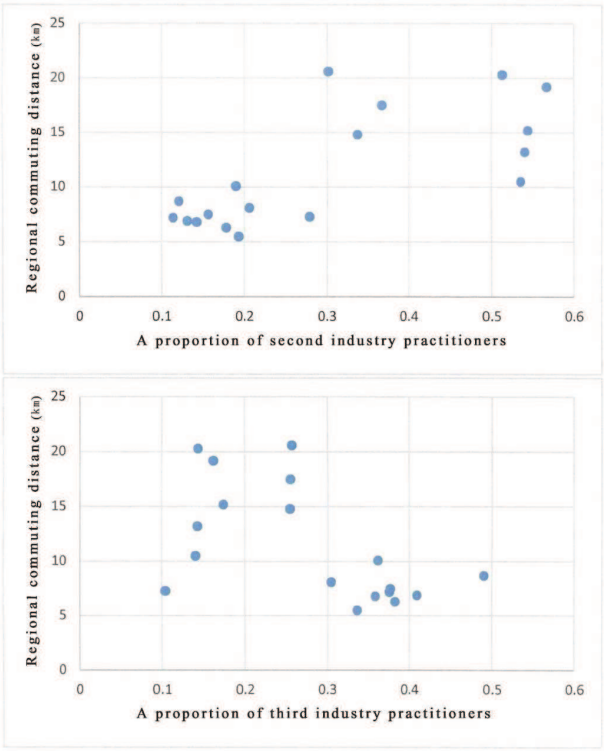


Fig. 8: Professional industry characteristics and job-housing balance.

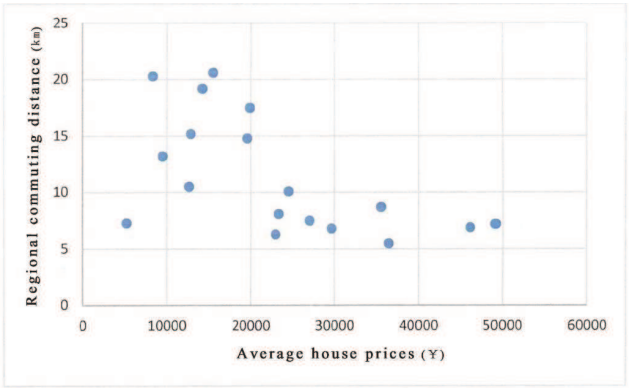


Fig. 9: Regional average house prices and job-housing balance.

## 5 CONCLUSION AND DISCUSSIONS

Based on the above analysis, the taxi travel commuting network figure of Beijing-Tianjin-Hebei metropolitan area is obtained (Fig. 10). In the figure, the red points represent the working area, and the blue points represent the residence zone. The sizes of the points represent the travel density (namely the ratio of travel times and the regional area). The line between the regions represents the corresponding travel behaviour. The frequent travel behaviours will generate the line with darker colour. The travel connectivity and commuting characteristics of each job-housing space in the metropolitan area can be directly observed in the figure, and the following conclusions are obtained:

The taxi traffic mode can better show the job-housing space structure in the new and old city. High intensity taxi flows often occur in large urban areas with special features and complementary functions, which mainly concentrate in the new urban districts composed of large-scale working areas and the residence zones. For example, there are several large-scale residence zones and important working area in the Tianjin Binhai New Area. Thus, it is a relatively independent job-housing area (The yellow boxes in Fig. 10). However, the job-housing commuting flow of the old urban area in the core city is significantly decreased. The developed urban public transport system in this area provides adequate transport capacity, more short distances commuting. Therefore, the travel could be dependent on bicycles even on foot, rather than taxis. In addition, Fig. 10 shows that there are few commuting travel across the whole city except for the trip to the airport or the railway station.


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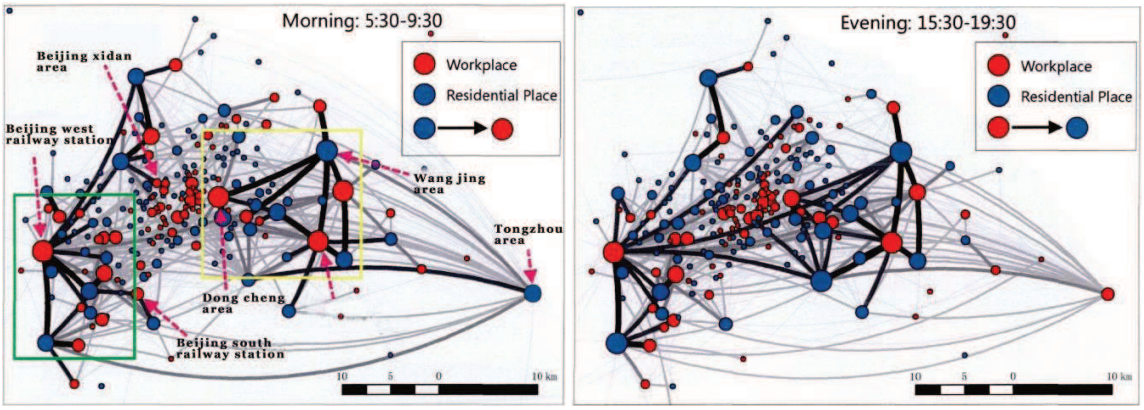


Fig. 10: The taxi commuter density and job-housing space connectivity

Residents' job-housing commuting travel flows are asymmetric in morning and evening. The travel flow from the residence to the working area in the morning is more concentrated and direct. However, the travel flow from the working area to the residence in the evening represents the characteristics of diversification and circuity. This mode indicates that residents are limited to the fixed working time in the morning, and directly departure to the working area. However, they have more free travel modes and purpose in the evening, and the more diversified taxi travel traffic space-time modes are presented.

As the most important transportation junction in the city, railway station and airport should have presented a neutral job-housing characteristic. That is to say, the passenger flow volume should be roughly equivalent in any time. However, the obvious working area characteristics are presented actually. This phenomenon is mainly caused by the behaviour mode of the passenger's choice of transportation means. Since it is pressed for time for departure in morning or return at night, the passengers are more inclined to take taxis. However, the time is quite ample if the passengers depart at night and return in morning, and they are inclined to choose other public transport modes.

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